# The Use of Massively Multiplayer Online Games to Augment Early-Stage Design Process in Construction


**by**

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# Abstract

Traditional 2-D contour models, Physical Models, Computer-Aided Architectural Design (CAD), Virtual Reality models, Google SketchUp, and Building Information Modelling (BIM) have all greatly enhanced the design process by enabling designers to visualise buildings and the space within them prior to their construction. A recent development is Massively Multiplayer Online Games (MMOG) such as *Second Life (SL)*. These offer users the opportunity to interact with other participants in real time, and so offer an excellent opportunity to experience the environment, layout and form of virtual buildings. However, the effectiveness of such applications to some extent depends upon how realistic the interactions of those using virtual spaces are in relation to interactions within the real world. This research examines the potential of this technology for enhancing and informing the early stage building design process. Initially, the tools currently used by architects at early stages of the RIBA Plan of Work were evaluated through interviewing architects. Then, the advantages of using MMOG over current tools at early-stage design were evaluated through interviews in *SL*. A virtual model was developed to examine how realistic the visualisation and interaction between end-users in an MMOG was. This was used to propose and validate guidance to incorporating MMOG into the early stages of the RIBA Plan of Work. It revealed that the virtual model created, the validated guidance and a successful example combining 2D sketches, Google SketchUp and MMOG at early-stage design can be used to guide architects to manage the complex decision making process in a simple, easy, cost-effective way, while effectively engaging both professional and non-professional stakeholders.

# Keywords:

AEC industry, Multi-user Virtual Environment, Game Engine Simulations, Second Life, MMOG, RIBA design stages, visualisation, non-professional stakeholders, architects

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| AEC Industry | Architectural, Engineering and Construction Industry |
| BIM | Building Information Modelling |
| CAD | Computer Aided Architectural Design |
| CAVE | The Cave Automatic Virtual Environment |
| GSA | General Services Administration |
| IAI | The International Alliance of Interoperability |
| ICT | Information and Communication Technologies |
| IFC | The Industry Foundation Classes |
| IFC2SKP | The Industry Foundation Classes to SketchUp |
| ISO | The International Organisation for Standardisation |
| IT | Information Technology |
| LCA | Life Cycle Assessment |
| LOL | Laughing Out Loud |
| MIT | Massachusetts Institute of Technology |
| MMOG | Massively Multiplayer Online Game(s) |
| MOO | MUD Object-Oriented |
| MUD | Multi-User Domain(s) |
| NBIMS | National Building Information Modelling Standard |
| NIBS | The National Institute of Building Science |
| nD Model | N Dimensional Model |
| OpenSim | Open Simulator |
| PRIMS | Primitive Objects in *Second Life* |
| RIBA | The Royal Institute of British Architects |
| RFID | Radio Frequency Identification |
| RMIT | Royal Melbourne Institute of Technology |
| *SL* | *Second Life* |
| UK | United Kingdom |

| | |
|---|---|
| USA | United States of America |
| 2D | Two Dimensional |
| 3D | Three Dimensional |
| VA | Virtual Architecture |
| VR | Virtual Reality |
| VRML | Virtual Reality Modelling Language |

# Chapter 1

# 1.0 Introduction

## 1.1 Background

Early-stage design in construction is important as it sets the basic parameters of form, cost and programme. During this stage, professional architects need to effectively engage non-professional stakeholders such as clients and end-users to identify all of the projects constraints, to produce a project brief including the overall design objectives and get clients' approval before moving to more detailed design stages. Failure to effectively engage clients and end-users at this stage may result in unnecessary costs being incurred by major changes to the design ideas at the detailed design stages. There are three main challenges of early-stage design in architecture: a complex decision-making process (Cilliers, 1998); communication issues between professional and non-professional stakeholders (Arlati et al., 1995 and Moum, 2006); and a lack of innovation in the design (Slaughter, 2000 and Winch, 1998).

The decision-making process at early-stage design is complex. During this stage, architects need to manipulate a wide range of interrelated design information to ensure the overall design fits its intended purpose. The areas architects consider include the following: the design problems clients bring to the architects, the data included in the project brief, the amount of information architects collected and researched for the brief, and various design concepts provided by architects to solve the design problems (Lawson, 2006). The large amount of information considered at early-stage design makes for a complex decision-making process involving many interrelated factors (Forgber, 1995). These include the multi-disciplinary knowledge domains, the simultaneous activities from multiple stakeholders involved, the regulations of the building industry, the development of various Information and Communication

Technologies (ICT) design tools, different architectural training required for stakeholders to be effectively involved in the decision-making process. During this process, many intentional planning activities take place, where the goals, requirements, constraints and strategies of the design evolve in a continual and recursive way (Arlati et al., 1995). But how architects propose holistic design ideas at such an early stage to meet all the constraints in the project (such as cost, time, technical issues, sustainability, materials, building regulations) cannot be identified immediately (Rowe, 1982). This heuristic nature of early-stage design (Neumayr and Budig, 2009) makes it difficult to find a tool to effectively address the large number of possible parameters for a preliminary solution (Aliakseyeu et al., 2006).

This complex decision-making process also causes the communication issues between professional stakeholders (such as architects) and non-professional stakeholders (such as clients and end-users). Stakeholders in the Architectural, Engineering and Construction industry (AEC industry) are from various sectors. Even the simplest construction projects may involve huge numbers of stakeholders from various industries, including individuals and organisations who "develop, design, construct, occupy, manage and live in the buildings" (Aouad et al., 2007: 3). Effective communication between stakeholders of various backgrounds "depends on the competence, knowledge and previous experiences of the participants in the communication process" (Moum, 2006). It is especially difficult to ensure effective communication between architects and non-professional clients/end-users. To convey the highly specialised information in a way non-professional clients and end-users can understand, to decide the overall project direction and procurement method is not easy. Architects, with professional training to acquire the specialised knowledge and experience to solve complex design problems often lead the early-stage design. Non-professional clients and end-users, with insufficient experience and knowledge about the architectural design process, rely heavily on the information and design options proposed by architects, and often become passive recipients rather than active contributors to the early-stage design (Mohamed et al., 2008). As a result, it is difficult for design information to be effectively communicated between professional architects and non-professional stakeholders such as clients and end-users (Moum, 2006). It is easy for information to become "misinterpreted, lost, incomplete and inaccurate" (Mohamed et al., 2008: 110) between architects and clients/end-users in this process, and thus hamper an effective decision-making process at early stage.

To effectively manage the complex decision-making process between multiple stakeholders at early-stage design puts pressure on architects, who may have less time and energy for the creative nature of design ideas required at this stage (Roozenburg and Eekels, 1995). Instead of generating a design solution completely from scratch, most architects find it easier to draw new inspiration from examples of similar architecture design cases acquired in previous architectural design projects. They use the materials (such as images, briefings, plans of work) of other projects, amending old design solutions to suit the new design problems (Lawson, 2006). This process saves the time necessary for architects to find an optimal solution to the complicated design issues at an early stage. However, this also gives them fewer opportunities to generate original design ideas to enhance the overall quality of their work in the long run. This can become a barrier impeding more creative design ideas from emerging at early-stage design (Moum, 2006), which results in many repetitive architectural designs that do not fully meet user needs.

Many different ICT systems have been developed to address the three main issues encountered during early-stage design, including the complex decision making (Cilliers, 1998), communication issues between professional and non-professional stakeholders (Arlati et al., 1995 and Moum, 2006) and a lack of innovation (Slaughter, 2000). However, it is still difficult to use current tools to capture the view of non-professional stakeholders. A new tool, which can overcome the limitations of current ICT systems and allow more active engagement from non-professional stakeholders in the decision-making process is needed.

A rapid development in the world of ICT is Massively Multiplayer Online Games (MMOG). MMOG is an Internet-based computer game, which enables a massive number of players to interact simultaneously in a digitally generated "synthetic world" (Castronova, 2005). Non-professional stakeholders' access to this virtual environment is relatively easier and cheaper than that of the traditional visualisation tools. This seems to offer the potential to capture the views of clients and end-users in the design process, and therefore bridge the communication gap between professional and non-professional stakeholders at the early-stage design. Also, it may be possible that MMOG can be used to generate more creative design ideas at the early stage to improve the quality of the overall design.

## 1.2 Choice of MMOG

The fast pace of globalisation and the wide application of new media technologies, such as the Internet are two outstanding advances in human history (Gills, 1997). Much attention has focussed on the possible social impact of these new media (Haythornthwaite, 2002), from the text-based Internet, to the interactive web 2.0, and the immersive MMOG such as *Second Life* (Khor and Marsh, 2006). Since the success of the film *The Matrix* (1999, and sequels 2003), the issue of "virtual" or "synthetic" worlds has been discussed widely. A key question is what is a "virtual world"? Is it simply the imagination of film directors or can it become something more useful? (Wankel and Kingsley, 2009). This question was answered by Philip Rosedale, the founder of Linden Lab, a Californian company. Rosedale developed a three-dimensional virtual world called *Second Life* (*SL*) in 2003. In contrast to previous computer games, which ask users to finish specific tasks predetermined in the games (such as *World of Warcraft*, *Happy Farm*, *Resident Evil* etc.), *SL* is based on users' own imagination. With free choice of avatar (the player's digital identity) and tasks to finish, participants can experience something entirely different from their everyday lives.

As a three-dimensional (3D) immersive virtual world, *SL* presents unbounded opportunities for architectural design (Ondrejka, 2006). With a range of simple tools, architects can “build items with a limited palette of primitive objects” (“PRIMS”) including cubes, spheres, cones, etc. (Kemp and Livingstone, 2007:13). These geometric objects can be “dragged off a template then stretched, positioned, sized, textured and combined to form anything imaginable”. This provides a powerful modelling tool for architects, who can rearrange the whole visualised space of a building quickly without incurring extra expenses or consequences (Rose, 2007:23). With highly immersive 3D interaction on a world-wide scale, *SL* can enhance the communication and collaboration between architects and their stakeholders globally. Many real-world architects have been using *SL* to simulate real building designs for real-world clients. They argue that *SL* provides the clients with an unprecedented level of visualisation and immersion into the design before construction starts (Chase et al., 2008). Academics have gone even further than traditional architectural design; the work of architectural students in *SL* demonstrate more originality, which challenges the way architecture is traditionally designed (Poutine, 2007). Many academic departments are using *SL* as a tool for architectural education, such as: the University of Auckland in New Zealand; Newcastle University, Royal Melbourne Institute of Technology (RMIT), Sydney University in Australia; Montana University, Massachusetts Institute of Technology (MIT), Stanford University, Harvard University in the United States of America (USA); the Royal Institute of Technology in Sweden; Ain Shams University in Egypt. The ability to use virtual design in *SL* may fundamentally change the way real-world architecture develops in the future. However, the simulated buildings are created in a utopian digital world, which is very different from reality. In comparison with traditional architectural modelling tools, such as Two Dimensional (2D) sketches, physical models, Computer Aided Architectural Design (CAD), virtual reality, multi-user virtual environment, game engine simulations tools, N-dimensional modelling (nD modelling) or Building Information Model (BIM), the visualisation in MMOG such as *SL* still have limitations.

The purpose of this research is to evaluate the potential of using MMOG at early-stage design of construction. As part of this research, a digital building model of the current Civil and Building Engineering School at Loughborough University was created in *SL*. Academics, researchers and students were invited to participate in various tests conducted in the virtual model. The research employs qualitative interviews to explore the architectural potential of MMOG, with the aim of answering the following research questions:

Q1: What are the issues which negatively impact on early-stage design?

Q2: What forms of visualisation are used in early-stage design and what are their limitations?

Q3: Can MMOG complement existing visualisation techniques?

Q4: How can a MMOG such as *Second Life* be used to better inform building design?

## 1.3 Research Aim and Objectives

The aim of this research is to explore the potential of MMOG in informing the early-stage design process. To satisfy this research aim, the following research objectives are presented:

1. Review current tools used in early-stage design;
2. Review research and practice pertaining to visualisation and the building design process in order to identify any deficiencies in supporting early-stage design decisions;
3. Examine the features of MMOG and their suitability for informing early-stage design;
4. To test the effectiveness of MMOG in simulating real-world environments;

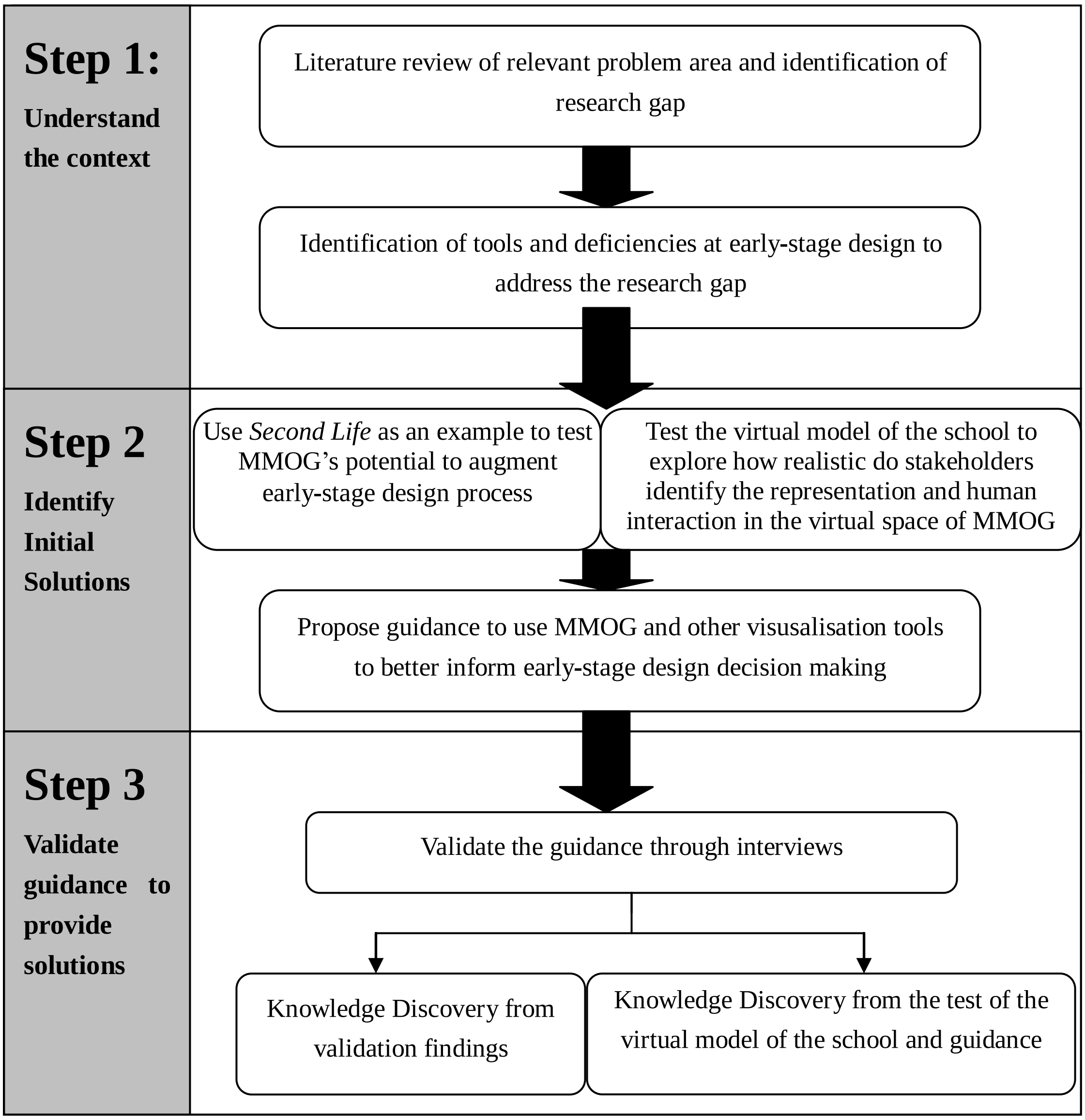
5. Develop and validate guidance on how and when MMOG should be deployed to best inform early-stage design.

## 1.4 Methodology

In this research, how useful MMOG is to support the early stage of architectural design relies on the way different people experience and appreciate MMOG, which is the position advocated by interpretivist epistemology. Also, it adopts the position of subjectivist epistemology. Subjectivist epistemology postulates that “values are constituted by subjects” (Rønnow-Rasmussen, 2003: 261). The value of using MMOG to augment early-stage design is constituted by the attitudes of different stakeholders in the AEC industry. Stakeholders with different interests, background, knowledge, experience and IT skills in the design process access the value of MMOG differently, which is the position advocated by subjectivist epistemology. This research is also based on an emic epistemology. The emic aims to understand phenomena from the “insiders’ view” (Holloway, 1997: 53). This research aims to elicit information from different stakeholders who are insiders to the architectural design process on whether MMOG should be applied to early-stage design, where using an emic epistemology is useful.

On the methodological level, it is based on a mixed methods research design, employing qualitative semi-structured interviews to collect data. The selection of the interviewees, sampling strategy, the development of the questionnaires for the interviews are discussed. The data collection methods and data analysis process are also reflected upon to highlight potential drawbacks of the research design and how these have been overcome. Figure 1.1 shows the research methodology.

**Figure 1.1 The Research Methodology**




## 1.5 Contribution to Knowledge

The extant literature this thesis covers includes the issues of early-stage design of the architecture (such as a complex decision-making process, the lack of innovation, communication gap between professional and non-professional stakeholders), issues of various early-stage design tools, the application of MMOG and its potential in augmenting architectural design conducted by professional stakeholders.

The main contributions to knowledge of this thesis include the following. It shows an understanding of the methods used by architects during the early design stage. It reveals the ineffectiveness of current early-stage design tools in engaging non-professional stakeholders through the examination of MMOG and its advantages over other visualisation tools currently used in the AEC industry. It explores the additional benefits that MMOG can offer above those tools currently used, and the factors that currently limit the uptake of MMOG by architects, the optimal stage at which to use MMOG during the early-stage design process. It develops guidance (see Section 7.4 Revised Guidance) to assist architects at the start of their design project in the choice of tools at the early stages in the Royal Institute of British Architects (RIBA) Plan of Work. It also gives an example of a simple process for using MMOG to complement other tools to achieve better early-stage design.

## 1.6 Structure of Thesis

The thesis is divided into eight chapters, together with the references and appendices.

- Chapter 1 introduces the background of this research, presents the research questions as well as the aim and objectives of this research. A brief overview of the methodology adopted in this research is also introduced. The contribution to knowledge and the structure of this research are presented.

- Chapter 2 reviews the main issues of early-stage design. Various architectural design tools are discussed, with their advantages and limitations identified. A brief history of MMOG and *SL* are presented, focusing on the potential architectural applications as well as various architectural activities in *SL*.

- Chapter 3 compares various research designs. Justification is presented for the selection of the research design, its philosophical basis, and choices of method. Difficulties that arose in the course of work and data collection are discussed, as are the reasons *SL* was chosen as the example of MMOG in this research.

- Chapter 4 presents the results from interviewing 30 real-world architects. In this chapter, the results focus on how the early-stage design decision-making process is managed by architects, identifying the advantages and limitations of various design tools used at early-stage design.

- Chapter 5 presents the results from interviewing 20 architects working in *SL* to assist their real-world architectural projects. The results analysed show that *SL* is a useful early-stage design tool. Also, the potential *SL* has over current tools are discussed. Issues in using *SL* for real-world architecture are discussed at the end of the chapter.

- In Chapter 6, a virtual model of the School of Civil and Building Engineering, Loughborough University is created in *SL* to test if MMOG can be used as a tool to augment the RIBA design stages. How realistic MMOG are to represent real-world architecture is also discussed, together with how participants consider the interaction within the virtual space. A comparison between other visualisation design tools and *SL* is presented at the end of the chapter.

- In Chapter 7, the main findings of this thesis are discussed against the literature. It also proposes guidance (see Section 7.2 Guidance in Using MMOG) to use MMOG to augment other current architectural design tools at the early stages of the RIBA Plan of Work. In-depth interviews with experienced architects and construction IT specialists were conducted to validate this guidance. Findings from the validation are discussed with revised new guidance presented (see

Section 7.4 Revised Guidance).

- Chapter 8 concludes the research with reflections on research questions, the main knowledge contributions, the limitations of this research and recommendations for future research.

# Chapter 2

# 2.0 Literature Review

## 2.0 Literature Review

This chapter reviews relevant research which is pertinent to this study. It examines how early-stage design is currently managed and the three key issues which often occur at this stage. In order to address various issues identified at early-stage design, a range of visualisation tools have been developed. The advantages and limitations of each of the tools to augment early-stage design are discussed. In considering the deficiencies of early-stage design and the various visualisations tools, MMOG are introduced to explore what features they have to augment this process. *Second Life* is chosen as an example of an MMOG to explore its potential to assist the early-stage design process. The historical development of architectural projects in *Second Life* is discussed. This review helps to identify the knowledge gaps in current research and provides the basis for research questions to emerge.

## 2.1 Early-stage Design

### 2.1.1 Design and Architecture

Design is an evolving process interlinked by various intermediate representations and information (Bouchard et al., 2003; Reeves and Shipman, 1992). Matchett (1968) defined design as “the optimum solution to the sum of the true needs of a particular set of circumstances” (Matchett, 1968: 163). However, Lawson (2006) argues that Matchett’s definition of design does not suit the design of architecture where the final result cannot be easily quantified by various measurements, and architects may not always know all design problems at the beginning of the process (Lawson, 2006). Many definitions of architecture exist, as it can be viewed from different perspectives. For example, based on the artistic/functional value, architecture is defined as “the applied art of building for people to satisfy their particular needs in a known environment” (Abdou, 2002: 66) or to create a place by defining meaningful space to fulfil a need or a function. With the scientific and technological aspect highlighted, architecture can be considered as a “science blended with arts that requires subjective imagination and creative ability based on objective analysis and justifications” (Abdou, 2002: 66). If the human/social aspect of architecture is considered, then architecture can be seen as “the expression of society or culture in a spatial, experiential form” (Campbell, 1995: 14). All of these definitions depict architecture as a “concept or idea that embodies both physical and virtual forms” (Campbell, 1996: 1).

The design of architecture also results from the interplay between the artistic/form, scientific/technological, and the human/social value highlighted in the definition of architecture (Abdou, 2002). This nature of architecture being multi-disciplinary makes it a complex design process. Various ICT have been developed to improve the communication between different stakeholders, such as 2D sketches, physical models, CAD, Virtual Reality, Multi-user Virtual Environment, Game Engine Construction Model, nD modelling, and more recently BIM.

### 2.1.2 RIBA Design Process

The architectural design process often begins with a design problem where architects collect a wide range of data; analyse it to come up with various solutions, communicating them in a simple way (for example, architects will use photos, 3D flythrough, and floor plan to help convey the design ideas) to non-professional stakeholders such as clients to get their approval to progress to other more well-defined stages.

Every stage can be characterised by different outcomes or tools used to achieve those outcomes. One well-established guide to design stages in the UK is the RIBA design process. The RIBA Outline Plan of Work is defined by the Royal Institute of British Architects as a standard construction process in the UK covering the outline design stage to the construction stage of architecture (Hughes, 2003; Lawson, 2006; Lee et al., 2000). There are 13 stages in total, namely RIBA stages A to L, which are shown in Table 2.1. In general, stages A and B are used in preparing for the design project, stages C to E are the main design stages, stages F to H focus on the pre-construction processes, with stages J to K for the construction of project and finally stage L for the use by the end-users (RIBA, 2008). In this plan, architects are seen as leaders in the design team, which is composed of stakeholders drawn from many disciplines. The RIBA plan of work specifies the role of other stakeholders (including engineers, quantity surveyors, authorities, specialists, bidders, users, and consultants) in the design process. With this work plan, both clients and architects will know what they should do and what they will get from each stage.

Table: 2.1 RIBA Outline Plan of Work 2007 (RIBA, 2008: 1)

| | RIBA Outline Plan of Work 2007.Design and Production Management |
|---|---|
| Preparation | A Appraisal:<br>❖ Identification of Client's needs and objective, business case and of possible constraints on development.<br>❖ Preparation of feasibility studies to enable the client to decide whether to proceed.<br><br>B Design Brief<br>❖ Development of initial statement of requirements into the design brief by or on behalf of the Client confirming key requirements and constraints.<br>❖ Identification of procurement method, procedures, organisational structure and range of Consultants and others to be engaged for the Project. |
| Design | C Concept<br>❖ Implementation of design brief and preparation of additional data.<br>❖ Preparation of Concept Design including outline proposals for structural and building services systems, outline specifications and preliminary cost plan.<br>❖ Review of procurement route.<br><br>D Design Development<br>❖ Development of concept design to include structural and building services systems, updated outline specifications and cost plan.<br>❖ Completion of Project Brief.<br>❖ Application for detailed planning approval.<br><br>E Technical Design<br>❖ Preparation of Technical design(s) and specifications sufficient for co-ordination of all components and elements of the Project. and information for statutory standards and construction safety. |
| Pre – Construction | F Production Information<br>❖ F1 Preparation of detailed information for construction.<br>❖ Application for statutory approvals.<br>❖ F2 Preparation of further information for construction required under the building contract. Review of information provided by specialists<br><br>G Tender documentation<br>❖ Preparation and collation of tender documentation in sufficient detail to enable a tender or tenders to be obtained for the construction of the Project.<br><br>H Tender action<br>❖ Identification, evaluation of potential contractors /or specialists for the construction of the Project.<br>❖ Obtaining and appraising tenders and submission of recommendations to the Client. |
| Construction | J Mobilisation<br>❖ Letting the building contract, appointing the Contractor.<br>❖ Issuing of production information to the Contractor.<br>❖ Arranging site handover to the Contractor.<br><br>K To practical completion<br>❖ Administration of the building contract up to and including practical completion.<br>❖ Provision to the Contractor of further information as and when reasonably required.<br>❖ Review of information provided by contractors and specialists. |
| Use | L Post Practical Completion<br>❖ L1 Administration of the building contract after Practical Completion and making final inspections.<br>❖ L2 Assisting building user during initial occupation period<br>❖ L3 Review of project performance in use |

### 2.1.3 Early-stage Design

According to the RIBA plan of work, stages A–D are referred to as early-stage design. The main objective during early-stage design is to develop a brief with a feasible design concept. Early stage design is important. During this stage, architects need to ensure all major issues of the design are fully considered. Based on the constraints of the project, architects consider a wide range of options based on cost, time, ethical, environmental and technical issues to come up with a design solution. At the early stage, architects need to get clients to approve the objectives of the design project, avoiding any extra cost that would be incurred by major changes of the design idea at a more detailed stage. Previous research has identified three main challenges of early-stage design: the complex decision-making process (Cilliers, 1998), the communication issue between professional and non-professional stakeholders (Aouad et al., 2007) and lack of innovation (Slaughter, 2000).

#### 2.1.3.1 Complex Decision Making

The decision-making process in early-stage design is characterised by manipulating a large amount of interrelated design information such as: details of the design problems clients bring to the architects; the data included in the briefing of the project; the amount of information architects collected and researched for the brief; and various options of design concepts provided by architects to solve the design problems (Segers, 2001). Clients come to architects with a list of requirements and specifications they need for their projects (Aliakseyeu, 2003). Some define this long list of requirements and clients' specifications as the project brief. The brief produced at the early design stage contains all the important information about the project, especially about the building function and the site location. Based on clients' requirements, architects research the project, collecting all relevant information to identify the design problems that may rise during the course of design (Aliakseyeu et al., 2006). Once the design problem is identified, architects develop various ideas, plans, concepts and themes to solve the design problems. The outcome from this stage is therefore greatly influenced by how to manage the large amount of information collected and analysed in addressing the complex decision-making process, by effective communication between professional and non-professional stakeholders, and by generating innovative design ideas (Gribnau, 1999).

The large amount of information processed during early-stage design makes it a complex decision-making process involving many interrelated factors (Cilliers, 1998), such as the multi-disciplinary knowledge domains, the simultaneous activities by multiple stakeholders involved in the design, the regulations of the building industry, the development of various ICT design tools, different architectural training to involve stakeholders effectively in the decision-making process (Gribnau, 1999). During this process, many planning activities take place, where the goals, requirements, constraints and strategies of the design evolve in a continual and recursive way (Arlati et al., 1995).

The complexity of the decision-making activities in early-stage design has resulted in the following problems. A reasonable configuration of the design problems cannot be easily verified at the early-stage design. Most clients specify the features they require in the architectural project at this stage, and then architects identify the design aims and problems from these specifications (Segers et al., 2001). But how architects propose holistic design ideas at such an early stage to solve all constraints in the project such as cost, time, technical issues or sustainability, cannot be identified immediately (Arlati et al., 1995). Also, most factors architects need to consider in the design are initially underspecified and vague at the early stage. This heuristic nature of early-stage design makes it difficult to find a tool to help effectively address the large number of possible issues for a preliminary solution (Arlati et al., 1995).

### 2.1.3.2 Professional vs. Non-professional: Communication Issue

Consultation with clients and end-users at the early-stage design is important to the success of the overall project. It helps to ensure that the issues raised by clients and end-users are fully considered before the detailed design stages to avoid structural changes or expensive amendments to the original design. However, an effective approach to involve all stakeholders at the early-stage design has never been easy. This is especially true between professional stakeholders (such as architects) and non-professional stakeholders (such as clients and end-users) and a clear communication gap has been identified between them (Boyd and Chinyio, 2006). Stakeholders in AEC projects are from various sectors. Even the simplest construction projects involve huge numbers of stakeholders from various industries. The stakeholders include individuals and organisations that "develop, design, construct, occupy, manage and live in the buildings" (Aouad et al., 2007: 3). This diversity of stakeholders from various industries may lead to an intermittent information flow between them.

How effective the communication between them can be "depends on the competence, knowledge and previous experiences of the participants in the design process" (Moum, 2006: 4). Between professional architects and non-professional clients/end-users, it is not easy to convey the highly specialised information in ways non-professional clients and end-users can understand. Architects, with professional training and experience often lead early-stage design. Non-professional clients and end-users, with insufficient experience and knowledge about the architectural design process, rely heavily on the information and design options proposed by professional architects and often become passive recipients rather than active contributors to early-stage design. "The complex nature of construction projects, the number of project stakeholders, the diversity and complexity of their relationships and that of their respective organisations" (Mohamed et al., 2008: 110) all make effective communication and collaboration between architects and clients/end-users difficult. As a result, it is not easy for architects to communicate their ideas effectively to clients and end-users or even actively involve them at the early-stage design (Moum, 2006).

Also, it is not easy for clients and end-users to convey their requirements in a technologically qualified way to the architects. There is a lack of a common language for effective communication between professional architects and non-professional clients/end-users (Arlati et al., 1995). Therefore, it is easy for information to become "misinterpreted, lost, incomplete and inaccurate" (Mohamed et al., 2008: 110) between architects and clients/end-users, and thus hamper an effective decision-making process at the early stage. Sometimes the fragmented information flow between professional and non-professional stakeholders may even incur unnecessary loss to clients and make the final construction project fail to meet its initial objectives (Moum, 2006).

#### 2.1.3.3 Lack of Innovation

Innovation is defined as "a functioning idea, practice or prototype object which is the result of creating new knowledge and generating technical ideas aimed at new and enhanced products, manufacturing processes and services" (Vlies and Bronswijk, 2009: 1). The AEC industry is a complex industry with interdependent systems (Hobday, 1998; Winch, 1998). For most companies, their "cost-competitive nature" (Slaughter, 2000: 5), which aims to reduce cost during the design process, is their main drive for innovation (Duke, 1988; Seaden et al., 2003). In reality, many of the innovations adopted by the AEC industry improve the performance of the design process rather than help to reduce the cost (Semlies, 1999). However, improved performance of the individual construction design project and the AEC company's long-term reputation, do not always offset the expected costs for the individual project in the short term (Slaughter, 2000: 5). Therefore, with so much uncertainty, there are many risks associated with the introduction of innovation at different stages of the design process (Winch, 1998). This issue becomes more complicated when AEC professionals also need to fully consider the types of innovation which may be needed to bring different levels of changes to the systems or knowledge domain.

Based on the level of knowledge advancement and links to other components in the system (Slaughter, 2000), innovation can be classified into five different types: incremental innovation (Marquis, 1988); architectural innovation (Henderson and Clark, 1990); modular innovation (Henderson and Clark, 1990); system innovation (Cainarca et al., 1989; Slaughter, 1998) and radical innovation (Nelson and Winter, 1977). Architects need to plan well beforehand to avoid introducing such change into the complicated AEC industry as to generate “a ripple effect of secondary and tertiary impacts” (Slaughter, 2000: 2).

In order to promote innovation in the AEC industry, a cycle of six stages is widely acknowledged as an effective way to allow innovation to be generated (Meyer and Goes, 1988; Goodman and Griffith, 1991; von Hippel and Tyre, 1995). The six stages are identification, evaluation, commitment, detailed preparation, actual use, and post-use evaluation (Slaughter, 2000). However, it is still not easy to implement such a complicated system in a “project-based industry” (Utterback, 1994: 24). Often, the AEC industry is considered as a backward industry which is less innovative in comparison to other sectors (Winch, 2003).

Considering these different factors during early-stage design becomes a challenge. During this stage, it is not easy to identify and define the multi-dimensional and interactive design problems. To manage complex architectural design problems and come up with high-quality design solutions to satisfy clients in a short time is not easy. Instead of generating a design solution completely from scratch, most architects find it easier to draw new inspiration from examples of similar architectural design cases. Architects use knowledge and skills acquired in previous architectural designs, or even follow the design solutions from similar architectural design problems in previous projects conducted by themselves or other architects, use the materials (such as images, briefings, or plans of work) of similar projects to amend old design solutions to suit the new design problems.

The design process is based on architects' "capacity to see unfamiliar situations as familiar ones, and to do in the former as they have done in the latter that enables them to bring their past experience to bear on the unique case" (Schön, 1983: 140). This process saves the time for architects to find an optimal solution to complicated design issues. However, this also gives them fewer opportunities to generate original design ideas to enhance the overall quality of their work in the long run. This can become a barrier impeding more creative design ideas from emerging (Moum, 2006).

This part of the review has identified some of the issues in early-stage design, including the complex decision-making process, the communication issue between professional and non-professional stakeholders, and the lack of innovation. However, this is not an exhaustive list of all the issues in early-stage design. There may be other issues that have negatively impacted on this stage, such as cost estimation (Arafa and Alqedra, 2011). Therefore, it is important to explore "What are the issues which negatively impact early-stage design?" This research question will be addressed through empirical work and data analysis based on the results of interviews with practicing architects.

## 2.2 Visualisation Tools Used at Early-stage Design

In order to address the issues outlined in section 2.1, various ICT tools have been developed to assist stakeholders to achieve better decision making at the early stages, such as 2D sketches, physical models, CAD, Virtual Reality, Multi-user Virtual Environment, and Game Engine Simulations. Traditionally, 2D sketches and physical models have been used by architects in early-stage design. But the limitations of traditional tools have resulted in more advanced computer-aided visualisation tools being developed. Some architects prefer to put all the information about their project in a single database to ensure the smooth flow of information throughout all the design stages. As a result, nD modelling and BIM have evolved to meet this increasing need. Constructed by "intelligent objects" which represent multiple elements in the projects (space, time, managerial and sensual), the nD model can simulate the whole construction process from early stage planning, designing, delivering and to the final construction and post-occupancy (Lee et al., 2005). Based on better ICT, these models aim to address various issues identified in early-stage design. However, there remain shortcomings that will need to be overcome before industry-wide application.

### 2.2.1 Traditional 2D Sketches

Using pen/pencil to produce 2D sketches is one of the most well-established tools used during early-stage design. The sketching activities use symbolic representation to serve two purposes: to capture the design concepts in the mind of architects on the paper; and to help architects to create innovative ideas for the design (Goldschmidt, 1994).

There are several advantages of using 2D sketches. Firstly, 2D drawings are simple and therefore easy to produce. Using sketches, architects can explore, compare and evaluate various design concepts with immediate investigative freedom, revising and improving the design ideas before they goes into more detailed design stages (Do, 2001). Secondly, the simple design tools used in sketches enable an efficient process in the design. Sketches are very natural to architects so that they do not need to pay too much attention to the tools themselves, but focus more on the design solution itself. The simplicity of the tools brings about two advantages: it allows architects to have great manipulative freedom and to have a fluid design thinking process through fully considering the mental and visual factors in early-stage design (Okeil, 2010). Thirdly, the simple and effective process allowed by sketches promotes more innovative design ideas at the early stage. The simple operation of using pen and paper allows quick schematic perspectives (Okeil, 2010) of the design. This quick turnaround of the creation-feedback cycle supports the reflexive nature of the design process and therefore allows architects to exert their creativity during the process (Do, 2001). The ambiguous nature of 2D sketches also brings about innovation. 2D sketches help to convey the design intention of the architects without showing the complete and finished details of the design. This abstraction, inaccuracy and incompleteness of design allows identification of various possible design concepts at a more detailed design stage. As confirmed by Bertol (1997), "the hand drawn line, which is bold to emphasize and thin to maintain ambiguity, allows a perfect continuity between hand and imagination in the conception of forms and design alternatives" (Bertol, 1997: 34). This ambiguous information demonstrated through 2D lines can be interpreted in various ways, which helps architects to come up with more creative design concepts (Okeil, 2010). Fourthly, using 2D sketches is cost effective. Paper, pen, pencils used in sketches are traditional design tools used by architects on a daily basis to sketch their design concepts.

However, 2D drawings also have limitations. For example, to look at ambiguous 2D lines and then to understand and imagine complicated 3D shapes is not easy. It requires a complex mental process to code and decode the incomplete information implied in those 2D lines. Architects have been trained to acquire these complicated visualisation skills. The work required to decipher incomplete information makes the design process "an arduous task for even the most dexterous mind" (Bulmer, 2001: 7). For less experienced architects and non-professional stakeholders such as clients and end-users, to understand abstract 2D sketches and see what experienced architects propose in 3D is difficult. This is mainly because most non-professional stakeholders have not been professionally trained to read 2D sketches to visualise the 3D buildings in their mind. This creates difficulty for the smooth information flow between professional and non-professional stakeholders. Sometimes the inability to decode the abstract information in the 2D sketches results in passive involvement of non-professional stakeholders such as clients and end-users at the early design stage (Okeil, 2010). Besides, 2D sketches represent not the space itself but various views of the space (Lawson, 2006). Traditional 2D contour models lack "spatial relationships" (Bulmer, 2001: 7), and can only show a few selected perspectives of the proposed design in a static way, rather than demonstrating the dynamic change of the design over time and movement. They are not effective in supporting the dynamic "proposal-verification-correction cycle of design" (Okeil, 2010). This static view can only represent the chosen section plans where real space is hidden between those sections. Besides, the ambiguous and selective information included in the 2D sketches can be easily interpreted and manipulated to create an ideal effect of the design concepts. They may not always represent the final detailed outcome of the design. The ambiguity and incompleteness of the information depicted in 2D sketches doesn't allow architects to fully consider all the intensive information collected and therefore may also pose difficulty in effectively managing the complex decision-making process in early-stage design.

In summary, 2D sketches allow architects to focus more on the design thinking process itself. This simplicity of tool allows an efficient thinking process by the architects and therefore generates more innovative design ideas at early-stage design. The tools needed for 2D sketches are cheap which also allows its industry-wide application. However, the selective and ambiguous information contained in 2D sketches does not include all the information architects collect at the early stage. It is difficult for architects to fully consider all the issues and manage the complex decision-making process needed at early-stage design through the use of 2D sketch. Also, the abstract and selective information contained in 2D sketches require additional mental power and expertise to decode into explicit language for smooth communication between professional architects and non-professional clients and end-users. Overall, it is easy to use 2D sketches to depict the most useful information and turn it into innovative design ideas, but the selected information contained in 2D sketches fails to allow architects to manage the complex decision-making process and also poses difficulties in addressing the communication gaps between professional and non-professional stakeholders. This difficulty with 2D sketches has led architects to explore design tools which are similar to 2D sketches, but which overcome their shortcomings to include all the available information, and bridge the perceived communication issue between professional and non-professional stakeholders.

### 2.2.2 Physical Model

Another tool used by architects at the early stage is physical models. They are also called scale models or building mock-ups. They are often used to serve the following purposes: to examine the aesthetics or forms of the design (such as intrusion, symmetry and repetition) and whether the form suits the function; to communicate between stakeholders in the design project through presenting the design in 3D; to check various dimensions and functions of the design, such as shading and lighting, the landscape of the design and how it fits within the surroundings (Piccolotto, 1998).

Simple materials such as cards and clay are often chosen at early-stage design to allow a physical model to be quickly constructed and easily modified. This quick 3D visualisation through a physical model allows architects greater freedom to test their design intention (Hadjri, 2003). Models are constructed in three dimensions and are effective to help convey real spatial relationships. Many students and architects find it useful to use physical models to explore form, space and surfaces in three dimensions without going into details. For example, some architects prefer using a physical model made of clay to quickly test out complicated 3D shapes proposed in their design that cannot be easily imaged through 2D sketches (Porter and Neale, 2000). In addition, physical model allows architects to better communicate their design ideas to non-professional stakeholders at the early-stage design (Liu, 1996). Physical models can be built to any scale and details based on different purposes. For example, if it is used to show how a building fits in the surrounding areas, an outline model showing the outside shape can be built without going into too much detail of the internal layout of the design. If an internal model is built to show the lighting of part of the design, only this selected part may be modelled (Moon, 2005).

However, there are also issues about physical models used at early-stage design, such as scaling (Vassalos, 1998). Most physical models are not constructed to the same scale as that of the final building. They are often constructed to a smaller scale. The smaller scale of the architectural design can affect non-professional stakeholders who may have a distorted perspective of the design, resulting in poor decision-making (Morris, 2006). The smaller scale of the model constructed may not always allow architects and end-users to imagine how effective the design could be to facilitate the real interaction of end-users in the built environment proposed.

In summary, physical models are also selective in the design information they represent. However, the 3D representation generated by physical models is useful at early-stage design (Downton, 2007). It helps non-professional stakeholders such as clients and end-users to see the design in 3D and better understand the design concept proposed by professional architects (Porter and Neale, 2000). This is an improvement in addressing the communication issue between professional and non-professional stakeholders, allowing non-professional stakeholders more active involvement in early-stage design decision making. However, the scaling of the physical model is an issue that architects need to consider fully, to engage the non-professional stakeholders.

### 2.2.3 Computer Aided Architectural Design

Due to the limitations of traditional design tools, architects have explored computer-assisted tools during early-stage design. The first CAD was developed in the 1960s, to help architects design their buildings more effectively. In 1963, Ivan Sutherland developed the first CAD system, which was called Sketchpad (Sutherland, 1963). With the increasing prevalence of affordable personal computers, the applications of CAD systems have been more and more popular in the AEC industry (Rosenman et al., 2007). Now, hundreds of CAD tools have been developed and employed in the AEC industry, some of the most popular applications including AutoCAD (Yarwood, 2010), ArchiCAD (Good, 2009), and 3D Studio Max (Gerhard et al., 2009). There are many definitions of CAD. Some researchers consider CAD as a "process" in which architectural designs are generated by a computer (Turk, 2001). Others argue that a CAD tool is "specialised computer software used to support architectural design" (Achten, 2007: 26). However, CAD is not "one typical design process" nor a "particular software" (Achten, 2007: 8), it covers all possible applications of computers throughout the whole lifespan of the architecture project, from the initial early-stage design process, through the detailed design stages, and to the post-occupancy stage of the design.

There are many advantages of using CAD in the architectural design. CAD can be used to assist architects in various applications, such as designing, communication with design partners, calculation of costs, structure, billing, or simulation of design performance. The creation and control of geometrical objects and drawings are the biggest advantages of CAD (Brown, 2003). It is argued that, CAD is able to "reduce actual construction time and costs" for the construction project (Novitski, 1992: 56). Also, CAD "simulates spatial reality" (Bulmer, 2001: 6) and enables the visualisation of architects' design ideas in three dimensions (Salman, 2004). This can help non-professional stakeholders to understand the design proposed by architects and therefore helps to reduce the communication gap between professional architects and non-professional clients and end-users. CAD improves techniques and approaches to enrich the knowledge, methods and concepts of architectural design (Achten, 2007).

However, some academics argue that the application of CAD in the AEC industry "seems rather primitive and limiting even after more than 40 years" (Reffat and Beilharz, 2003: 2). There are several limitations when employing CAD tools. Firstly, it is difficult to fill in the "reality gap" of CAD application. The term "reality gap" refers to the difference between the "expected potential of the scientific and technical development" (theory), and the actual performance (reality) (Turk, 2001: 156). Theoretically, CAD is supposed to achieve two objectives: design automation and visual representation. The former is to "replicate the cognitive design process of humans with computer intelligence" and the latter is to "develop computerized means for the representation of the architectural design" (Koutamanis, 2003; Suwa et al., 2000). Early-stage design is a "search activity" to explore a range of all possible solutions and "subsets of feasible, candidate, or constraint satisfying solutions" (Turk, 2001: 158). It is a "complex cognitive process" which requires creative imagination, artistic intuitions, as well as a wide range of relevant scientific knowledge. It is not about finding out what the prospective architecture is, but about the exploration of what it might be (Mitchell, 1990). With limited computing resources, it is difficult to use computers to achieve the complex cognitive goal of early-stage design. CAD 3D flythrough can be useful to show clients the design in 3D at the early design stage. However, the time and cost it takes to render a 3D flythrough within CAD makes it difficult to justify this visualisation technique at the early stage. Therefore, CAD is not that widely used at early-stage design (Salman, 2004). This may not be the case in 2011 (Bhatt et al., 2011; Salim et al., 2011). Secondly, as a detailed visualisation tool for designing, CAD is not suitable for the conceptual design stage (Lawson, 1997). This was discussed in 1997, however, 14 years' after that, there is still scant literature on whether this remains a shortcoming of CAD. Conceptual designing occurs when the designer is trying to understand the design problem and set the situation for the following design processes. During this period, a wide range of ideas, problems are collected and analysed by architects to come up with innovative design solutions that sometimes cannot be easily defined at early stage stages (Liu and Bligh, 2003). The application of CAD can narrow down the designer's creativity and design options, which may incur poor designs outcome at stages that are more detailed. Therefore, many architects still prefer hand-drawn sketches for conceptual designing, rather than CAD tools (Akin and Lin, 1995; Lawson, 1994; Won, 2001). However, others disagree with this point (Madrazo, 1999; Breen et al., 2003). As a tool for visual thinking, the detailed application of CAD can be used to "enhance form understanding" during the conceptual design stage (Madrazo, 1999). The "intensive visualisation and immediate feedback" in CAD application can enable designers to generate images in their minds more frequently. Therefore, some argue that a better way to solve this issue is to combine both sketching and CAD application in early-stage design (Breen et al., 2003).

In summary, CAD applications have high level of accuracy, which can assist architects in a wide range of applications at different stages of architectural design. Therefore, theoretically, they can be used to store and manage the complex decision-making process of intensive information at early-stage design. However, CAD is not good at generating innovative design ideas at early stage because of two reasons: first, its current capacity is not advanced enough to achieve the complex cognitive goal of early-stage design; second, such high level of accuracy at an early-stage design can confine architects' freedom of creativity. The ability to generate vivid 3D flythrough visualisation helps non-professional stakeholders such as clients and end-users to better understand the design proposed by professional architects and therefore improve the communication between professional and non-professional stakeholders. The knowledge gap identified using CAD at early-stage design is as follows. Architects need to find a tool, which is capable of managing the complex decision-making process at early stage, which has the 3D flythrough function to communicate design ideas effectively between professional and non-professional stakeholders, and which overcomes the limitations of CAD on innovation related issues.

### 2.2.4 Virtual Reality

Another popular technology applied in the AEC industry is Virtual Reality (VR). VR is a fast progressing technology aimed at creating an illusion of reality using a computer generated digital environment. It is able to "simulate real environments with various degrees of realism" (Bulmer, 2001: 14) and allow the user to interact with the digital environment and objects in an immersive way.

VR can support the early design process better than CAD because it has the potential to demonstrate highly complex information in an easily understandable form (Okeil, 2010).

VR is an intuitive early-stage design tool. It allows a higher level of interaction between stakeholders and virtual space. Users of VR can directly control the design objects by naturally moving their hands. This direct manipulation of design object is intuitive, similar to the way design objects are generated with 2D sketches and physical models (Okeil, 2010). With VR, architects can immediately see the outcome from the design concept proposed. This can accelerate the hypothesis-creation-feedback-modification cycle at early-stage design (Okeil, 2010). This intuitive tool can also be used to free architects from the time and energy required to encode and decode the information between using 2D data to represent a 3D space or vice versa. Therefore, architects can focus more on solving the design problem itself, rather than how to best use the design tool. This simplified cognitive process can provide architects with a more dynamic understanding of space and place. This is beneficial to generate innovative design ideas. In addition, the intuitive nature of VR is able to allow non-professional stakeholders such as clients and end-users to give useful feedback to architects. Less experienced clients and end-users have not been trained to use 2D sketches to visualise and understand 3D geometric shapes. VR generates large models with high quality rendering of photo-realism in real time (Wickman and Söderberg, 2003: 9) while still including all necessary physical attributes of the architecture simulated. It has the capability to increase the "dynamic, interactive, immersive and experiential" design process at the early stage (Bulmer, 2001: 14). It allows the users to interact with the virtual environment in an immersive way, exploring and experiencing the space in real time. This sensation of presence allows users to create a feeling of actually being in the virtual space. It becomes easier for clients and end-users to understand the design ideas, examine various 3D features of the proposed design such as scale and proportion, and give feedback to architects before detailed design stages. This empowers non-professional stakeholders to contribute more actively at the early stage. Due to the above-mentioned advantages, VR has been applied in the AEC industry to design better architecture and cities (Ab and Day, 2006). Some researchers argue that some Internet-based VR models may enable a new concept of public participation in urban design (Bulmer, 2001). However, others disagree due to the current limitations of these

VR models, such as cost (Santos et al., 2008), human performance (Stanney, 1995) and barriers to innovation (Moum, 2006).

The development, installation, and application of VR systems is often expensive. The budget allocated to these systems can be as much as several million pounds. For example, it cost about 2 million USD for the Pennsylvania State University to develop the Cave Automatic Virtual Environment (CAVE) project to test the use of VR for nuclear power plant construction (Messner et al., 2003). In the past 15 years, the use of VR has been pushed mainly by big manufacturers in the automobile industries (Zimmermann, 2008). However, the vast majority of companies in the AEC industries are small and medium sized, and cannot afford expensive VR tools (Santos et al., 2008). Many VR tools aim to enable real-world human interaction in the built environment, allowing users to interact with the virtual environment in real time. However, it is not easy to achieve optimal human performance of VR due to many factors. These factors include "task characteristics; user characteristics; design constraints imposed by human sensory and motor physiology; integration issues with multi-modal interaction; and the potential need for new visual, auditory and haptic design metaphors uniquely suited to virtual environments" (Stanney, 1995: 28). As a result, better training needs to be provided to allow participants to better navigate in the virtual environment using various computer-monitored sensors. Also, more powerful and improved VR systems need to be developed to cater to the needs of human interaction in the virtual built environment (Moum, 2006).

In summary, architects need to find a tool, which has the potential of VR as an intuitive tool to better engage non-professional stakeholders and help architects with creative design ideas, but is also cost effective, needs less training and has a better human-computer interface to help engage non-professional stakeholders.

### 2.2.5 Multi-user Virtual Environments

Predicting the actual use of the space by multiple end-users has never been easy for architects. This is especially difficult at the early design stage. Poor prediction about the actual use of the space can result in the final design not meeting clients' requirements. Based on previous VR technology, researchers have developed Multi-user Virtual Environments, which brings about more social interaction in the simulated environments to ensure the space designed meets the actual need of multiple intended end-users.

An Multi-user Virtual Environment is designed to simulate multiple average users' responses to building environments (Kalay, 2004). It enables many users to explore the virtual environment at the same time. It uses a predictive approach, modelling for both the environment and the humans who will use it, simulating their interrelation in given contexts to improve construction design. Researchers now have the potential to find out more about both the "perception and cognitive process" of people in the building environments and their "judgmental processes" (Kalay, 2004). It can be a "valuable tool" to simulate human behaviour where "much variance among inhabitants" of building environments is expected (Lam et al., 2008: 60).

Simulation models for general human spatial behaviour have been developed by many researchers in AEC studies, such as Archea (1977), Glaser and Cavallin-Calanche (1999). They have used "simple scripts or more complex Artificial Intelligence-based algorithms to steer individuals in a crowd" (Aouad et al., 2007: 295). In 2004, a situation-based approach was developed for studying the structure of crowd behaviour in complex environments (Sung et al., 2004). There are two main aspects to Sung et al.'s methods. Firstly, "certain actions are applicable only to certain areas of the environment". Secondly, all complex behaviour can be divided into "simulation-related higher-level actions". These higher-level actions can be further divided into lower-level actions with a range of "possibilities among preset possible choices". Therefore, when the users enter a scenario, they are equipped with some selected possible choices and they will be able to react accordingly (Aouad et al., 2007: 295). The situation-based model is often driven by goals (Lam et al., 2008). The users have to follow some prearranged plans in their trips to complete the tasks, such as shopping (Haklay et al., 2001; Kerridge et al., 2001). Goal-driven simulation models have also been used to study pedestrian way-finding behaviour and emergency evacuation behaviour (Batty, 2001). In pedestrian simulation, the models try to work out how pedestrians interact with one another and the environment. There are general walking rules based on obstacle avoidance. In 1997, Helbing et al. developed an active walker model, which responded to the environment as the pedestrians moved around and altered the viewpoint of the same environment as it moved. In this way, the walkers would not collide with the environment. However, it was still likely that they might bump into other walkers (Helbing et al., 1997). In order to solve that problem, other rules were introduced. In 2001, Helbing et al. (2001) designed a more advanced walker model. It used rules of shortest cut, an individual desired speed, and keeping a certain distance from other pedestrians and borders (Batty, 2001). The model designed by Helbing et al. in 2001 is better than previous models developed in two respects. Firstly, the walker can avoid colliding with both the environment and other walkers. Secondly, there is also optimisation of the route choices and walking speed (Helbing et al., 2001).

Goal-driven simulation models are also used in emergency evacuation, where fire and crowds are the main topics. For simulation, emergency egress models were first used by Stahl in 1982 (Stahl et al., 1982) and later by Ozel in 1993 for fire events, simulating crowd behaviour in evacuation. In Ozel's model, the behavioural rules of virtual agents are defined by employing goal modifier libraries (such as "sound the alarm") and actions (such as "go to exit"). Goal modifier libraries include the factors that can "influence or trigger a change in goal". For example, "alarms, smoke detectors, usual noises, fire-fighter arrival, an impaired person, and smoke tolerance" can all trigger changes in the behaviour of people in a fire event (Ozel, 1993). Therefore, they can be used to study all of the possible factors that may influence group behaviour in a fire. In this fire-event model, the rules of human behaviour are decided by the building configuration, and the characteristics of the people.

In these goal-driven simulation models, virtual users can interact with one another and the environment according to predetermined behavioural rules. The behaviours of the virtual users are somewhat autonomous – they react according to the conditions present in the environment rather than any predefined action schedule (Lam et al., 2008). Therefore, they are useful to test the level of service – to study and predict how people carry out certain activities within the building environment. However, the goals and behavioural rules set up by researchers in the environment have to be carefully predefined by the designers to allow the "natural" human behavioural patterns of the users to be represented (Lam et al., 2008).

However, there are also problems. Three challenges have been identified in these goal-driven models. Firstly, it is not easy to define appropriate rules in more complicated behaviour models. In way-finding and fire-egress simulations, researchers need to design only a narrow range of human behaviour and related activities (Batty, 2001). In such cases, it is not difficult to use the Virtual Reality Modelling Language (VRML), "the International Organisation for Standardisation (ISO) standard for 3D modelling" (Aouad et al., 2007: xxix; Zhang and Zheng, 2011), to set the proper rules of behaviour "tailored for the storyboard" (Lam et al., 2008). However, real social interaction within building environments is autonomous, and fully researcher-controlled goal models cannot be applied to more complicated human interaction. Secondly, the users cannot fully explore the building environment according to their own interest. With the predefined schedules, the users have to follow preset goals and fulfil the tasks. With few choices along the way, they cannot fully interact with the environment or other users. They do not know how to deal with situations that took place earlier or that will take place later (Lam et al., 2008). If there are no choices of actions, they cannot interact fully with the environment or other users. Thirdly, the movement of the users does not have much "degree of flexibility" (Aouad et al., 2007: 294). In these models, the movement of the avatars is controlled either by “program algorithms” or by “human operators” (Aouad et al., 2007: 290). Although human-operated avatars can give some sense of “being there”, such avatars are still mainly assisted by program algorithms to control the design studies. Therefore, the users can often only choose where the avatar moves, not how. This semi-directed viewing of design reduces the degree of realism. Due to these three challenges, the human interaction in this virtual environment still lacks the interactivity of the real world.

In summary, allowing Multi-users to interact in a Virtual Environment during early-stage design is useful to give non-professional clients and end-users a better understanding about the actual use of the proposed design. Therefore, this kind of tool helps to address the communication issues between professional and non-professional stakeholders. However, there is little literature on how Multi-user Virtual Environments can be used at early-stage design to generate innovative design ideas. In addition, like Virtual Reality, IT constraints means the multiple group interaction in the Multi-users Virtual Environment is not yet fully autonomous and hence does not reflect the real-world use of the building being designed. This shortcoming in Multi-user Virtual Environments means that architects still need to explore other platforms, which allow multiple users to explore the virtual environment to assist early-stage design, to help manage the complex design process as well as promoting innovation at early-stage design.

### 2.2.6 Game Engine Construction Models

In order to solve the issues caused by designing predefined rules to predict real human interaction in the virtual environment, architectural design solutions are also “developing towards interactive environments” (Aouad et al., 2007: 287), such as game-engine construction models. This seems to be an overall trend in the development of ICT. Interactive graphics such as games are increasingly affecting all ICT applications, such as how the applications are used, their purposes and the people using them (Oliveira et al., 2011).

However, most game models developed in the AEC industry are not used to assist architects at early-stage design. Up to now, gaming simulations in the AEC industry have only been used for training. The earliest trial was in 1969 called “Construction Management Game” (Au et al. 1969). In this game, the researchers design the scenarios to simulate the bidding process in the construction industry. Players had to cope with a series of challenges before getting the bid for their desired construction projects. All challenges were based on the real-world bidding process; therefore, it was useful in improving the bidding skills of real managers in the construction industry. After the success of this game, other researchers have used gaming simulations for construction training. For example,

- “Constructo”(Halpin and Woodhead, 1970) and “Vircon” (Jaafari et al., 2001) – games for teaching construction management;
- “SuperBid”– an advanced bidding game for the construction industry (AbouRizk, 1992);
- “Arousal”– a real-world game for Construction Site Management (Ndekugri and Lansley, 1992);
- “Simphony”– a game engine platform for Building Special Purpose Construction (Hajjar and AbouRizk, 1999);
- “Parade of Trades”– a game illustrating the impact work flow variability has on the performance of construction trades and their successors (Choo and Tommelein, 1999);
- “Strategy”– a Construction Environment Simulation Game (McCabe et al., 2000);
- The Construction Marketing Game (Bichot, 2001);
- “ER”– the Equipment Replacement Game in construction environments (Nassar, 2002); and

- ❖ “The Virtual Coach”– for Construction Education (Rojas and Mukherjee, 2005).

Providing a competitive environment and interactivity with other users, these game-based models have been effective in “providing stepping-stones towards creating interactive, participatory, and contextually rich educational environments in construction engineering and management” (Dossick et al., 2007: 81). However, the application of game modelling in the AEC industry only stands as a tool for educational purposes, not for design decision making such as early-stage design. This is mainly due to “the complexity in defining behavioural patterns tailored for the storyboard” within the computing resources required (Lam et al., 2008: 60). Like the Multi-user Virtual Environment, autonomous agents are seldom used in these gaming environments.

There is a “natural trade-off between highly detailed behaviour models and computational cost” (Aouad et al., 2007: 295). With the development of computer technology, it has now become possible to simulate true-to-life virtual buildings and humans with the necessary physical attributes. However, the more detailed the behaviour models are, the more difficult it is to compute effectively. It takes large amounts of computing resources to simulate a digital environment with a sufficient degree of realism. For example, to enable the user to feel real-time in the virtual game environment, the 3D scenes must have sufficient frame rates –“25 frames/sec or more” (Aouad et al., 2007: 290). This is only for one scene in the game scenario. In training games with predefined tasks, the amount of computing resources is still manageable. With a narrow range of human behaviour associated with the training target, the computer can readily simulate the several scenario environments needed. Therefore, it is relatively easy to mock up “naturally appealing behavioural patterns” without negatively affecting the performance of the overall gaming environment (Lam et al., 2008: 68).

Unlike the simple goal-driven games, the human behaviour in autonomous gaming environments is far more complex. With limited computer resources, it is difficult to incorporate autonomous agents in gaming models defining all possible human behaviour. If every user in the game environment is allowed to explore the building environment as they like, there will be too many possibilities of human behaviour. The computing resources required are thus “multiplied by the number of users” (Lam et al., 2008: 62). When all the users become autonomous in the digital environment, their behaviours are interconnected with each other’s actions. This interrelationship demands exponentially strong processing power from the computers. With preset computing resources, the more choices the users have been given, and the more numerous they are in the virtual environment, “the more undesirable [the] effects on the performance” of the computer systems. There may be slow “rendering speed and response rates” (Lam et al., 2008: 62). Sometimes the computer games may become frozen or even collapse. Therefore, to make the best of limited computing resources, game engine simulations in construction research have to be goal-driven, for training only. For the study of more autonomous human behaviour required for early-stage design, there is still a long way to go before the gaming platform is sufficiently advanced.

However, as modern construction engineering and management practice is predicated on human interaction within the building environment, the exploration of more autonomous and real-life virtual models has never stopped (Borchers, 2000). A tool which would “allow a programme to easily access individual character, crowd or ergonomic simulation features” (Aouad et al., 2007: 290) and utilise these features in a very straightforward manner does not yet exist. However, researchers are working on the introduction of more autonomous virtual models, which will enable all users to explore virtual buildings according to their own interests. Ultimately, researchers are expecting a completely autonomous game model, which enables a more credible simulation of the complex multiple end-user interaction in the virtual environment for early-stage design. This creates an opportunity to explore the use of game engine based software in the built environment to assist the design process, especially during the early-stage design process.

### 2.2.7 BIM

In the AEC industry, a BIM may include all types of building project information in design, construction and operation phases, including the demolition phase. According to the General Services Administration (GSA):

> BIM is the development and use of a multi-faceted computer software data model to not only document a building design, but to simulate the construction and operation of a new capital facility or a recapitalized (modernized) facility. The resulting information model is a data-rich, object-based, intelligent and parametric digital representation of the facility, from which views appropriate to various users' needs can be extracted and analysed to generate feedback and improvement of the facility design (GSA, 2007: 3).

There are various sub-categories of BIM, such as Open-BIM (also named as Integrated BIM), a concept of making all information about the buildings in open format to better share information (Kiviniemi et al., 2008). Therefore, in an Open-BIM, information such as physical objects (walls, doors, ducts, elevators, etc.) and abstract objects (relationships, types, groups, etc.) are made standardised for everyone to access and change. Often, Open BIM use The Industry Foundation Classes (IFC) to cover all disciplines, allowing all stakeholders to process the information (Hallberg and Tarandi, 2011).

Besides Open-BIM, another important concept is the minimum BIM. A National Building Information Modelling Standard (NBIMS) was developed by The National Institute of Building Science (NIBS) to define the minimum BIM (NIBS, 2007). The definition includes semantic information such as "data richness, life cycle views, delivery method, graphical information, information accuracy and interoperability etc." (Hallberg and Tarandi, 2011: 448).

There are many advantages of BIM. It can become an efficient way to share semantic building information across different disciplines and software. Semantic e-Construction, is an ICT-based approach for distributed engineering. This method puts special emphasis on the extensive use of semantic construction objects and pre-defined design models which are both commonly used in the BIM. Therefore, BIM has the potential to lead to fast and flexible production of customised and industrialised complex solutions with embedded intelligence (Rezgui et al., 2009). Also, the digital models enabled in the BIM are useful to both non-professional and professional stakeholders. This object-oriented and parametric approach allows BIM to become a virtual copy of the real building, rather than just “a stack of lines and layers” (Hallberg and Tarandi, 2011: 447). Therefore, BIM can allow requirements from non-professional stakeholders to be easily captured. Some non-professional stakeholders find it difficult to understand a 2D plan of work. 3D digital models allow them to better understand what is proposed by professional stakeholders such as architects. Also, the adoption of BIM in construction will open up new opportunities for architects. Instead of following traditional paper-based processes at early-stage design, BIM enables architects to move towards an integrated process through designing the virtual built environment (Bedrick, 2006; Kolarevic, 2003). The development of BIM-related software applications will also allow new possibilities of efficient computerised information management in the AEC industry. For example, the adoption of BIM enables timesaving in the design documentation stage (Kam et al., 2003). This advantage allows more time to be spent on economic and environmental Life Cycle Assessment (LCA) and planning of constructability in the design process (Hallberg and Tarandi, 2011). BIM can also be used in facility assessment and planning to improve the work-process efficiency. This can be achieved through reducing work effort in data generation and updating, and by improving data quality and accuracy (Eastman et al., 2008).

Despite all the advantages of BIM, there are various disadvantages. For example, there is some confusion about what can be considered as a BIM. There are a variety of definitions of BIM. Different interpretations of BIM also exist. Most often, BIM is considered by non-professionals of the AEC industry as a 3D CAD model. This only shows some features of a BIM, which usually appear as a 3D computer-modelling tool. However, one of the main features of BIM is the "stack of parametric objects with inherent information about themselves and their relations to other objects" (Hallberg and Tarandi, 2011: 448). BIM can also be presented in 2D (Wix et al., 2007). It does not matter in which way a BIM is presented, in 3D or 2D, what matters is the information contained in a BIM (Wix et al., 2007). Besides, the static representing of built environment in the BIM can limit its ability to provide real building performance. Energy Efficient Architectural Design should be developed for a dynamic representation of a building to ensure the building's adaptability to its usage and environment throughout its life cycle (Rezgui et al., 2009: 614). There are issues with the experiments with web-based BIM and its industry application. Issues such as "data quality assurance, quality of service (continuity and recovery plans), as well as trust, authentication, security, validation, and certification framework (authentication and trust)" (Rezgui et al., 2009: 615) are still under discussion by academics. It takes time for those issues to be properly addressed before industry-wide application of web-based BIM can become possible. Despite the fact that BIM can offer benefits to both professional and non-professional stakeholders in the AEC industry, reconsiderations of how to best deploy current teamwork models are needed. The issues of a large amount of information exchanged at design cannot be easily solved by employing a BIM. In order to solve this problem, the International Alliance of Interoperability (IAI) IFC standard has been developed as an open standard for better information sharing (IAI, 2007). With the IFC standard, it is possible to allow building information to be shared between different IFC-compatible BIM applications. However, how far this IFC-based Open BIM can promote the life cycle design and sustainable constructions still needs further research.

In 2011, the UK government announced its Government Construction Strategy "to introduce a progressive programme of mandated use of fully collaborative Building Information Modelling for Government projects by 2016" (Cabinet Office, 2011: 34). It pushes the AEC industry to move further in the direction of digital modelling than it has done before. This can give further impetus to digital modelling, allowing more opportunities to address various issues of BIM for industry-wide uptake.

### 2.2.8 nD Models

While some researchers are working to simulate the most true-to-life Virtual Reality/Multi-user Virtual Environment modelling to ensure the design of architecture really fits the actual need of the end-users, others are working to ensure the information intensive early design stage can be managed in one conceptual model – the nD model. The nD model is based on BIM, a concept first introduced in the 1970s (Eastman et al., 2008). A BIM is essentially a computer database of all aspects of building design, information, products and attributes. In this model, rich information about the building, such as construction, management, operations and maintenance, can all be integrated (Graphisoft, 2003). nD models are based on BIM, but with the further ability to create and manage all project information in one consolidated data repository, representing the whole life-cycle of the building (Lee et al., 2003).

The principle of using nD modelling is to extend the normal three spatial dimensions (called x, y and z) to the fourth dimension of time (i.e. x, y, z and t). Other suggested dimensions include management attributes such as cost, schedule, procurement, materials, accounting, colour and acoustics to allow project participants to visualise and manage the object information. In this model, all senses are also included, such as visual, acoustic (for ambient sound) and smell (to simulate polluted environments). Since 2000, significant research has been undertaken on nD modelling, with many papers published on this topic, including “Developing a Vision of nD-Enabled Construction” and “nD modelling roadmap: a vision for nD-enabled construction” (Lee et al., 2003; 2005).

nD modelling aims to help design better buildings by integrating existing and non-existing modelling approaches to address all dimensions of a project. Constructed by "intelligent objects" which represent multiple elements in the projects (space, time, managerial and sensual), the nD model can simulate the whole construction process from early stage planning, designing and delivering to the final construction and post-occupancy (Lee et al., 2005). The massive amount of information required for the project is incorporated in only one system. Accordingly, all the information concerned can be kept coordinated and accurate and made available to all organisations involved (Lee et al., 2003). Any change made in this database by any participant will be "automatically reflected in the resultant" data, and be notified to all the stakeholders. Also, different views of the same information can be shared automatically. This consistent and accurate flow of data among all stakeholders should tremendously improve communication and collaboration in construction projects, fostering a better outcome (Graphisoft, 2003). Therefore, nD modelling has been considered as a vehicle to solve the AEC industry's problem of poor information and communication during the design and construction processes.

However, there are also challenges that researchers need to address carefully. The theoretical advantage of the nD model is to include all design concepts, and to systematically assess and compare the strengths and weaknesses of different designs. This ability of nD modelling to incorporate the wider dimensionality (the dimensions involved can be as many as the limitless *n*), emphasises the overall performance of the project, rather than the individual input by different participants (Lee et al., 2003). Therefore, there are two questions that researchers will have to address. Firstly, there is not yet a standard to evaluate what constitutes an additional *n* dimension. Up to now, space, time, management attributes, colour and acoustics have all been considered as dimensions pertinent to construction projects. However, due to the complexity of the AEC industry, many other dimensions may need to be incorporated. There is ongoing debate among academics on the necessity of introducing additional dimensions to ensure the best performance of building projects (Lee et al., 2005). Secondly, considering all the *n* factors with different attributes, is not easy for one system to accommodate so many potentially conflicting dimensions. All the dimensions are said to be equally important to the success of the building projects, but there is no doubt that space, cost and time are always given top priority in construction. When the decision maker has to make a choice between other *n*-dimensions, which one should come first? The challenges discussed have been experienced by many researchers. Therefore, nD model developers have reported difficulty in addressing the different and sometimes conflicting needs of various participants during the design process. When a conflict of priority occurs, nD models cannot automatically offer a proper solution. Stakeholders in the construction project have to find other ways to negotiate. Thirdly, the wide application of nD modelling is not yet possible. Due to the work involved in incorporating the nD model throughout all sectors of the construction project, the AEC industry is reluctant to work together in an interdisciplinary way. This has made nD modelling difficult to achieve for the time being. Therefore, in the short term, the wide applicability of nD modelling CAD in the construction industry is not yet practical. Many researchers are still working to “enable widespread nD implementation over the coming years”. The “global nD uptake” only “presents itself as a research agenda” at this moment (Aouad et al., 2007: 342-343). Fourthly, the development of nD models is similar to BIM, which mostly aims to enhance the information flow between AEC professionals. Therefore, the interface of nD modelling is similar to BIM. They have both been developed to support AEC professionals with years of industry training who have the capacity and special knowledge to understand and utilise the systems. For non-professional stakeholders who do not have the related capacity and knowledge, direct use of nD modelling and BIM is difficult. Last but not least, similar to BIM, many architects argue that although nD modelling should theoretically be used throughout the whole lifespan of the architectural design, at early-stage design the need to use BIM or an nD model is not clear. The reason for that is because in comparison with detailed design stages, at early-stage design there is not so much information to be managed. In practice, using nD modelling or BIM at early-stage design is not necessary. nD modelling and BIM are more useful at a later stage of the design when more and more information about the projects becomes available.

This section of the review has explored various tools used at early-stage design, including 2D sketches, physical models, CAD, Virtual Reality, Multi-user Virtual Environment, Game Engine Construction Models, BIM and nD models. These tools have been identified in the literature as tools used at early-stage design. However, it is still not clear how effective each of them is at early-stage design, especially in terms of engaging non-professional stakeholders. Also, is each of them still being used at early-stage design as they should? Therefore, it is important to explore what forms of visualisations are used in early-stage design and what are their limitations. This question is proposed as the second research question of this thesis with further empirical work conducted to find the answer.

## 2.3 Massively Multiplayer Online Games

Architects are still exploring new simulation tools to address all the three issues identified at early-stage design. One potential area is the use of MMOG (Massively Multiplayer Online Games). A Massively Multiplayer Online Game is an Internet-based computer game, which enables a massive number of players to interact simultaneously in a digitally generated "synthetic world" (Castronova, 2005).

MMOG originate from Multi-User Domains (MUD), the text-based Internet games, which became available in the late 1970s. MUD used text-based commands to describe the virtual world and the players within it (Livingstone and Kemp, 2008). Later, MUD were able to use object-oriented techniques to organise their database of objects, which gave birth to MUD Object-Oriented (MOO). A MOO has the ability to enable users of the games to modify and extend the virtual world they are playing (Livingstone and Kemp, 2008). Since the 1980s, more and more MUD began to adopt graphics rather than texts in the game, allowing a more user-friendly interface (Coleman and Dyer-Witheford, 2007).

MMOG requires all users to have access to the Internet for online interaction. Every user of a MMOG uses the “client”, which is the copy of the MMOG software installed on their computer, to log into the online virtual world. In order to allow hundreds or thousands of users to interact simultaneously, MMOG need to have a proper Information Technology (IT) structure. There are two types of computer architectures to achieve this goal: client-server and peer-to-peer server. Most MMOG adopt the online client-server scheme. In the client server IT architecture, the central servers receive all the requests of actions sent by users to the virtual world. The central servers process these requests and simulate the entities requested in the digital world for tens of thousands of users. The advantage of this centralised architecture is that developers of MMOG have full administrative control over the game to avoid any negative issues such as cheating or inappropriate behaviour of individual users (Kabus et al., 2005). Also, this centralised server can ensure consistency and persistence of the information flow between users themselves and the virtual world (Rhalibi and Merabti, 2006). It is straightforward for game developers to implement this structure. However, there are also problems with this IT structure. To simulate the large amount of data requested by hundreds of thousands of online users interacting simultaneously, tens of thousands of online central servers must be in place to support the virtual world. Also, the bandwidth on the server side must be wide enough to allow large amount of information to be processed, simulated and transmitted between massive number of users and the central servers. The client-server IT structure is expensive and the scalability of MMOG is limited. For example, the cost of having enough bandwidth to support 30,000 simultaneous players is about 100,000 USD, and the cost for the servers needed to simulate the requests of the 30,000 players is 800,000 USD per month (Mulligan and Patrovsky, 2003). This was the case in 2003, although various new solutions have been provided to minimise the cost with the development of more powerful servers (Maggiorini and Ripamonti, 2011); the cost required by the large number of centralised online servers remains an issue.

As a result of the limitation of client-server architecture, more and more researchers are exploring the solutions to problems such as scalability (Francis et al., 2001); robustness (Knutsson et al., 2004); security (Smed and Hakonen, 2002); bandwidth savings (Knutsson et al., 2004); network and transport protocols; and delay compensation techniques (Bernier, 2000). However, the structural issues of the client servers make it difficult to provide a flexible solution. Therefore, more and more MMOG developers are testing the feasibility of using peer-to-peer structure to improve the IT structure of MMOG, which may allow MMOG to have unlimited scalability with cheaper cost. However, as there is no central server in the peer-to-peer structure, how to ensure the consistency, persistence and security of information between users of MMOG becomes a problem. Some of the latest platforms used to develop MMOG therefore allow MMOG developers to use both centralised client-servers and decentralised peer-to-peer structure. For example, Open Simulator (*OpenSim*), allows both structures to be used in developing various MMOG.

### 2.3.1 Types of MMOG

As a result of the Internet boom in the 1990s, MMOG have enjoyed rapid expansion across the globe (Rhalibi and Merabti, 2006). Currently, there are more than 40 MMOG in the world (Woodcock, 2005). Generally, they can be put into two categories: scenario-based MMOG with preset missions and characters and open-ended MMOG, where the users generate most of the content in the virtual world. For the former MMOG, examples include *EverQuest*, *Ultima*, *Asheron's Call*, *World of Warcraft*, *Happy Farm* and *There* (Woodcock, 2005). Open-ended MMOG include *Second Life*, which was launched by Linden Lab in 2004, and *BlueMars* developed by Virtual Space Entertainment in 2009.

The choice of MMOG as a research topic is based on the following reasons. Firstly, MMOG is Internet-based, which can offer easy access to allow stakeholders based in different physical locations to easily access and collaborate in the design process. This collaborative feature is not often easily available in other forms of visualisation, which are not based on the Internet. Secondly, MMOG is not developed as an industry standard architectural design platform, but a general social interaction platform to allow people from all professions to easily interact with each other. This user-friendly feature can potentially enable non-professional stakeholders to become more involved in the design process. Thirdly, most MMOG are free to use. In the cost competitive AEC industry, this can potentially attract more architects in testing their potential to assist their design practice rather than spend budget purchasing expensive professional visualisation tools. Fourthly, there has been increasingly more discussion in the MMOG community to provide better interoperability with industry standard BIM. With the UK government pushing for industry uptake of BIM models (Cabinet Office, 2011), it is possible that MMOG can be developed to allow direct import and export of BIM to meet the industry need. Lastly, MMOG allow massive numbers of real-world people to interact with each other in an immersive way. Most visualisation tools used in the AEC industry cannot allow non-professional stakeholders such as clients and end-users to participate in the design process effectively. This immersive and massive interaction feature of MMOG could potentially allow fast prototyping of the design, and immediate feedback between non-professional stakeholders and the architects.

### 2.3.2 Second Life

One of the most successful open-ended MMOG is *Second Life* (Woodcock, 2005), which is based on centralised client-server IT structure. In the past seven years, the number of people becoming residents of *SL* has grown to over 20 million (Data collected from *Second Life* client on 18th March, 2012). The success of *Second Life* (*SL*) is also about the social impact it has created and is creating. Unlike most MMOG that have preset goals, *SL* is based on the users' own imaginations. With a free choice of avatar (the player's digital identity) and tasks to finish, it may be possible to use *SL* to test out architectural designs, which are expensive, or difficult to conduct in the real world. Meanwhile non-professional stakeholders can be given the opportunities to interact with each other in the virtual environment to find deficiencies of the design at an early stage.

Based on these issues identified from the literature review, the third research question of this thesis is proposed: "Can MMOG complement existing visualisation techniques in construction?"

## 2.4 The Potential of *SL* to Augment Architectural Design

In comparison with other AEC simulation tools, MMOG may have the potential to augment the architectural design process through better engagement of non-professional stakeholders in the design. This is mainly because of its potential to better simulate autonomous real-world human interaction in a virtual environment. Like nD modelling, which incorporates *n*-dimensional factors in one building model for consideration, *SL* also has advantages over previous AEC models, including real-time, real-world human behaviour, easy access, and relatively low cost.

### 2.4.1 Real-time, Real-world Human Behaviour

A potential benefit of using *SL* over previous AEC visualisation tools lies in its provision of the real-time, real-world representation of human behaviour. As a parallel world, *SL* globally connects 20 million people (Data collected from *Second Life* client on 18th March, 2012), who spend large amounts of time immersed in this digital world. It is an autonomous virtual environment with no specific task to finish (Woodcock, 2005). There are no preset human behaviour rules to conform users' activities to other users and the environment. Everything is about free imagination and creativity. As Kirriemuir quoting Aleks Krotoski said, the social networks of the virtual world are "unique, emergent social properties reflective of offline social life" (Kirriemuir, 2007: 5). The residents of *SL* imagine, learn, create and interact with each other, to form complex social networks where reality has become hard to define (Ondrejka, 2006). For the majority of users, "the generation of Millennial" (those born after 1980), *SL* is no less important than the real world. This generation has grown up with the increasingly interactive and visualised communication technologies of the network society. This social experience shapes them in trusting technology as an ultimate tool to enrich their lives. Therefore, as research shows, for them, there is no difference between friendship developed in the real world and online and they would prefer the virtual world to manage their social network (Bray and Konsynski, 2007). However, that is more likely the case for young people who are used to technology and social media. For the older generation, it may not be the case.

### 2.4.2 Accessibility and Cost

The easy access to *SL* makes it a cost-effective visualisation tool for architects. Unlike traditional visualisation tools that are expensive, the installation and application of *SL* are cost-effective. The *SL* software can be downloaded from the *SL* website free of charge. The use of *SL* software is also cost effective. Architects do not need to spend anything unless they want to rent or buy a plot of land to visualise their projects. There are two types of accounts users can choose from: free and premier. Most users choose to use a free account to access *SL* and all facilities in the virtual world. Other experienced users who want to develop their own projects choose to buy a premier account. With a premier account, users have access to more IT and individualised support from *SL*. Organisations and companies who have big projects normally purchase a premier account to develop their activities in the virtual world. Many *SL* landowners provide small areas on their island as a free sandbox for the public to test out design ideas. Most of those free sandboxes are big enough for a single residential house. If architects need better security and larger areas for bigger projects, the cost of land renting or purchasing is still cheap in comparison with traditional visualisation tools.

Secondly, *SL* is based on the Internet, which can be accessed globally. It is possible for anyone to access *SL* anytime with a computer and a broadband Internet connection. For architects who are dealing with clients and end-users in the same country, *SL* can "enable sophisticated analyses for engineering companies of various sizes" (Aouad et al., 2007: 287). For architects who want to engage different stakeholders in an international design project, *SL* improves the communication in international collaboration with fewer limits in time, space and budget. Architects can talk "face-to-face" in *SL* with clients and end-users based in another country without worrying about extra cost on travel, accommodation and visas. With the cheap application of *SL*, even entrepreneurs from small-sized architectural studios who cannot afford expensive simulation packages, are now able to "develop mega-sized building projects and carry out comprehensive what-if analyses and scenario studies" (Aouad et al., 2007: 287). For the clients and end-users, *SL* has the potential of providing them with an unprecedented level of visualisation and immersion into the design before construction starts (Chase et al., 2008). From their computer screens, the clients can virtually inhabit the building, and suggest changes based on their first-person evaluation. This may not be as immersive as a Virtual Reality system. However, the cheaper cost and better accessibility can potentially offset the efforts made to make users interaction more immersive. As advertised in the website of Crescendo Design, an *SL*-based real-world architectural company, "During virtual meetings, we can test different design ideas in "real time" – meaning the changes we make appear on your screen immediately as they're made. Clients and builders can even learn the simple building tools and make their own suggestions. The virtual model works great for testing out material choices, paint colours and eventually even landscaping options and furniture layouts" (Brouchoud, 2005). In this way, the "building performance can be interactively explored and understood from the viewpoints of interest" (Aouad et al., 2007: 290). It provides a new extension to building engineering analysis solutions. With avatars, the building performance can be analysed interactively from the human viewpoint, such as visual comfort. This may solve some of the limitations of traditional visualisation tools.

However, the advantages have only been applied by small architecture studios that specialise in single residential housing, where the engagement of the client is also the engagement of end-users. This is a simple scenario architects have identified, which can be used to prove the potential of using MMOG. However, how to use MMOG such as *SL* at early-stage design remains largely unknown.

# 2.5 Architectural Development in *Second Life*

## 2.5.1 *SL* Architects

In late 2006, Anshe Chung, a virtual property entrepreneur, became *SL*'s "first real estate millionaire" (Collins and Colonist, 2007: A19). With extensive media coverage, the story of Chung attracted the attention of the business world and many real-world architects (Usborne, 2007). With the hope of creating a business success similar to Anshe Chung's, more and more real-world architects have entered *SL,* such as Jon Brouchoud and Lester Clark. The simple but powerful construction tools provide architects with an ability to develop abstract designs in a model that clients with no professional design knowledge can understand and contribute to. Enjoying the convenience and better communication with clients, many architects soon become full time workers in this virtual world, in an effort to further explore the tremendous potential for Wiki-style 3D design collaboration.

An incubator for these virtual world architects is the *SL* Architecture Island, which was created in 2006 by real-life architect Jon Brouchoud (or Keystone Bouchard in *SL*). As one of the earliest architects to use *SL* for virtual and real-world combined architectural design, he is one of the leaders who heads the Architecture in *SL* community group (Chase et al., 2008). As the founder of Crescendo Design (a real-world design studio), Brouchoud had been working on affordable green residential designs. Brouchoud's exploration of *SL* began when he used virtual construction to represent the design, bringing clients in for tours of their simulated homes (Brouchoud, 2005). Figure 2.1 shows the virtual prototype Brouchoud developed in *SL* to help engage his clients in giving feedback on the real-world single residential housing he developed for the clients. Like many architects, it took him less than a week to master the simple construction tools in *SL*. With these tools, he mocks up the structure of real houses and collaborated with his clients to improve the design (Poutine, 2006). When the virtual house is ready, he invites his clients to join *SL* and visit the incarnated house. They can visualise their home and have input into its design.

**Figure 2.1 Affordable Green Residential House Designed by Jon Brouchoud in *SL* (Brouchoud, 2005)**

In comparison with real-time design tools, such as drawings, still renderings, or other expensive CAD models, the virtual buildings in *SL* are not only cheaper, but also able to capture the imagination in a way that is impossible with traditional tools (Poutine, 2006). However, virtual buildings in *SL* still lack the exact details and complexity of a real building (Rose, 2007: 23). To ensure accurate representations of the designs, Brouchoud imported useful plans and elevations from Architectural Desktop 2007 (Wong, 2007). With the combination of virtual and real-world tools, he has been able to design “healthy, green, energy efficient” homes at a price far below the cost of a fully customised home design (Brouchoud, 2005). This advantage has gained his studio more popularity than traditional real-world architects have. Accordingly, he considers *SL* to be a powerful visualisation tool, which is a key to the prosperity of his real world design studio.

Other SL architects are interested in the virtual replication of architectural masterpieces. For example, Farnsworth House, as shown in Figure 2.2, a masterpiece of the famous architect Mies van der Rohe, has been recreated virtually by the real-world architect Lester Clark, which is shown in Figure 2.3. “I have 400 to 500 Second Life visitors a day” said Clark. He considers SL to be professionally a powerful tool to “showcase a build to anyone around the world and have them interact with it on a virtual level” (Rose, 2007: 23).

**Figure 2.2 Farnsworth House, developed by architects Mies Van er Rohe (Rose, 2007)**

**Figure 2.3 The virtual Farnsworth House replicated by real-world architects Lester Clark, simulating the real-world masterpiece designed by Mies van der Rohe (Rose, 2007: 23).**

## 2.5.2 *SL* Architectural Academia

The simple construction simulation in *SL* has not only attracted virtual property developers and architects, but also lecturers and students from architectural backgrounds. Virtual building developers and architects follow the conventional architectural practice in *SL*, with their works representing real-world buildings or scenarios in science fiction movies. However, the work of architectural students in *SL* demonstrates more originality, challenging much real-world architecture. Two academic departments pioneer the use of *SL* as a tool for architectural education. They are the School of Architecture and Design at Australia's RMIT University and the Royal Institute of Technology Stockholm in Sweden (Poutine, 2007).

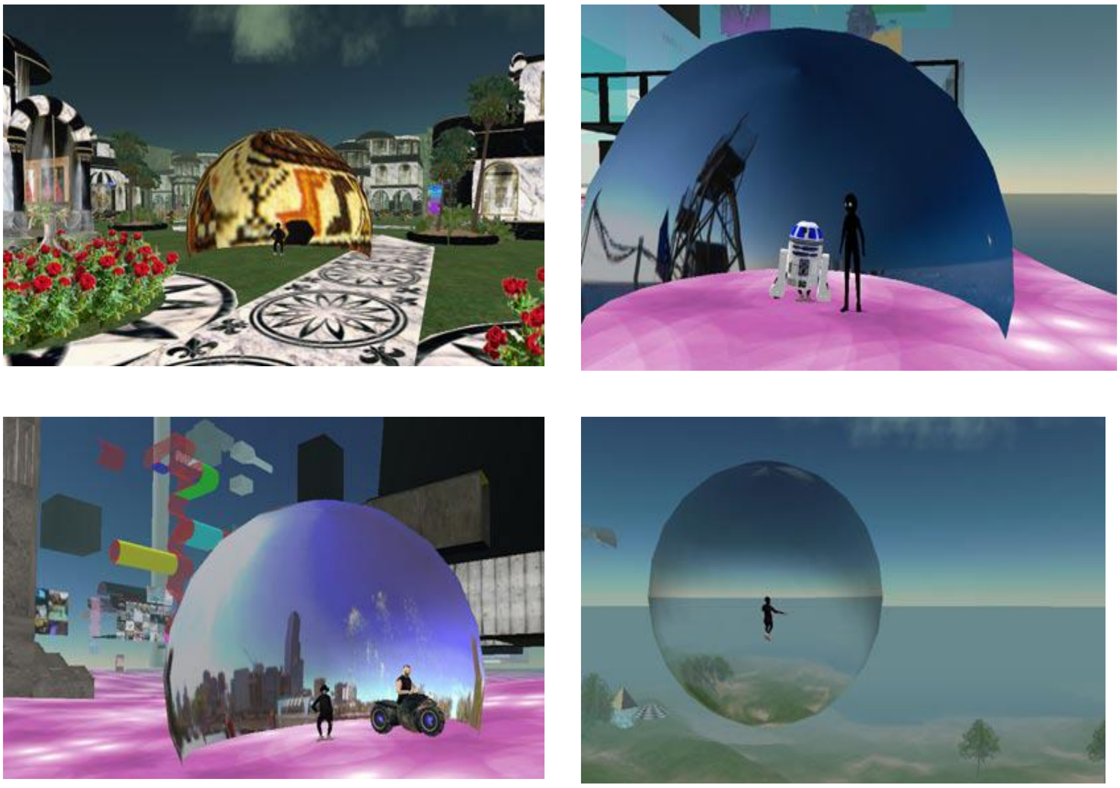
In the digital RMIT Island and the LOL (Laughing Out Loud) Architects Island, students are creating imaginative works rarely achieved in corporate builds (Poutine, 2007). They evaluate the potential and limitations of the virtual construction, to push the boundaries of architectural possibility in a world where the line between reality and virtuality is blurred. RMIT projects focus on more explicit design briefs, such as the "Lost" project, a space of refuge. Inspired by Borges' story on the relationship between the map and its territory, they use this architectural design to examine the spatial and cultural relationship of refuge. In LOL projects, on the other hand, students are given more freedom to use their imagination (Poutine, 2007). In 2006, 4th year students of architecture at Royal Institute of Technology, Stockholm (RITS) created LOL Architects, then the world's largest virtual architecture office. Since then, with the guidance of Tor Lindstrand, RITS Professor and founder of LOL Architects, more and more students from the department are encouraged to use *SL* to practice their designs. The originality of some of the projects they have created may challenge the way conventional architecture is designed and changed. Two of the most imaginative designs are the YURT ++ Project, which creates a mobile architecture that can be worn by the avatar, while the other is the "Transforming Structure", an interactive architecture that can react to the needs of the user.

### 2.5.3 Imaginative Works LOL Architects Island

#### 2.5.3.1 Yurt ++ Project- Wearable Architecture

Magnus Nilsson, a student from the School of Architecture, Lund Institute of Technology, Sweden, has found a way of "having the house as an extension of your skin, and wear it into any public space" (Ring, 2007). Aimed to meet the mobile needs of virtual residents in *SL*, he drew the inspiration from the Mongolian nomadic yurt. His research project YURT++ (see Figure 2.4 and Figure 2.5) is based on the question "could an old Mongolian nomadic yurt be used as a role model for new virtual spaces" (Nilsson, 2006: 2). Nilsson argued that, with more and more people immersed in *SL* in their daily lives, "a need for a virtual home naturally arises" (Nilsson, 2006: 2). However, as not everyone is willing to buy the expensive Dreamland housing created by Anshi Chung, "virtual homelessness" has become a problem for *SL* residents. He wanted to fundamentally address the issue of virtual homelessness by designing a customised architecture attached to the avatars, which could be worn like clothing. The avatar can wear this house wherever s/he goes and store anything s/he wants in it. Accordingly, as the researcher discussed, in these avatar-bound spaces 'fashion and architecture becomes one' (Nilsson, 2006: 2).

**Figure 2.4 YURT++: Wearable Architecture (Nilsson, 2006)**



This extremely mobile creation is highly regarded by other *SL* users as "resourceful, both in terms of economy and social interactions". Tor Lindstrand, Nilsson's lecturer, also appreciated the innovation demonstrated in the work, stating that this design has "pointed towards architecture as something mobile and something one performs - rather than stable structures" (Ring, 2007).

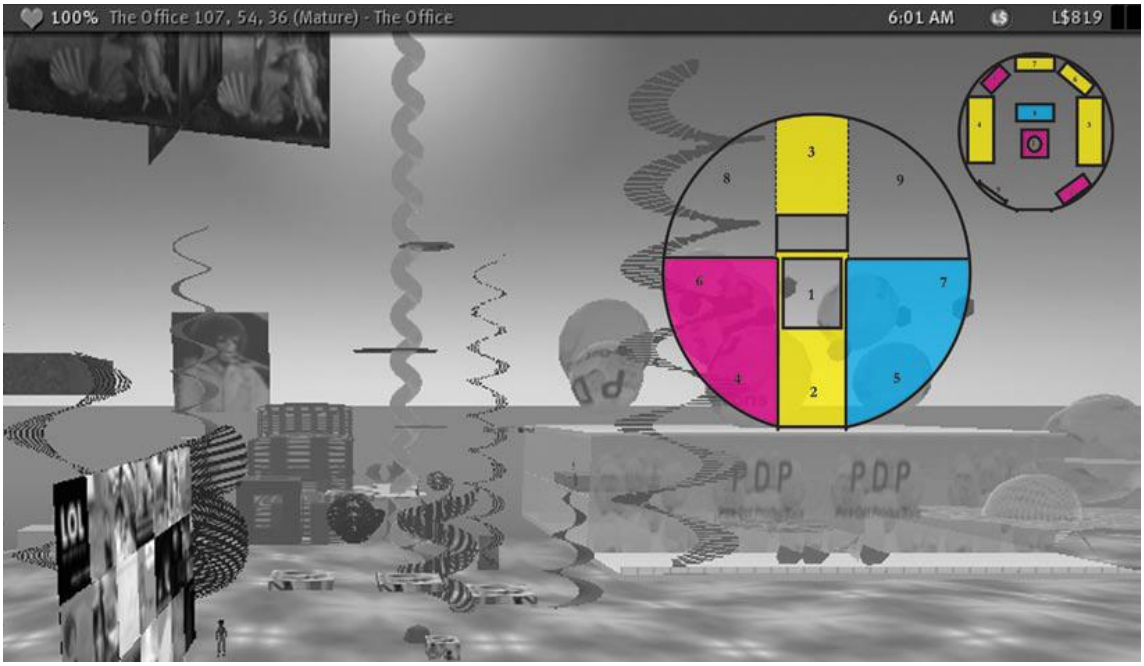



**Figure 2.5 The interior structure of YURT++ H.U.D (Heads-up Display) (Nilsson, 2006)**

From the YURT ++ project, *SL* demonstrates great potential to help architectural students to rethink on real-world buildings, and enable limitless imagination and originality to change routine design. As argued by Tor Lindstrand, the true value of *SL* is not only a new cool tool to develop virtual representation for architecture, but a digital platform to help real-world architects to "think out of the box" and discuss the underlying structures of architectural production (Ring, 2007). To help "think beyond the real world" is what virtual worlds can contribute most to the architectural industry and academic research. However, there are also issues identified by those two universities on using *Second Life* for real-world architectural design, such as transferability of the virtual design into real-world workable architectural design.

## 2.5.4 Industry Uptake of *SL*

Other sectors of the AEC industry have also shown interest in *Second Life*. For example, Autodesk, the company that produces the industry standard CAD tools created a virtual island in *Second Life*, named as AutoDesk Island. This island was created in 2006, with the aim to showcase the potential of virtual environment during Autodesk University.

They created an Autodesk University Community in *Second Life* to promote knowledge exchange and testing for better Autodesk applications and development. This island has also held various events to discuss the future application of architecture in the virtual world, inviting interested stakeholders from around the world (Bennett, 2007).

## 2. 5. 5 Summary of Architectural Development in *SL*

In a virtual world entirely created by its own residents, construction activities have been going on in *SL* since it was first made available to the public in 2004. From 2004 to 2007, the architecture was mainly conventional construction, operated by virtual property entrepreneurs and small groups of individual architects. Virtual real estate developer Anshe Chung built themed Dreamlands to fulfil residents' sense of belonging to the virtual community. Anshe's success story inspired more architects to enter the virtual world. These architects have used *SL* as a powerful tool to represent their designs, collaborating more effectively with their clients to create improved designs at an affordable cost. Universities from around the world have undertaken research in *SL*, including academia in architecture. Two academic departments, one from Australia, the other from Sweden, took the initiative to formulate the limitations and potentials of virtual-world architecture. Unlike the architectural industry that has used *SL* as a tool for mocking up real-world architecture, students from the universities are injecting considerable creativity and imagination, to rethink the way real-world architecture should develop. The new inspiration they are drawing from virtual design in *SL* may fundamentally change the way real-world architecture evolves in the future. The industry uptake of *SL* is also discussed through the example of AutoDesk. This historical literature review shows that there is a lack of research conducted to systematically explore how MMOG can be best used to augment design of architecture. Therefore, the following two research questions are proposed in this thesis.

Q3: Can MMOG complement existing visualisation techniques?

Q4: How can MMOG such as *Second Life* be used to better inform building design?

## 2.6 Summary of the Chapter

The literature review starts with the definition of design and moves to the feature of architecture and then architectural design. RIBA Design Plan of Work is discussed to show how architectural design is defined in the UK. Early-stage design and three main challenges identified at RIBA early design Stages A to D are discussed, including the complex decision-making process, communication issues between professional and non-professional stakeholders and a lack of innovation.

Based on the three main issues identified in early-stage design, the advantages and limitations of various design tools are discussed to explore how far they can address some or all of the three main issues to improve early-stage design. However, this is not an exhaustive list of all the issues at early-stage design. It is important to explore Q1 "What are the issues which negatively impact early-stage design?" This question is proposed as research question 1 of this thesis. Various tools have been identified as tools used at early-stage design. However, it is not clear that how effective each of those tools is at early-stage design. Therefore, it is important to explore Q2 "What forms of visualisations are used in early-stage design and what are their limitations? This question is proposed as research question 2 of this thesis.

From the review, it is found that, in order to manage the complex decision-making process at early-stage design, a computer-aided model that includes all information of the design project is useful. Design tools, such as nD models and BIM are theoretically useful to meet the demands of the process. However, there are various issues BIM and nD models need to address. A new model, which adopted a similar nD approach, may have the capacity to meet this need. This creates a question "Will MMOG such as *SL* be developed in a way similar to nD models or BIM to include all information in one model"? Here the third research question "Can MMOG complement existing visualisation techniques" is postulated.

In order to generate innovative design ideas, the tools must be intuitive and simple to operate so that the architects can concentrate fully on the design process itself rather than how to best employ the tool. In this sense, simple and intuitive tools, which allow flexibility and ambiguity such as 2D sketches, physical models, and virtual reality, all have features offering architects simple design processes to generate innovative design ideas. Most design tools used during early-stage design (such as 2D sketches, physical models, Google Sketch Up, CAD etc.) are for professional stakeholders such as architects only. Few tools have been developed to effectively enable non-professional stakeholders to play a more active role. In order to support non-professional stakeholders, the tool must be simple and easy to understand. Also, it must allow real multiple end-users to interact in the virtual space before construction to test out design ideas. Currently, Multi-user Virtual Environment and Game Engine Simulation Models are moving towards simulations that are more autonomous to allow end-users to better identify design problems through interacting virtually in the proposed virtual design. Current models have pre-defined rules, which do not represent real-world interaction between multiple end-users and the space. There is a need to find a tool which is simple but allows autonomous interaction between multiple users to explore the virtual space before construction.

One promising development is the use of MMOG to simulate massive human interaction within the building environment, which also has the flexibility to promote innovation at early-stage design. In comparison with traditional AEC simulation tools, the potential value of MMOG lies in their autonomous simulation of real-world human interaction. However, this is not the only value of MMOG. Like nD modelling, MMOG also have much more potential than previous AEC models, such as the autonomous simulation of real human behaviour in a building environment, simple construction tools and fast construction processes, easy access, cheap cost, and global collaboration opportunities. Through this review, it is found that there is no comprehensive work done so far to explore these features of MMOG and their suitability to be used as an early-stage design tool. Therefore this knowledge gap allows research objective 2

“Examine the features of MMOG and their suitability in early-stage design” to emerge. With that research objective raised, research question 3, “Can MMOG complement existing visualisation techniques” and research question 4, “How can MMOG such as *Second Life* be used to better inform building design”, emerged.

This review provides the basis for the research questions and allows the thesis to examine the main question, how to use MMOG at the early-stage design of construction.

# Chapter 3

# 3.0 Research Design and Methodology

This chapter addresses research questions identified in Chapter 2, the Literature Review, to explore ways to generate the knowledge needed to answer the following research questions of this thesis:

Q1: What are the issues which negatively impact on early-stage design?

Q2: What forms of visualisations are used in early-stage design and what are their limitations?

Q3: Can MMOG complement existing visualisation techniques?

Q4: How can MMOG such as *Second Life* be used to better inform building design?

To answer research questions Q1 and Q2 above, early-stage design is examined by interviewing 30 architects, so that the challenges of this design stage are identified and understood. Different visualisation tools that can be used at this stage are identified and their advantages and limitations to support early-stage design are evaluated through the literature. To answer research questions Q3 and Q4, the methodology is designed around a specific MMOG (*Second Life*), to explore the advantages and limitations of using these technologies at the early design stage, to determine what role they can perform in complementing other visualisation tools. This is achieved through interviewing 20 architects who are using *SL* for real-world architectural design and 20 *SL* residents who have become more engaged in the architectural design process as non-professional stakeholders. The data collected to address question 3 was further analysed to propose guidance to assist the effective implementation of MMOG during the design process.

A virtual model representing the Civil and Building Engineering School in Loughborough University was created in *Second Life*. Various tests were carried out to elicit feedback from representative stakeholders involved in both the re-design process and the use of the physical School. 48 interviews were conducted among these stakeholders to explore how realistic the model is and how it can be used as a tool to better engage AEC professionals and non-professional stakeholders, and therefore improve the architectural design process.

## 3.1 Overview of Research Design

This project adopts a "critical realism" perspective to examine the potential of MMOG to inform design as an alternative to other visualisation techniques, and explore how interaction in MMOG can enhance the design of buildings. This research discusses a number of established academic disciplines such as Environmental Psychology (Bell et al., 2001), Management Theory (Gladwin et al., 1995), Social Science theory (Giddens, 1979), and Behavioural Science theory (Smelser and Baltes, 2001), but is based within Construction and the Built Environment (Assmann et al., 2010; Dainty et al., 2007). Based on the research questions, aim and objectives specified, the research design and methodology was developed to achieve the goals of this research. In this chapter, various research designs are compared and justification is presented for the selection of the selected research design, philosophical basis, and choices of method. Difficulties that arose in the course of work and data collection are discussed. The structure of this chapter mirrors the order of the aim and objectives and concludes with a short summary.

The selection of semi-structured interviews as data collection methods is discussed. The development of questionnaires for the interviews, the sampling strategy and the selection of the interviewees is described. The use of Template Analysis as a data analysis process is also reflected upon to highlight potential drawbacks and ways to defend it. A validation of the methodology is also included at the end of this chapter.

## 3.2 Research Approach

### 3.2.1 Philosophical Considerations

In academic research, a research framework must be developed to help researchers to tackle the research questions in different academic disciplines. The research framework normally includes first, a philosophical position which explains the logic of the research; second, a methodological position which discuss various methods employed and the rationale of choosing them so as to validate the philosophical position; and third, axiological positions to defend the value of the research (Seni and Hodges, 1996). The philosophical considerations are generally made up of two polarised, ontological, epistemological positions (Fitzgerald and Howcroft, 1998).

There has been lots of debate on the legitimacy of employing various research frameworks. Academic research on managerial practice in the built environment follows the debate on these competing research paradigms in the 1990s (Seymour et al., 1997, Raftery et al., 1997; Runeson, 1997; Harris, 1998). Since Construction Management research in the built environment is multidisciplinary and evolves from both the natural and social sciences, methodological pluralism is widely used.

Fitzgerald and Howcroft (1998) proposed a holistic model for research methodology in Information Science. The simplified model of their proposal is used as the framework of this thesis. This framework model is composed of an ideal set of continuums. In a real research context, philosophical positions exist somewhere between those two extremes. The level described by Table 3.1 ranges from the broad ontological level down to the more detailed axiological level. This research does not discuss all the set of continuums proposed by Fitzgerald and Howcroft. For all paradigms discussed, each level is examined in more detail in the following sections.

**Table 3.1“Soft”vs.“hard”research dichotomies (Fitzgerald and Howcroft, 1998: 160)**

| Soft | Hard |
|---|---|
| **Ontological Level** | |
| **Relativist**<br>Belief that multiple realities exist as subjective constructions of the mind. Socially-transmitted terms direct how reality is perceived and this will vary across different languages and cultures | **Realist**<br>Belief that external world consists of pre-existing hard, tangible structures, which exists independently of an individual's cognition. |
| **Epistemological Level** | |
| **Intepretivist**<br>No universal truth, understand and interpret from research's own frame of reference. Uncommitted neutrality impossible. Realism of context important | **Positivist**<br>Belief that would conforms to fixed laws of causation. Complexity can be tackled by reductionism. Emphasis on objectivity, measurement and repeatability. |
| **Subjectivist**<br>Distinction between the researchers and research situation is collapsed. Research findings emerge from the interaction between researchers and research situation, and the values and beliefs of the researcher are central mediators. | **Objectivist**<br>Both possible and essential that the research remain detached from the research situation. Neutral observation of reality must take place in the absence of any contaminating values or biases on the part of the researcher. |
| **Emic/Insider/Subjective**<br>Origins in anthropology. Research orientation centres on insider's view, with the latter viewed as an appropriated judge of adequacy of research. | **Etic/Outsider/Objective**<br>Origins in anthropology. Research orientation of outside researcher who is seen as objective and the appropriate analyst of research. |
| **Methodology** | |
| **Qualitative**<br>Determining what things exist rather than how many there are. Thick description. Less structured, more responsive to need and nature of research situation | **Quantitative**<br>Use of mathematical and statistical techniques to identify facts and causal relationships. Samples can be larger populations within known limits of error. |
| **Exploratory**<br>Concerned with discovering patterns in research data and to explain/understand them. Lays basic descriptive foundation. May lead to generation of hypotheses. | **Confirmatory**<br>Concerned with hypothesis testing and theory verification. Tends to follow positivist, quantitative modes of research. |

| | |
|---|---|
| **Induction**<br>Begins with specific instances which are used to arrive at overall generalisations which can be expected on the balance of probability. New evidence may cause conclusions to be revised. Criticised by many philosophers of science, but plays an important role in theory/hypothesis conception. | **Deduction**<br>Uses general results to ascribe properties to specific instances. An argument is valid if it is impossible for the conclusions to be false if the premises are true. Associated with theory verification/falsification and hypothesis testing. |
| **Field**<br>Emphasis on realism of context in natural situation, but precision in control of variables and behaviour measurement cannot be achieved. | **Laboratory**<br>Precise measurement and control of variables, but at expenses of naturalness of situation, since real world intensity and variation may not be achievable. |
| **Idiographic**<br>Individual-centred perspective which uses naturalistic contexts and qualitative methods to recognise unique experience of the subject. | **Nomothetic**<br>Group-centred perspective using controlled environments and quantitative methods to establish general laws |
| **Axiological** | |
| **Relevance**<br>External validity of actual research question and its relevance to practice emphasised, rather than constraining the focus to that researchable by “rigorous” methods | **Rigour**<br>Research characterised by hypothetico-deductive testing according to the positivist paradigm, with emphasis on internal validity through tight experimental control and quantitative techniques |

### 3.2.2 Ontological Level: Objectivist Ontology

The ontological paradigm is the highest level of the research framework, which overarches all aspects of life and dictates our view of human existence. “An ontology is an explicit formal specification of how to represent the objects, concepts, and other entities that are assumed to exist in some area of interest and the relationships that hold among them” (Sørensen et al., 2008: 419). Ontology defines “what exists” and specifies the conceptualised field. It broadly means conceptions of reality.

It can be divided into objectivist ontology and constructivist ontology. The difference between them is in how they see social phenomena and their meaning. Objectivist ontology concerns the nature of the social phenomena being investigated, they consider social phenomena as something existing independently of social actions, whereas constructivist ontology concerns the nature, form, acquisition and communication of knowledge with the belief that social phenomena are produced through social interaction and are therefore constantly revised (Bryman and Bell, 2003: 19–20).

Ontologically, the research is based on objectivist ontology. The motivating concern of objectivist ontology is to "provide people with rational knowledge that will help them function successfully" in the external world, which is about the "the external aspects of understanding" (Huizing, 2007: 7). The research question of this thesis is to explore the possibility of using MMOG as a tool in the early stage of architectural design. The emergence of MMOG for architectural use is a reality in its own right, which is independent of what people think about it. This is in line with the independency characteristics of objectivist ontology where social phenomena are considered independent of the social actions taken by people. Also, the aim and objectives of this research are to provide architects and other stakeholders with guidance in using MMOG as a tool to better inform early-stage design. Because of the above-mentioned two reasons, objectivist ontology is chosen.

Objectivist ontology is one form of realist ontology (Lakoff, 1987). Both realist and objectivist ontology agree that "the existence of a real, physical world is external to individuals and includes human experience" (Schuh and Barab, 2008: 71). Realist ontology "merely assumes that there is a reality of some sort" (Lombardo, 1987: 159) while objectivist ontology gives specific details about "what the real world must be, in terms of entities and properties" (Schuh and Barab, 2008: 71). According to Table 3.1, at the ontological level, the ideal sets of continuums are relativist and realist ontology. In this thesis, an objectivist ontology is chosen, which is realist research.

### 3.2.3 Epistemological Level: Interpretivist, Subjectivist, Emic

Ontology discusses the essence of the phenomena, while epistemology means what should be regarded as acceptable knowledge in a discipline. It specifies what constitutes appropriate knowledge in the field, where it is and how it can be represented and transferred (Dainty, 2007).

At the epistemological level, there are three pairs of competing paradigms: interpretivist vs. positivist, subjectivist vs. objectivist, and emic vs. etic. There are strong debates in the literature regarding different approaches to research including the differences between these three pairs of paradigms. In this thesis, the following three positions are adopted: interpretivist epistemology, subjectivist epistemology and emic epistemology.

#### 3.2.3.1 Interpretivist vs. Positivist

According to Table 3.1, positivist epistemology sees that the methods of the natural sciences should be applied to the study of social phenomena, while interpretivist epistemology considers a difference between the objects of natural science and people, in that phenomena have different subjective meanings for the actors studied. Understanding the influence those competing paradigms have on the way in which research is carried out is fundamental to understanding the contribution that it makes to knowledge. Between positivist and interpretivist, the former supports the use of natural science methods in the social sciences, whereas the latter is concerned with how things appear to people and how they experience the world.

Epistemologically, the research is based on an interpretivist position where “knowledge of the world is intentionally constituted through a person’s lived experience” (Weber, 2004: iv). The knowledge of a virtual world that all MMOG are based on, is intentionally constituted through people’s individual experience. Different stakeholders in the architectural design process will interpret this virtual world in different ways.

How valuable MMOG is to support the architectural design process mainly relies on how different people interpret it, which is the position advocated by an interpretivist epistemology.

As a result, the knowledge found through this interpretive research puts the validity of the findings into question. The knowledge generated needs to be validated through various methods to ensure the findings are defensible. It is the same with reliability of the research. Researchers need to address all the issues caused by the subjective interpretation of the data collected and analysed.

#### 3.2.3.2 Subjectivist vs. Objectivist

Subjectivists and objectivists hold different views on how values are defined. Subjectivists believe that "values are constituted by subjects" (i.e., by their final attitudes) while objectivists hold that "values are supervenient properties" (Rønnow-Rasmussen, 2003: 261).

According to Table 3.1, subjectivists believe that a researcher is dependent on their research situation. The interaction between the observer and the situation being observed brings in the subjectivity of the research. In this research, the observer is the researcher. The situation being observed is MMOG. According to subjectivists such as Weber et al. (1978), the researcher cannot distance herself from 1) What is being studied: MMOG or, 2) the research methods chosen (interviews), because the researcher needs to address the inherent bias she has due to her own interests, beliefs, skills, values, resources or backgrounds. For example, if the researcher has the IT skills to develop a new MMOG platform, which is created to meet the 87needs of the AEC industry, rather than explore the potential of a general MMOG platform such as *Second Life*, the results of this research will be more valuable to the AEC industry.

#### 3.2.3.3 Etic vs. Emic

Etic and emic are two different methods to describe the same results (Franklin, 2009). They were coined by the American linguistic anthropologist Kenneth Pike in 1954, who suggested that researchers can use two methods to study cultural systems (Pike, 1967). According to Table 3.1, the emic is also called the "insiders' view", which aims to understand phenomena from the insider's point of view; while the etic is called "the outsiders' view" (Holloway, 1997: 53), which aims to connect cultural practices to external factors (Morris et al., 1999). The emic view is "domestic, mono-cultural, structurally derived", whereas the etic view is "alien, cross-cultural, prepared in advance as a typological grid, somewhat absolute, often measurable" (Franklin, 2009:1).

The emic/insider's view describes behaviour from the actor's self-understanding, which is often bound culturally and historically (Pike, 1967). For example, in this research, the study of MMOG at early-stage design is bound by the cultural setting in the AEC industry. The research results cannot be applied equally to other industries, because the self-understanding (the ability to understand one's own action) of stakeholders in different industries is different. This is clearly the emic view.

### 3.2.4 Methodological Level

Similar to the philosophical considerations, there is much debate on choices of appropriate research methods. The key questions at a methodological level are the research approach, research methods, and the research process.

#### 3.2.4.1 An Ecumenical Research Approach

Research paradigms and methods are closely linked with each other (Fitzgerald and Howcroft, 1998). A paradigm is a "cluster of beliefs and dictates which for scientists in a particular discipline influence what should be studied, and how research should be done" (Bryman, 1988: 123). Based on different paradigms, researchers developed corresponding research designs and methods to implement the research and make new contributions to knowledge (Dainty, 2007). Decisions about research design and methodology are affected by research paradigms: "Paradigm issues are crucial; no inquirer ought to go about the business of inquiry without being clear about just what paradigm informs and guides his or her approach" (Guba and Lincoln, 1989: 218). Based on this theory, many researchers have adopted an ecumenical approach in their research methods, namely, choosing the most appropriate research methods and research design to allow the independent evaluation of the research questions (Bryman, 1988; Wing et al., 1998). For example, interpretive researchers often employ qualitative research methods while positivist researchers prefer quantitative methods (Dainty, 2007).

However, many other researchers argue that researchers should consider the design and methods of each research question based on its own merits. Therefore, choosing one particular research paradigm does not necessarily mean the same research methods will be used (Bryman, 1988; Fitzgerald and Howcroft, 1998). Increasingly, a pluralistic approach is employed by researchers in the Construction Management area (Wing et al., 1998; Dainty, 2007). The basic principle of methodological pluralism is to use multiple theoretical models and multiple methodological approaches in one research study whenever appropriate (Bryman and Bell, 2003; Dainty, 2007).

Both ecumenical and pluralistic approaches are popular within Construction Management (Raftery et al., 1997; Wing et al., 1998). This thesis is a project to explore how MMOG can be used as a tool to augment early stage architectural design. All the four research questions are designed to meet the aim of this research. Therefore, instead of choosing a pluralistic approach with different methods, an ecumenical research approach is adopted to use the most appropriate research methods to answer the research questions.

#### 3.2.4.2 Qualitative Research Methods

Quantitative and qualitative research methods are sometimes viewed as competing views about the way in which social reality ought to be studied. For example, qualitative research methods present a “processual view of life” whereas quantitative research methods provide a static account (Bryman, 1988). According to Table 3.1, qualitative research places emphasis on understanding through looking closely at people's words, actions and records, whereas quantitative research methods look past these words, actions and records to their mathematical significance. Qualitative research methods are less structured to identify what exist while quantitative research methods use mathematically accurate techniques searching large samples to find facts (Fitzgerald and Howcroft, 1998: 160). More differences between qualitative and quantitative research methods can be found in Table 3.2 and Table 3.3.

However, other researchers argue that “research methodologies are merely tools, instruments to be used to facilitate understanding” (Morse, 1991: 122). Therefore, this debate on the value of qualitative and quantitative methods leads to the argument that both have their own advantages and disadvantages. The “real issues” for choosing qualitative or quantitative methods have become “methodological flexibility and appropriateness” (Patton, 1989: 181).

**Table 3.2 Differences between Qualitative and Quantitative methods**

| Concepts usually associated with quantitative methods | Concepts usually associated with qualitative methods |
|---|---|
| **Type of reasoning** | |
| Deduction | Induction |
| Objectivity | Subjectivity |
| Causation | Meaning |
| **Type of Questions** | |
| Pre-specified | Open-ended |
| Outcome –oriented | Process-oriented |
| **Type of analysis** | |
| Numerical estimation | Narrative description |
| Statistical inference | Constant comparison |

**Table 3.3 Theory building in quantitative & qualitative research (Patel et al., 2006: 69)**

| Differences | Quantitative research | Qualitative research |
|---|---|---|
| **Logic of theory** | Deductive | Inductive |
| **Direction of theory building** | Begins from theory | Begins from reality |
| **Verification** | Takes place after theory building is completed | Data generation, analysis and theory verification take place concurrently |
| **Concepts** | Firmly defined before research Begins | Begins with orienting, sensitising or flexible concepts |
| **Generalisations** | Inductive, sample-to-population Generalisations | Analytical or exemplar Generalisations |

Construction Management research used to be described as something based on a quantitative and empirical tradition (Loosemore et al., 1996). However, more and more researchers are advocating methodological pluralism (Wing et al., 1998; Dainty, 2007) in this discipline where qualitative methods are becoming popular (Dainty et al., 2007; Loosemore et al., 1996). In most Construction Management research, qualitative methods are used to test or generate theory (Dainty, 2007). Qualitative methods analyse words, language, behaviour and actions of participants to capture key information to answer research questions. The following are some of the popular qualitative research methods (Bryman, 1988; Yin, 1994; Dainty, 2007):

- Observation – both participant and non-participatory
- Interviews – both semi-structured and unstructured
- Focus group
- Document
- Visual data analysis – e.g. photographs and video tapes

In this research, qualitative research methods are used. The use of observation in the virtual world of MMOG, both as a non-participant observer or participant observer are time-consuming. Also, it is difficult to obtained informed consent in the virtual world where most participants prefer to keep anonymity, separating their virtual-world activities from their real-world identity. The use of documents is not consistent with the phenomenological approach (Moustakas, 1994). The use of visual data analysis is not available to the researcher. After all the other qualitative research methods considered as inappropriate or unavailable, interviews are chosen in this research to achieve data validity and reliability in the target population frame (Elliott, 2005).

#### 3.2.4.3 Research Process: Deductive and Inductive Combined

Besides the choice of research approach and research methods, research process is also important at the methodological level. Research process is about how to manage the research theory and the data collected from different participants. It can be categorised into the following two approaches, a deductive (or "top-down") approach or an inductive (or "bottom-up") approach (Deshpande, 1983; Neuman, 1997).

According to Table 3.1, deductive research is theory-testing while inductive research is theory-generating. Deductive research works from the general to the specific (it is knowledge-driven) whereas inductive research works from specific observations to broader generalisations or theories (it is feature-detecting). The theoretical concerns and philosophical positions of the research can influence the choice of different research approaches and research methods. It is the same with choosing between deductive or inductive processes. Often deductive research is linked with quantitative experiments or surveys, while inductive research is linked with qualitative interviews or ethnographic work. However, this is not always the case; most research combines both deductive and inductive elements in their research process in a circular way where theory leads to observations which in turn lead to identification of new patterns, and then it leads to the development of new theories (Ali and Birley, 1999).

The research process of this thesis is both deductive and inductive. The research questions of this thesis are:

Q1: What are the issues which negatively impact on early-stage design?

Q2: What forms of visualisations are used in early-stage design and what are their limitations?

Q3: Can MMOG complement existing visualisation techniques?

Q4: How can MMOG such as *Second Life* be used to better inform building design?

In order to answer the first two questions, 30 real-world architects were interviewed to generate the knowledge to understand the issues of early-stage design, and the forms of visualisation tools used at early-stage design. This is an inductive approach, which analyses specific observations to generate broader theories. Then, to test how to use MMOG to complement other forms of visualisation tools and inform better early-stage design, 20 real-world architects who are using MMOG to augment the early-stage design process were interviewed. This is also achieved through interviewing 20 *SL* residents who provide feedback on how *SL* can engage non-professional stakeholders in the design process. A virtual model of the Civil and Building Engineering School of Loughborough University was created with various tests conducted to validate how realistic the model is and how far stakeholders of the School consider this kind of human interaction as realistic. These three datasets use the deductive approach to test how useful MMOG can be in the early-stage design process. Guidance was developed to assist architects to use MMOG to augment early-stage design of construction. When the guidance was validated by various stakeholders, the results from that validation suggested that MMOG can be used not only as a tool, but also as a more user-friendly interface where other sets of data can be presented to engage various stakeholders at the early-stage design process, which is again inductive.

### 3.2.5 Research Design: "Mixed Method" Design

Research design is the basic strategy of the research; a logical framework that guides researchers in the process of collecting, analysing and interpreting data (Yin, 1994) to answer the research questions, as well as to provide the framework to conduct the investigation (Bryman and Bell, 2003: 32). The purposes of research design are multiple, it can be used to keep the data collected relevant to the initial research question (Oppenheim, 1992), to make a research question researchable by framing the study to allow specific answers to specific questions, to define whether the findings can be applied to a larger population or to different situations (Bryman, 2001). Researchers can choose many research designs while the best design is a matter of appropriateness (Oppenheim, 1992). Research designs can be used for exploratory, descriptive or explanatory purposes. Researchers usually consider three factors so as to choose the research design: type of the research question; how much control they have over actual behavioural events and; the degree of focus on contemporary as opposed to historical events. Research design is fundamental to both the philosophical positions and the knowledge contributions of the research (Dainty, 2007).

Construction Management is a discipline that draws inspiration from both the natural and social sciences. The research designs for Construction Management are generally variable, ill-structured and not well-defined. However, there are four kinds of main research designs, which are widely used in construction management: experiment, survey, action research and case study (Dainty, 2007).

An experiment is a systematic and scientific approach to research in which the researcher manipulates one or more variables, and controls and measures any change in other variables (Rudestam and Newton: 1992). The aim of experimental methods is to develop theory through replicating similar hypotheses, comparing and contrasting the results to make sound judgment (Campbell and Stanley, 1963). Most experiment research design tests only a single theory. This deductive approach leads to a restrictive focus when unforeseen, conflicting theories become difficult to identify (Cook and Campbell, 1979).

Survey research design uses questioning as a strategy to elicit information from subjects on a number of variables in a standardised form to examine data from selected populations through different variables (Fellows and Liu, 1997). A written survey is called a questionnaire; an oral survey is called an interview. Both approaches use probability statistical sampling (Schwab, 1999). The advantage of survey research design is that it permits statistical analysis of data, facilitates replication, improves the reliability of observation and the generalisability of research results to a bigger population (McClintock et al., 1979).

Action research is "a participatory, democratic process concerned with developing practical knowing in the pursuit of worthwhile human purposes, grounded in a participatory worldview which we believe is emerging at this historical moment" (Reason and Bradbury, 2001: 1). Therefore, Action Research is also called participatory research, collaborative inquiry, emancipatory research, action learning or contextual action research (O'Brien, 2001: x). Action research involves working closely with other stakeholders involved in the issue being resolved and provides a "real-life" understanding of the context and parameters of the research domain. This enables interventions to be planned, implemented and monitored, and practical recommendations made to address the issue. Therefore, the advantage of action research is to help integrate action and reflection, theory and practice (Reason and Bradbury, 2001). Using action research is effective in advocating a process whereby many stakeholders in the project can learn the knowledge by doing, and thus facilitate a more active collaboration between researchers and participants.

A case study is "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, when the boundaries between different phenomena and the context are not clearly evident, and in which the multiple source of evidence are used"

(Yin, 1994: 13). It is a comprehensive research strategy, which concentrates on perceiving the dynamics present within single settings (Howe and Eisenhardt, 1990). A case study is especially suitable for examining “who”, “why” and “how” questions in management research, which are questions about emerging new phenomena over which the researcher has little or no control (Saunders et al., 2007; Yin, 1994). Therefore, the case study strategy is often employed in explanatory and exploratory research of new social phenomena (Saunders et al., 2007).

In addition to the above-mentioned four main types of research design, mixed research design has become increasingly popular (Leech and Onwuegbuzie, 2007) and is advocated by more and more researchers as a legitimate, stand-alone research design (Creswell, 2003). Mixed research design is relatively new. Sound guidelines are still in the process of development (Leech and Onwuegbuzie, 2007). Mixed research “is a research design with philosophical assumptions as well as methods of inquiry. As a methodology, it involves the philosophical assumptions that guide the direction of collecting, analysing, and mixing both quantitative and qualitative data in a single study or series of studies” (Creswell and Plano Clark, 2007: 5). In mixed research, “the data are collected concurrently or sequentially, are given a priority, and involve the integration of the data at one or more stages in the process of research” (Creswell et al., 2003: 212). The aim of mixed research design is to facilitate the richness of data and to expand the interpretation of the findings (Leech and Onwuegbuzie, 2007).

### 3.2.6 Research Design of the Thesis

This research adopts a mixed research design, which is mainly based on qualitative research methods, combined with both inductive and deductive research processes. The discussion about research methodology is illustrated in Table 3.4. It is clear from Table 3.4 that the design of research methodology is organised around each of the four research questions and five research objectives of this thesis. In order to answer each research question of this thesis, relevant data-collection methods are proposed. Criteria for methods used to analyse each of the datasets are measured. Results from each of the datasets are presented to discuss how they can achieve each of the five research objectives of this thesis.

In order to achieve Research Objective 1, “Review current tools used in early-stage design” and Research Objective 2, “Review research and practice pertaining to visualisation and the building design process to identify any deficiencies in supporting early-stage design decisions”, Research Questions 1, “What are the issues which negatively impact early-stage design?” and 2, “What forms of visualisations are used in early-stage design and what are their limitations?” are asked. Thirty real-world architects with no experience of MMOG were interviewed. The data collected from them are used to achieve Research Objectives 1 and 2, and to answer Research Questions Q1 and Q2. It is found that four tools are mainly used at early-stage design. Each of the four tools has limitations identified.

In order to achieve Research Objective 3, “Examine the features of MMOG and their suitability for informing early-stage design”, Research Question Q3, “Can MMOG complement existing visualisation techniques?” is asked. Data is collected through interviewing 20 real-world architects who are using MMOG to augment their real-world architectural practice, and 20 *Second Life* users who became more involved in the architectural design process as non-professional stakeholders. Results from Dataset 3, interviewing 20 architects, confirm Finding 2, “Architects are using various features of MMOG to augment early-stage design” and Finding 3, “MMOG are used to better engage clients and end-users”. Results from data obtained by interviewing 20 *Second Life* users show Finding 3 “MMOG are used to better engage clients and end-users”.

In order to achieve Research Objective 4, “To test the effectiveness of MMOG in simulating real-world environments”, Research Question Q3, “Can MMOG complement existing visualisation techniques?” is asked. To achieve this research objective, Dataset 3 is collected through interviewing 20 *Second Life* users, which shows Finding 3, "MMOG are used to better engage clients and end-users". Also, it is achieved through Dataset 4, obtained by interviewing 48 professional and non-expert stakeholders in the MMOG model test. The finding F5 from this dataset helps to answer how realistic stakeholders consider the virtual environment and the virtual interaction between people in MMOG is.

To achieve Research Objective 5, "Develop and validate guidance on how and when MMOG should be deployed to best inform early-stage design", Research Question Q4, "How can MMOG such as *Second Life* be used to better inform building design?" is asked. Dataset 5 was collected through compiling all the previous four datasets, and comparing the four main findings, to come up with Finding 6, the initial guidance to inform architects when and where to use MMOG during early-stage design. For Dataset 6, five architects/Construction IT experts were interviewed to test and validate the guidance. The outcome from this data analysis is Finding 7: the revised guidance identifying various factors such as stages, projects, procedures, cost, time, training that AEC professionals need to consider, as well as various limitations and future development of this guidance.

In the research design, there are six main datasets, including semi-structured interviews of 30 architects with no experience of MMOG, 20 architects experienced in MMOG, 20 *SL* residents, 48 stakeholders of the MMOG virtual School, comparing the previous four main datasets to come up with the initial guidance to inform architects when and where to use MMOG during early-stage design, and interviewing five architects and Construction IT experts. Most of the six datasets only answer one specific research question of the thesis. There are only two exceptions. To answer Research Question Q3, "Can MMOG complement existing visualisation techniques?" Dataset 3, "semi-structured interviews of 20 architects experience in MMOG" and Dataset 4, "Semi-structured interviews of 48 stakeholders of the hub" were collected. To answer Research Question Q4, "How can MMOG such as *Second Life* be used to better inform building design?", all six main datasets collected in the thesis were used.

With the guidance of all the five research objectives, the new knowledge generated through this thesis will be divided into three areas: the MMOG environment, the guidance on how to best use MMOG at early-stage design, and testing and validation of the guidance.

**Table 3.4 Overview of the Research Methodology**

<table>
<tr><th>Aims</th><th>Research Objectives</th><th>Research Questions</th><th>Data</th><th>Measured by Findings from Data Analysis</th></tr>
<tr><td rowspan="11">To explore the potential of MMOG in informing the early-stage design process.</td><td rowspan="2">O1.<br>Review current tools used in early-stage design.</td><td>Q1<br>What are the issues that negatively impact early-stage design?</td><td rowspan="2">D1:<br>Semi-structured interviews of 30 architects with no experience of MMOG.</td><td rowspan="2">F1:<br>4 tools which are mainly used at early-stage design and the limitation of each tool.</td></tr>
<tr><td>Q2<br>What forms of visualisations are used in early-stage design &what are their limitations?</td></tr>
<tr><td rowspan="2">O2.<br>Review research and practice pertaining to visualisation and the building design process to identify any deficiencies in current practice</td><td>Q1<br>What are the issues which negatively impact early-stage design?</td><td rowspan="2">D1:<br>Semi-structured Interviews of 30 architects with no experience of MMOG.</td><td rowspan="2">F1:<br>4 tools that are mainly used at early-stage design and the limitation of each tool.</td></tr>
<tr><td>Q2<br>What forms of visualisations are used in early-stage design &what are their limitations?</td></tr>
<tr><td rowspan="3">O3.<br>Examine the features of MMOG and their suitability for informing early-stage design.</td><td rowspan="3">Q3<br>Can MMOG complement existing visualisation techniques?</td><td rowspan="2">D2:<br>Semi-structured interviews of 20 architects experienced in MMOG.</td><td>F2:<br>Architects are using MMOG to augment early-stage design.</td></tr>
<tr><td>F3:<br>MMOG are used to engage clients and end-users.</td></tr>
<tr><td>D3:<br>Semi-structured interviews of 20 SL residents.</td><td>F4:<br>MMOG are used to better engage clients and end-users.</td></tr>
<tr><td rowspan="2">O4.<br>To test the effectiveness of MMOG in simulating real-world environments.</td><td rowspan="2">Q3<br>Can MMOG complement existing visualisation techniques?</td><td>D3:<br>Semi-structured interviews of 20 SL residents.</td><td>F4:<br>MMOG are used to better engage clients and end-users.</td></tr>
<tr><td>D4:<br>Semi-structured interviews of 48 stakeholders of the hub.</td><td>F5:<br>How realistic the representation of the virtual environment and the virtual interaction in MMOG is.</td></tr>
<tr><td rowspan="2">O5.<br>Develop and validate guidance on how and when MMOG should be deployed to best inform early-stage design.</td><td rowspan="2">Q4:<br>How can MMOG such as Second Life be used to better inform building design?</td><td>D5: (D1, D2, D3,D4)<br>Data collected in previous 4 parts are put together.</td><td>F6: (F1, F2, F3, F4, F5)<br>Findings from the previous 5 findings are summarised to form the initial guidance</td></tr>
<tr><td>D6:<br>Semi-structured interviews of 5 architects/ Construction IT experts.</td><td>F7:<br>Revised guidance on how and when to use MMOG at early-stage design.</td></tr>
<tr><td colspan="5">Contribution to knowledge:<br>1. MMOG Environment.<br>2. The guidance on how to best use MMOG at early-stage design.<br>3. Testing and validation of the guidance.</td></tr>
</table>

## 3.3 Research Process

The research process in the thesis includes the following three parts: data collection, data analysis and the validation of the research methodology. In the data collection section, choice of the research subject, *SL* (one type of MMOG) is discussed and the use of semi-structured interviews as the main research methods are justified. The development of the interview questionnaires, their constraints, and sampling strategy are discussed. In the data analysis section, template analysis is introduced with a detailed step-by-step process adopted in this research. The advantages and limitations of using template analysis are also highlighted. Finally, the methodology used in this research is validated.

### 3.3.1 Data Collection

The data collection starts with the decision on which MMOG should be used for this particular research. After the research object, *SL,* is confirmed, the type of qualitative research method – semi-structured interviews – are chosen. The reason for choosing it is justified. Then, the questionnaires for the interviews are designed, considering various constraints and sampling strategy.

#### 3.3.1.1 The Choice of *SL*

This research chose *SL,* one of the many MMOG available, as an example to test how MMOG can be used with other visualisation tools to assist real-world architectural design decision making. The reason for choosing *SL* is mainly because *SL* was considered as one of the most suitable MMOG for architectural research in 2007 when this research was proposed.

Firstly, the virtual world of *SL* is based on content generation by its users, with easy and quick design tools available, which is useful to architectural research. At that time, other

MMOG available were not as well developed as *SL* for academic research in the built environment. In 2007, *SL* was one of the few MMOG which supported user-generated content of the virtual environment. To encourage users to actively create the content of the virtual world, such as all types of buildings, goods, transportation, clothes and food, to simulate real world living, working and studying environments, easy and quick 3D design tools were made available in *SL*. *World of Warcraft* was popular in 2007, however, its scenario was based on war strategy. The platform of *World of Warcraft* was not based on users generating the content of the virtual world. It was not suitable for augmenting the architectural design process. Also, *SL* is a MMOG with no pre-determined tasks to finish. It can allow the researcher to explore all of its potentials for architectural research, rather than using any construction-industry-specified MMOG to solve specific issues designed by those platforms.

Secondly, there have been successful examples of academics using the *SL* virtual environment to solve real-world engineering and scientific research problems. With the free choice and tools available to create the content of everything in the virtual environment, many different experiments were conducted in *SL* for engineering and scientific research. The findings of those academic experiments proved to be successful and effective. However, not so much academic research has been done in *SL* to explore its real-world architectural potential. Choosing *SL* as an example of a MMOG can potentially pave the way for future adoption of *SL* as a design aid for the built environment, hence its contribution to new knowledge.

Thirdly, *SL* was the MMOG with the most active community of architects exploring real-world architectural applications. During the time of this research (between 2007 and 2010), *SL* as a MMOG had the largest number of active real-world architects. After successful real-world architectural design simulations had taken place in *SL* in 2006, other open-ended MMOG were launched to attract industry-based professional stakeholders in their world, such as *OpenSim* (available in 2007), *RealXtend* (available in 2008), *BlueMars* (available in 2009). However, most architects who are exploring

MMOG to augment their real-world architectural design, start their experiments in *SL*. Many of them remain active in *SL* while starting to explore other MMOG for real-world architectural applications. This is helpful to this research, because it is easy to use *SL* to find out what most architects are using MMOG for in real-world architectural design. Architects exploring other MMOG are most likely to have an active presence in *SL*: interviewing *SL* architects can potentially allow effective use of other MMOG for architectural design to be included in the research as well.

Fourthly, it is cheaper to develop the model in *Second Life*. At the time when the research began, Loughborough University purchased an island in *SL* for various interested Schools and individual researchers to develop their academic research. Choosing *SL* meant the researcher incurred no added costs purchasing the land for a virtual building to validate the findings.

#### 3.3.1.2 Interviews

Interviews are one of the most popular qualitative research methods in Management Science (Bryman, 1988; Oppenheim, 1992), and are increasingly popular in Construction Management (Dainty, 2007). Table 3.5 listed some of the advantages and disadvantages of interviews. In this research, interviews are adopted mainly because they are "particularly suited for studying people's understandings of the meanings in their lived world, describing their experiences and self-understanding, and clarifying and elaborating their own perspective on their lived world" (Kvale, 1996: 105). The issues of using interviews are addressed in different sections of data collection, data analysis and validation of methodology to ensure valid results.

Interviews can be put into three categories; unstructured interviews, semi-structured interviews and highly structured interviews, depending on how much control researchers want to have over the interviewees (Hughes et al., 1996; Fellows and Liu, 1997). In this research, semi-structured interviews are used to ensure the researcher can have control over the questions, but also allow participants to give as much information as possible about the question raised (Yin, 1994). All interviews in this research were conducted on a one-to-one basis.

The 20 practising architects and 48 stakeholders of the hub were interviewed face-to-face; interviews were recorded and transcribed afterwards. Most interviews conducted in MMOG, such as *Second Life*, were based on the instant messaging function enabled in *Second Life*, with text messages being automatically saved by the computer. Some of them were based on "voice chatting", which was recorded and transcribed afterwards. For the validation interviews with architects and IT construction specialists, three of them were conducted online in *Second Life*, two of them were interviewed by telephone.

**Table 3.5 Advantages and Disadvantages of Interviews (Hughes, 1996)**

| Advantages | Disadvantages |
| --- | --- |
| Ability to obtain large amounts of expansive and contextual data quickly | Difficult to replicate |
| Facilitates access for immediate follow-up data collection for clarification and omissions | Processes are not always explicit or depend on researchers opportunities or characteristics |
| Provides flexibility in the formulation of hypotheses | Data often subject to observer effects, obtrusive and reactive |
| Provides backgrounds context for more focus on activities, behaviours and events | Dependent on the ability of the researcher to be resourceful, systematic, and honest to control bias |
| | Depends on the co-operation of a small group of key elements |

#### 3.3.1.3 Development of Questionnaires

The development of questions is important in interview design (Turner, 2010). Effective questions can allow researchers to elicit maximum information from the participants. Methods to encourage participants to answer questions in an optimal way have been identified (Cannell, et al., 1981). Often, participants execute each of four steps one by one:

1. They must interpret the question and deduce its intent.
2. They must search their memories for relevant information.
3. They must integrate whatever information comes to mind into a single judgment.
4. They must translate the judgment into a response, by selecting one of the alternatives offered by the question.

To complete each of the above-mentioned steps requires a large amount of cognitive work (Tourangeau et al., 2000). Therefore, how to effectively construct the questions in the interviews to allow optimal answers from respondents becomes important. Guidance has been proposed to assist researchers to better design questions for their interviews. For example, McNamara (2009) proposed a number of recommendations, which helps to generate well-structured interview questions:

1. Questions should be open-ended rather than closed.
2. Questions should be as neutral as possible.
3. Researchers should ask one questions at a time.
4. Questions should be worded clearly, no jargon, acronyms, etc.
5. Researchers should be careful asking “why” questions.

Creswell and Plano Clark (2007) suggest that questions should be constructed to ensure flexibility and reduce any misunderstanding. For example, to ask follow-up questions during the interview can help to obtain optimal response (Turner, 2010). One of the most commonly used methods to create optimal question design is called Conventional Wisdom. Key points from common wisdom suitable to interview questions design can be summarised as follows (Krosnick and Presser, 2010: 264):

1. Use simple, familiar words (avoid technical terms, jargon, and slang).
2. Use simple syntax.
3. Avoid words with ambiguity.

4. Wording should be specific and concrete, rather than general and abstract.
5. Avoid leading or loaded questions that push respondents toward an answer.
6. Ask one question at a time.
7. Avoid questions with single or double negations.

Conventional wisdom also contains advice on optimising question order (Krosnick and Presser, 2010: 264):

1. Early questions should be easy and pleasant to answer so that rapport between the participants and the researcher can be built.
2. Questions at the very beginning of the interview should explicitly address the topic of the survey.
3. Questions on the same topic should be grouped together, from general to specific.
4. Questions on sensitive issues should be placed at the end of the interview.
5. Filter questions should be included, to avoid asking respondents questions that do not apply to them.

In this research, questionnaires designed for the interviews follow the principles recommended by Krosnick and Presser (2010). Five different interview questionnaires (See Appendices Five, Six, Seven, Eight, Nine) are designed to answer four research questions of this thesis. Two pilot interviews were conducted for each of the five questionnaires. These two pilots interviews were designed to test whether the logic, order and wording of each question proposed in the questionnaires was effective in eliciting maximum information from participants on related issues.

#### 3.3.1.4 Constraints of the Questionnaires

There are various constraints that researchers need to consider when designing interview questionnaires. Two of the major constraints are financial resources and respondents' ability to answer the questions in the interviews.

The financial resources available to undertake the questionnaires for the interviews are an important constraint. The sample size of the questionnaire, the time allocated for each respondent, as well as the optimal number of questions included in a questionnaire are also influenced by the financial resources in a research project. Most of the time, with a given budget, there is a trade-off between different sample size and the amount of information researchers can get from interviewing each participant (Kvale, 1996). In a qualitative research, the questionnaire can be designed to elicit more in-depth information from a small sample size. However, as the sample size is small, the accuracy of the information elicited from the questions can be affected by the resources available (Glewwe, 2005).

Questions are constructed to elicit as much in-depth information as possible from every single participant of this research. The accuracy of information collected in the small sample is not a major concern. This is mainly because the research result is not intended to be generalised back to the population that was selected, as in quantitative research. The generalisability of this research is an "analytical generalisation", which is about making a "reasoned judgment about the extent to which the findings in one study can be used as a guide to what might occur in another situation" (Kvale, 1996: 231-235).

The willingness and ability of the participants being interviewed to provide the desired information is another major constraint. Whether or not participants are willing to provide optimal answers to the questions is largely influenced by the desires they may have for "self-expression, interpersonal response, intellectual challenge, self-understanding, altruism, and emotional catharsis (Warwick and Lininger, 1975: 185-187). Their ability to answer those questions are determined by "the extent to which respondents are adept at performing complex mental operations, practiced at thinking about the topic of a particular question, and equipped with pre-formulated judgments on the issue in question" (Krosnick and Presser, 2010: 269).

In this research, in order to encourage participants to give as appropriate answers as possible, the wording of the questionnaires for the interviews used simple and easy words so that it could potentially reduce the complex mental operation participants have to go through to produce the desired response. Also, the number of questions is controlled with no more than 12 questions per interview so that the efficiency of response is not decreasing with too many questions.

#### 3.3.1.5 Sampling Strategy

Choosing a sample is an important step in any research project since it is rarely practical, efficient or ethical to study the whole population (Marshall, 1996: 522). A sample is a subset of the population where researchers select the participants for their research. The process of selecting a portion of the population to represent the whole population being studied is called sampling. In order to achieve a representative sample of the population, most researchers will use a sampling strategy, a plan to select a quality sample to ensure robust data for the research (Malterud, 2001). Therefore, it is important for a researcher to fully understand how and why a sample is chosen and how the samples chosen impact on the outcome of the research such as on generalisability of the research findings. Researchers consider various questions at the beginning of their research to inform a well-organised sampling strategy, such as the following (Wilmot, 2005: 2):

1. What are the research objectives?
2. What is the target population? Who should be excluded/included in the sample?
3. What is the budget? What is the reporting time? How many qualified researchers are available to work on the project?
4. What sampling technique(s) should be employed?
5. How are the data to be analysed? What data collection methods should be employed?
6. What are the sample criteria? What size should the sample be? What should be

used as the sampling frame?

7. How long will the interview be? How should potential respondents/participants be recruited?

#### 3.3.1.6 Sample Techniques

In qualitative research, there are three main techniques to select a sample: convenience sampling, purposive sampling, and theoretical sampling (Marshall, 1996).

Convenience sampling is the least rigorous sampling strategy. It involves the selection of the most accessible subjects. The advantage of convenience sampling is that a researcher can choose whoever is willing to participate in the research (Malterud, 2001). Often, it is the sampling strategy that allows the researcher to take a shorter time, make less effort, or spend less money to access the population he/she requires to participate in his/her research (Wilmot, 2005). The limitation of convenience sampling is that the data collected through this strategy is of poor quality, often without intellectual credibility. In many qualitative studies, there is an element of convenience sampling, but a more thoughtful way to select a sample is usually justified (Marshall, 1996).

Purposive sampling, is also called judgement sampling. It is the most common sampling strategy used to select participants who serve a specific purpose consistent with a study’s main objective, to answer the research questions. This can involve developing a framework of the variables that may influence an individual's contribution, and will be based on the researcher's practical knowledge of the research area, the available literature and evidence from the study itself. This is a more intellectual strategy than convenience sampling, though age, gender, experience, and social class might be important variables (Wilmot, 2005).

Purposive sampling can be put into different categories (Marshall, 1996):

1. Criterion sampling is also known as critical case sampling, which is to select participants who have experienced the phenomenon of interest. It is especially useful in phenomenology where the goal is to investigate experiential phenomenon.
2. Maximum variation sampling, which involves selecting participants who can provide a variety of descriptions of the phenomenon of interest.
3. Ethnographic opportunistic sampling involves seeking out opportunities to talk with and observe people who illuminate the researcher's understanding of a culture or group.
4. Key informant sampling is used to select subjects with special expertise.
5. Snowball sampling is a strategy to get participants to recommend useful potential candidates for study.
6. Confirming and disconfirming sampling. During interpretation of the data it is important to consider subjects who support emerging explanations and subjects who contradict the emerging explanations.

In most qualitative study, the research design evolves in an iterative way. As a result, samples in qualitative research are usually theory driven. Theoretical sampling means to build theories from the emerging data while selecting a new sample to further examine the new theory generated. Theoretical sampling is usually used in a grounded theoretical approach, but it is also often used in most qualitative investigations necessitating interpretation (Malterud, 2001).

#### 3.3.1.7 Sample Size

Choosing the right size of the sample is important. The size of the sample is determined by the optimum number necessary to enable valid inferences to be made about the population. The optimum sample size depends upon the parameters of the research subject being studied, for example the rarity of the event or the expected size of differences in outcome between the intervention and control groups (Malterud, 2001).

An appropriate sample size for a qualitative study is one that adequately answers the research question. For simple questions or very detailed studies, this might be in single figures; for complex questions, large samples and a variety of sampling techniques might be necessary. In practice, the number of required subjects can usually be identified when the data collected becomes saturated, which means new categories, themes or explanations stop emerging from the data (Marshall, 1996).

#### 3.3.1.8 Sampling for the Research

In this research, in order to develop a well-organised sampling strategy, all of above mentioned questions have been considered at the beginning of the research. The aim of this research is to explore the potential of MMOG in informing early-stage design process. The research objectives of this research are as follows:

1. Review current tools used in early-stage design.
2. Review research and practice pertaining to visualisation and the building design process in order to identify any deficiencies in supporting early-stage design decisions.
3. Examine the features of MMOG and their suitability for informing early-stage design.
4. Test the effectiveness of MMOG in simulating real-world environments.
5. Develop and validate guidance on how and when MMOG should be deployed to best inform early-stage design.

Based on the five research objectives, the population of this study was chosen. "The population for a study is the "entire set of individuals or other entities to which study findings are to be generalised". It should only include "the aggregation of elements that researchers actually sample from, not some larger aggregation that they wish they could have studied" (Schutt, 2006: 134). In order to define the included and excluded elements of the target population of interest, researchers usually use a sampling frame.

The sampling frame is to inform inferences gleamed from research data (Neuman, 1997). Within the sampling frame, “the individual members of this sample are called elements, or elementary units” (Schutt, 2006: 133). In this research, the sampling frame is included in Table 3.6. It includes the following five parts:

1. PhD students, researchers and academics who are end-users of the hub in the Civil and Building Engineering School, Loughborough University; professional stakeholders who participated in the re-design of the Civil and Building Engineering School, Loughborough University.
2. Real-world architects based in the UK who are using various design tools, other than MMOG to augment their early-stage design process.
3. Real-world architects who are using various MMOG such as *Second Life* to augment their real-world architectural design process at the early stage.
4. Non-AEC professionals who are using MMOG such as *Second Life* to become more involved in the architectural design process.
5. Experienced architects and Construction IT specialists who have advanced knowledge of using MMOG to augment early-stage design.

The first stage involved in-depth interviews with 30 architects who were working in traditional AEC visualisation models. Convenience sampling, key informant sampling strategy and snowball sampling were used at this stage. To save travel costs of the research, most architects interviewed in this research are close to the location where the researcher is based. Ten of them are architects based in Loughborough, nine of them are architects based in Leicester. This selection of sample shows the feature of a convenience sample. However, to make the sampling more rigorous, the snowball sampling strategy was adopted with most of the architects interviewed in Loughborough and Leicester recommending architects based in London and other cities to participate in this research. Seven architects are based in London, four architects are based in other cities. The data was collected and analysed and then an interpretative framework was constructed. New themes stopped emerging after 18 interviews and an acceptable interpretative framework was constructed after 30 interviews – the stage of thematic saturation.

The second stage involved in-depth interviews with 20 real-world architects who are using various MMOG to assist their real-world architectural design. Maximum variation sampling, criterion sampling, key informant sampling strategy and snowball sampling were used at this stage. To find the most experienced real-world architects who are using MMOG to augment their real-world architectural projects, the initial sampling strategy used at this stage was a maximum variation sampling. Three of the most renowned real-world architects who are using *Second Life* to assist their real-world architectural design process were selected as the sample. All of them can provide a variety of descriptions of the phenomenon of interest (maximum variation sampling), because they are considered to have in-depth expertise and wide experience of using MMOG to improve their real-world architectural design. All three of these architects recommend their own contacts (about 10 participants) among real-world architects who are exploring MMOG to assist real-world architectural design to the researcher, which is snowball sampling. Besides, the researcher also used various *Second Life* architects' groups to find other architects who have the experience and expertise utilising MMOG for real-world architectural design. This adopts a key informant sampling strategy.

The third stage involved interviewing 20 end-users in *Second Life* who are not from an architectural profession in the real world, but are also using *Second Life* to experiment with their own virtual architecture. The sampling strategies at this stage were composed of ethnographic opportunistic sampling and criterion sampling. Most of these participants were recruited when the researcher visited the site of various virtual architectural competitions in *Second Life*. The researcher either talked "face-to-face" using avatars when the participants were constructing their virtual architecture at the competition site, or found their names through clicking on the virtual architecture they created on the competition site and then using *Second Life* messaging services to contact them about their virtual architecture. This sampling strategy is criterion sampling because the participants were selected because they have experienced constructing virtual architecture in *Second Life* and are not from the architectural profession in the real world. However, this sample also showed the characteristics of ethnographic opportunistic sampling, where the researcher seeks out opportunities such as the virtual architectural design competition to observe participants who illuminate the researcher's understanding of a culture or group.

The fourth stage involves the use of criterion sampling. A sample of 24 PhD students, 15 researchers, nine academics working in the hub of Civil and Building Engineering School, Loughborough University are interviewed. The reason that they are chosen is because all of them are end-users of the School hub, which is used as an example to demonstrate how MMOG can be used to engage non-professional stakeholders in the architectural design process. Therefore, this sample is a criterion sample. The advantage of this approach is that it is well structured to select the participants who have experienced the phenomena being studied in the research – the hub. There are two limitations of this approach. First, the size of this criterion sample does not reflect the real population of end-users in the School, which has 120 PhD students, 30 post-doctoral researchers and 60 academics. However, the generalisability of this sample is not to extend the results of this given study to the whole end-user population of this School. The generalisability in this sample is an analytical generalisation, which is often used in qualitative research to justify the "reasoned judgment about the extent to which the findings in one study can be used as a guide to what might occur in another situation" (Kvale, 1996: 233). Second, PhD students, researchers and academics have different levels of expertise in the phenomena being studied, which may influence the results collected and analysed. Therefore, at the end of this stage, six out of seven professionals in the AEC industry who participated in the re-design of the School were interviewed. All six of them are selected as a key informant sample, which has special expertise of the architectural design process. They were also selected using criterion sample because all of them had experience the subject of the research – the hub. After about 48 interviews, new findings stopped emerging. This indicated the stage of thematic and theoretical saturation.

The fifth stage is about interviewing five experienced architects and Construction IT specialists. Two of them are specialised in Construction IT, three of them are experienced MMOG real-world architects. These experienced AEC professionals are selected based on the recommendation of most of the 20 architects interviewed in *SL* as the most experienced AEC professionals in using MMOG to better real-world architectural design processes. This is snowball sampling. Meanwhile, all those five AEC professionals are considered as the most experienced experts in using MMOG to improve architectural design. This is also a maximum variation sampling. The choice of these interviewees are to elicit in-depth information from experienced MMOG users, to validate the MMOG guidance proposed and explore further application of MMOG in the architectural design process.

In this research: criterion sampling, key informant sampling and snowball sampling are used three times; maximum variation sampling is used twice; and ethnographic opportunistic sampling and convenience sampling are used once. Therefore, key informant sampling, snowball sampling and maximum variation sampling are used as the main sampling strategies in this research, with convenience sampling and ethnographic opportunistic sampling used to help the data collection.

**Table 3.6 The Sampling Frame of this Research**

| Stage | Interviewees | Sampling Strategy | The Reasons for this Sampling Strategy |
|---|---|---|---|
| **Stage 1 30 architects** | 30architects with no experience using MMOG | Key informant sampling (30 architects). | All the architects are selected because they have been RIBA qualified architects in the UK. They use the RIBA Plan of Work to conduct their design work on a daily basis. |
| | | An element of convenience sampling (19 architects). | To save travel costs to interview architects, 10 of them were interviewed in Loughborough and nine in Leicester, based close to the researcher. |
| | | Snowball sampling (11 architects). | The 19 architects interviewed in Loughborough and Leicester recommended and put the researcher into contact with another 11 architects in London and other cities. |
| **Stage 2** | 20 architects who are using MMOG | Maximum variation sampling (3 architects). | Three of the most renowned architects who are using *SL* for real-world architecture can provide a variety of description of the phenomenon of interest. |
| | | Snowball sampling (10 architects). | The three famous architects recommended about 10 other architects working in *SL* for real-world architectural design. |
| | | Key informant sampling (7 architects). | Architects were found through using various *SL* groups on architecture. All of them are architects who have special expertise using MMOG for real-world architectural design. |
| **Stage 3** | 20 *SL* users | Criterion sampling. | The participants are selected because they become more involved in the architectural design process in *SL*, with no real-world architectural design experience. |
| | | Ethnographic opportunistic sampling. | The researcher seeks out opportunities e.g. virtual architectural design competition to talk to and observe participants who illuminate the researcher's understanding of a group. |
| **Stage 4** | 42 end-users of the hub | Criterion sample | They are end-users of the hub, used as an example to demonstrate how MMOG can be used to engage non-professional stakeholders in the architectural design. |
| | 6 professional stakeholders of the hub | A key Informant Sample | They have special expertise of the architectural design process |
| | | A criterion sample | They have experienced the subject of this research |
| **Stage 5** | 5 top architects and Construction IT experts | Snowball sampling | 5 of them are recommended by the 20 architects interviewed in *SL* as the most experienced AEC professionals in using MMOG to improve real-world architectural design. |
| | | Maximum variation sampling | 5 of them are considered as the most experienced experts in using MMOG to improve real-world architectural design. |

### 3.3.2 Data Analysis: Template Analysis

In this research, qualitative methods are used. Therefore, the data analysis needs to capture the qualitative nature of the data. There are many ways to analyse qualitative data, one of the most popular ways is template analysis.

Template analysis is also called codebook analysis, or thematic coding (Crabtree and Miller, 1992). It is a method of organising and analysing textual data according to themes. "Researchers using this method produce a list of codes (a 'template') representing themes identified in the textual data … A code is a label attached to a section of text to index it as relating to a theme or issue in the data which the researcher has identified as important to their interpretation" (King, 2004: 119-120). Template analysis can be used to elicit information from interview transcripts, diary entries or open questionnaires (King, 2004).

There are many ways to conduct a template analysis. One of the most widely adopted is proposed by Braun and Clarke in Table 3.9 (Braun and Clarke, 2006: 87).

**Table 3.7 Phases of Template Analysis (Braun and Clarke, 2006: 87)**

| **Phase** | **Description of the process** |
|---|---|
| 1. Familiarising yourself with the data | Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas. |
| 2. Generating initial codes | Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code. |
| 3. Searching for themes | Collating codes into potential themes, gathering all data relevant to each potential theme. |
| 4. Reviewing themes | Checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic 'map' of the analysis. |
| 5. Defining and naming themes | Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme. |
| 6. Producing the report | The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis. |

#### 3.3.2.1 Phase 1: Familiarising Yourself with Your Data:

At this stage, it is vital for researchers to familiarise themselves with the data. They can achieve that through repeated reading and re-reading of the data, actively searching for meaning, patterns and so on. If the data collected is not in written form, researchers should firstly transcribe the verbal data into written form so that a template analysis can be conducted. The process of transcription is not only a good way to ensure accuracy and verifiability of the data, but also helps the researcher to start familiarising themselves with the data (Riessman, 1993). During this phase, some researchers begin writing down some initial notes about what is in the data to help generate codes in the following phases (Braun and Clarke, 2006).

In this research, all the interviews have been recorded and transcribed in written form. The process of transcribing all the semi-structured interviews is time-consuming, but it helps the researcher to become more familiar with the content of the data both in depth and in breadth. Some initial ideas about what the data implies are listed, to be used at the next stage.

#### 3.3.2.2 Phase 2: Generating Initial Codes

This phase starts to create some initial "codes" which helps to organise the data into meaningful groups (Tuckett, 2005). Codes are "the most basic segment, or element, of the raw data or information that can be assessed in a meaningful way regarding the phenomenon" (Boyatzis, 1998: 63). Codes are also "terms representing possible themes" (Stein et al., 2009: 130) which the researcher finds useful to answer the research questions (Boyatzis, 1998). Coding can be done both manually, writing down the notes on the texts analysed, or with the help of computer software such as NVivo. Unlike content analysis whose codes are fixed, the coding in template analysis is an intertwined iterative process with the introduction of new codes, removal of some codes and splitting codes into more detail to better reflect the content of the data (Krippendorff, 2004). When extracting the codes, research should aim to (Braun and Clarke, 2006: 87):

1. Code for as many potential patterns as possible.
2. Code inclusivity to ensure no important context is lost (Bryman, 2001, cited in Braun and Clarke, 2006: 87)
3. Code individual extracts of data in as many different "themes" as necessary to allow flexibility.
4. Retain accounts that depart from the main story in the analysis because no dataset can always be produced without any contradiction.

In this research, initial coding is conducted manually through highlighting different codes (using e.g. BIM, 2D sketches) in the Word documents. The researcher read through the whole dataset and followed the recommendation of Braun and Clarke (2006) to code as extensively as possible to ensure no important content that helped to answer the research questions of this thesis was lost during this process. During this iterative coding process, new codes were added while some codes were deleted; codes reflecting the same pattern were collated together while some codes were divided into sub-codes to provide more information when necessary. The data that were relevant to each of the initial code were collated together.

#### 3.3.2.3 Phase 3: Searching for Themes

After all transcripts are coded initially, a list of codes is identified across the whole dataset. At this stage, researchers should put different codes and the coded data extracts into relevant themes. Themes are also called "units of analysis", which are "recurrent and distinctive features of participants' accounts, characterising particular perceptions and/or experiences" (King and Horrocks, 2010: 150). Often themes are considered by the researcher as relevant to the research question. At this stage, researchers can use a variety of visual ways to help categorise the codes into different levels of themes (e.g. sub-theme, main theme), such as mind-maps, tables and charts. The links between different codes, between themes, and between different levels of themes are considered (Braun and Clarke, 2006). At the end of this stage, often, an initial template of the data demonstrating all the potential themes, sub-themes and extracts of data coded around the themes can be produced.

In this research, based on the research questions and questions of the interviews, all the initial codes are organised into broader themes to create an initial template. For example, in Appendix One, to answer research question Q2, “What forms of visualisations are used in early-stage design and what are their limitations?”, an initial template was generated with data extracts collected around those themes.

#### 3.3.2.4 Phase 4: Reviewing Themes

At this stage, researchers review and refine all the potential themes. This stage requires the researcher to review and refine their themes at two levels. Level One is to review all the coded data extracts. Researchers should read through all the collated extracts in each of the themes to find out whether all the data extracts in these potential themes fit well with each other to form a coherent account. If yes, the researcher can move onto the second level of review. If not, researchers need to discover the issue: they need to rework the theme to solve the issue accordingly, whether it is the problem of the theme itself, whether some of the data extracts should be put into another theme, or whether the data extracts do not fit into any theme. Level Two is to review each individual theme against the whole dataset. The criteria are to consider whether individual theme “accurately reflects the meanings evident in the data set as a whole” (Braun and Clarke, 2006: 91). Besides, researchers also need to introduce new codes to categorise any additional data within themes that were not included earlier (Braun and Clarke, 2006). This two-level review process is ongoing until “a satisfactory thematic map” can be achieved when “any further refinements are not adding anything substantial” (Braun and Clarke, 2006: 91-92). At the end of this stage, different themes should be identified, with a clear story about how they fit together to clarify what is the most important information in the data collected.

In this research, all the potential themes have been reviewed at this stage. Two levels of reviews have been conducted to ensure all the final themes are accurate reflections of the meaning shown in the entire dataset. When reviewing all the data extracts at the first level in each of the themes in Appendix Two, some of the sub-themes were deleted due to lack of data, while many of the data extracts were moved into other themes where the accounts of the data fit better.

During the process of reviewing individual themes against the whole dataset, several issues have been identified and resolved. For example, various themes of the datasets are organised chronologically. Theme 1: The Virtual School Test was conducted first and was therefore labelled as Theme 1. However, after comparing this theme with the remaining themes in the template, it is found that this theme should be put after Theme 2: *SL* for Real-World Architecture, as a detailed example to demonstrate how realistic the model created in MMOG can be and how effective they are in engaging stakeholders at early-stage design. Therefore, the whole template was revised to ensure the flow of the whole story line of this thesis fitted well with all its five themes. This is shown in Appendix Three.

#### 3.3.2.5 Phase 5: Defining and Naming Themes

At this stage, researchers further review and define the themes to find out the essence of them. This is often achieved through analysing all the collated data extracts for each theme, "organising them into a coherent and internally consistent account, with accompanying narrative (Braun and Clarke, 2006: 92). Normally, researchers also write a detailed analysis for each of the main themes, identifying the main content of that theme, and how each theme fits together to tell the whole storyline to answer various research questions of this research. Also, at this stage, the researcher decides whether any sub-theme is needed in one or more of the main themes to help better structure themes, which contain complicated information. At the end of this stage, researchers can finalise all the main themes and sub-themes of the template, with concise and punchy names (Braun and Clarke, 2006).

In this research, each of the main themes identified have been added with a detailed analysis at this stage. All the themes and sub-themes are analysed against each of the research questions of this thesis to further define each of the themes. It is found that Theme 4: Future use of MMOG for Architecture, does not fit well with the whole storyline of this thesis, which is to explore the potential of MMOG to augment real-world early stage construction design process. Most content in Theme 4 is on how architects develop architecture without real-world physical attributes, which cannot be transferred into real-world architectural design. This does not help answer any research question of this thesis. Therefore, this theme is deleted in the revised version of the template, which is shown in Appendix Four. Names of all the themes and sub-themes are re-considered to make them concise.

#### 3.3.2.6 Phase 6: Producing the Report

At this stage, researchers aim to tell the complicated story of their data in a clear, concise and logical way to convince readers of the merits and validity of the analysis. Sufficient data extracts to demonstrate the essence of the issue should be used as evidence to support individual themes identified at the previous stages. In addition, the written analysis should not be about the description of the data template, but how researchers can form arguments to answer specific research questions about the issues (Braun and Clarke, 2006).

In this research, the researcher followed this guidance (see Section 7.1) and organised the data analysis in a way that helps to answer various research questions of this thesis. The purpose is to ensure that a coherent and logical storyline can be produced to convince readers of the contribution this research makes to existing knowledge on using MMOG to augment early stage construction design process.

#### 3.3.3.1 Advantages and Limitations of Template Analysis

There are many advantages of using template analysis. Firstly, it is a highly flexible method, which can be modified for the requirements of any study in a particular area. Secondly, the prescription and processes needed to conduct template analysis are easy and simple. Therefore, it is especially useful to analyse research aims, to explore specific phenomena or experiment in organisational or management science which contains a lot of prescriptive data (King, 2004). Thirdly, it is similar to content analysis, a well-established data analysis method for qualitative data. Therefore, the principle embedded in template analysis makes it possible to be easily understood by researchers who are new to qualitative methods. Finally, using template analysis follows a well-structured approach to analysing the data. This is helpful to create an organised, coherent and clear set of data for research (King, 2004).

There are also disadvantages of using template analysis. For example, in comparison with other more well-established data analysis methods, such as content analysis and discourse analysis, the lack of literature on this method may pose difficulty for researchers to make the best of this method. Also, the choice of templates and codes may also have some issues. During the process of coding, researchers need to remove fragmented parts of the text from its context, which may result in loss of meaning or confusion about the text analysed. Besides those two limitations, the fundamental issue of this method is that researchers need to make a balance between how much they want to be open to the data collection to maximise information elicited, and impose a clear structure on the procedure of analysing data, rather than over-structuring. The result will be incoherent and chaotic if too much openness of the data analysis is allowed. In order to solve various issues in template analysis, various measures have been used in Section 3.3.4 to validate the data analysis process.

### 3.3.4 Validation of the Methodology

This research adopts a qualitative approach to data collection and analysis, combining both inductive and deductive research processes. To ensure the quality of the research, various techniques have been used to validate this research methodology.

#### 3.3.4.1 Validity, Reliability, Generalisability

There has been a lot of debate about what can be considered as rigorous qualitative research (Angen, 2000; Hammersley, 1987; Lincoln and Guba, 1985; Maxwell, 1992; Morse, 1999; Whittemore et al., 2001). At the centre of the debate, the issues of validity, reliability and generalisability are often discussed to defend the methodology of qualitative research.

In qualitative research, there are many different definitions of validity. One of the most cited definitions is that “an account is valid or true if it represents accurately those features of the phenomena that it is intended to describe, explain or theorise” (Hammersley, 1987: 69). This concept of validity is “rather a contingent construct, inescapably grounded in the processes and intentions of particular research methodologies and projects” (Winter, 2000: 1). Some researchers argue that the word “validity” is a quantitative term; qualitative research should use other terms to better reflect the nature of qualitative research (Lincoln and Guba, 1985; Seale, 1999). Therefore, many qualitative researchers have redefined the concepts of validity in qualitative research, with new wordings such as quality, rigor and trustworthiness (Lincoln and Guba, 1985; Mishler, 1986 Seale, 1999).

Besides validity, reliability is another factor many researchers need to consider to justify their qualitative research (Patton, 2002). The definitions for reliability are as complex as those for validity. Reliability in qualitative research generally means “to adopt research methods that are accepted by the research community as legitimate ways of collecting and analysing data" (Collingridge and Gantt, 2008: 390). In quantitative research, reliability is often referred to as the "replicability" of research findings (Collingridge and Gantt, 2008). To be more specific with qualitative research, Lincoln and Guba (1985) use the word "dependability" to replace reliability (Lincoln and Guba, 1985: 300).

Generalisability in qualitative research is not intended to mean generalised back to the population from which the research sample is selected, as in quantitative research (Maxwell, 1992). The generalisability of qualitative research is an "analytical generalisation", which is about making a "reasoned judgment about the extent to which the findings in one study can be used as a guide to what might occur in another situation" (Kvale, 1996: 231-235). It is a useful beginning to understand similar situations or people, rather than being representative of the target population (Maxwell, 1992).

#### 3.3.4.2 Triangulation and Member Checking

Various methods have been proposed to maximise validity, reliability and generalisability of qualitative research, to defend the methodology and the knowledge claims. For example, Lincoln and Guba outlined four criteria (credibility, transferability, dependability and confirmability) for evaluating qualitative research (Lincoln and Guba, 1985). Another popular criterion to evaluate the quality of qualitative research is called "verification", proposed by Creswell (1998). He proposed eight types of techniques to validate qualitative research. These eight types of techniques include prolonged engagement, triangulation, peer review, negative case analysis, reflexivity, respondent checking, thick description and external audit. Also, he suggested that qualitative researchers should use at least two of them to justify and defend their research methodology (Creswell, 1998). In this research, data triangulation, investigator triangulation, and member checking are used to defend the methodology of this thesis.

**Table 3.8 Validation Methods**

| Methods for validation | How the methods are used? | Why |
|---|---|---|
| **Data Triangulation** | Research Question Q3: used 3 types of data to get an accurate understanding.<br><br>Research Question Q4: used 4 types of data to get an accurate understanding. | To "constitute a more resourceful approach to interpret the findings of the study and to appreciate the level of complexity" (Ben Said, 2011: 68) of the phenomena studied in this thesis, MMOG, data triangulation was used to answer two research questions in this thesis |
| **Investigator Triangulation** | Two lecturers were invited to become the investigators in the process of investigator triangulation.<br><br>They both did the preliminary coding for six transcripts. Each transcript was randomly chosen from six different types of data collected in the research (See Table 3.4 for each of the six types of data).<br><br>The preliminary templates produced by these two external experts and the researcher were compared and discussed.<br><br>No major modifications were made to the initial template except for a few minor changes.<br><br>2. Validate the initial guidance proposed with 5 experienced architects and Construction IT Specialists to form the final guidance which architects can use to incorporate MMOG to augment early stage construction design. | The researcher of this thesis has been doing research on MMOG since 2007, interested in exploring the use of MMOG at early-stage design process in construction.<br><br>If it is only the principal researcher who conducted the data analysis, it can be difficult to ensure an unbiased analysis is produced.<br><br>1. To avoid the bias of the researcher<br>2. To defend the main data analysis technique used: the template analysis.<br>3. Check the validity of the reporting process of the findings. |
| **Member checking** | In every single interview conducted in this research, the researcher summarised key points to each of the questions answered by participants and asked participants to check its completeness, accuracy. | Ensure that an accurate, complete and fair view of the participants is recorded as part of the data collection process. |

Triangulation is a common strategy used in qualitative research to enhance the validity and reliability of research (Golafshani, 2003). It is defined as a strategy to combine two or more theories, sources of data, views, approaches, or methods in an investigation to gain an accurate understanding of the phenomena (Denzin, 1978). There are various sub-categories of triangulations, such as methods triangulation, data triangulation, investigator triangulation and theory triangulation (Patton, 2002). Through comparing data collected, analysed through different sources, methods or analysts, triangulation can cross-validate the research results to ensure better credibility than when they are based on one single data source or methods (Yin, 1994; Bonoma, 1985; Benbasat et al., 1987). However, some researchers are worried about triangulating different research methods because it is difficult to directly compare data collected from different methods, which normally come in different forms (Bloor, 1997).

In this research, in order to ensure the validity and reliability of the data collected, data triangulation is implemented. In order to enhance the quality of the data analysis process, investigator triangulation and member checking are used. To ensure the validity of the reporting process of findings, investigator triangulation is used.

#### 3.3.4.3 Data Triangulation

Data triangulation, is the use of multiple data sources, including time, space and people, in a study, rather than relying on one single form of data to answer research questions. In 1959, when the concept of triangulation was first introduced in academic research, data triangulation was highlighted as one of the two key measurements to ensure validity of academic findings (Campbell and Fiske, 1959). Since then, data triangulation has been widely accepted as a simple way to ensure the validity and reliability of qualitative research (Maxwell, 1996). Based on the robustness of data collected, data triangulation can be put into three types: time, space and person (Denzin, 1978). The quality of data can vary due to the time period they were collected, the cultural and social situation from which they were collected, and the people involved (Begley, 1996).

Data triangulation is considered as one of "the most popular, easiest to be implemented" types of triangulation. It is especially useful to get robust data from different stakeholders who have a "vested interest" in the research topic (Guion, 2002: 1-2).

The research topic in this thesis is the use of MMOG to augment early-stage design in construction. In order to address this research topic, the data need to cover a wide range of stakeholders at the early-stage design process, including professional architects who know the issues of early-stage design in construction but with no experience of MMOG, and professional architects who are using MMOG to augment their early-stage design process, as well as non-professional stakeholders who are using MMOG to become more involved in the early-stage design. According to Table 3.8, to "constitute a more resourceful approach to interpret the findings of the study and to appreciate the level of complexity" (Ben Said, 2011: 68) of the phenomena studied in this thesis, MMOG, data triangulation was used to answer two research questions in this thesis. Detailed information can be found in Table 3.4, Overview of the Research Methodology.

For example, in order to answer research question Q3, "Can MMOG complement existing visualisation techniques", three types of participants were interviewed (D2: 20 architects who are using *SL* to augment real-world architectural design, D3: 20 *SL* users who became more involved in real-world architectural design process as non-professional stakeholders, D4: 48 end-users and professional stakeholders of the hub). These three types of people are professional and non-professional stakeholders who have different level of expertise and involvement in the early-stage design process. Their experience in exploring the use of MMOG to assist early-stage design is different as well. Collecting data from these three groups helps to achieve a wider understanding of Q3 and therefore enhance the validity of the findings to address Q3..

In order to answer research question Q4, "How can MMOG such as *Second Life* be used to better inform building design?" data needed to be collected from different types of stakeholders with different level of expertise and experience to give a more valid account. In this thesis, data were collected initially from four groups (D1: interview 30 architects with no experience of MMOG, D2: interview 20 architects experienced in MMOG, D3: Interview 20 *SL* residents, D4: interview 48 stakeholders of the hub). These four sets of data were put together to form initial guidance to assist architects to better use MMOG to augment early-stage design. Then (D5) five architects and Construction IT specialists specialised in using MMOG to augment early-stage design process were interviewed to validate the initial guidance proposed. Using different data collected from different stakeholders on the issue under investigation, data triangulation can cross-validate the research results to ensure better credibility than when they are based on one single data source (Benbasat et al., 1987).

#### 3.3.4.4 Investigator Triangulation

Investigator triangulation can be defined as "the use of more than two researchers in any of the research stages in the same study" (Hussein, 2009: 3). Often, each investigator analyses the data and compares their analysis to form a thorough and in-depth view of the issue being investigated. If the findings from different investigators are largely similar, validity of the findings can be secured. If not, further research is needed to identify the accurate finding (Guion, 2002). Investigator triangulation has "the ability to confirm findings across investigators – without prior discussion or collaboration between them … [and] … can significantly enhance the credibility of the findings" (Hales, 2010: 15). It is especially crucial to use investigator triangulation to reduce bias in collecting, analysing, and reporting data (Hales, 2010: 15). Investigator triangulation is often considered as one of the most used sub-categories of triangulations. The reason for that is because multiple researchers are often needed to analyse the data for most academic studies (Mathison, 1988).

There are some issues to be addressed to achieve the best outcome from investigator triangulation. For example, it may not always be practical to assemble different investigators as a result of time commitment and schedules (Guion, 2002). Also, the criteria for choosing investigators and their level of involvement in the research process can be problematic. For example, using untrained students or unmotivated research assistants as evaluators in investigator triangulation can have a negative impact on the validation (Denzin, 1978).

In this thesis, to avoid the bias of the researcher and to defend the main data analysis technique used (template analysis), investigator triangulation was implemented. The researcher of this thesis has been doing research on MMOG since 2007, interested in exploring the use of MMOG at early-stage design process in construction. If it was only the principal researcher who conducted the data analysis, it was difficult to ensure an unbiased analysis was produced. According to Table 3.8, two lecturers were invited to become the investigators in the process of investigator triangulation. These two lecturers were selected based on their experience of using template analysis and expertise on IT-related academic research. Both of them were well briefed about the content of this research, such as the aims, objectives, and research questions. They both did the preliminary coding for six transcripts. Each transcript was randomly chosen from six different types of data collected in the research (see Table 3.4 for each of the six types of data). The preliminary templates produced by these two external experts and the researcher were compared and discussed. The two lecturers were asked to check if there was any issue in the coding process, if any of the important texts, codes or themes of the data were overlooked or dismissed without proper consideration. No major modifications were made to the initial template except for a few minor changes. For example, Appendix Three: Template Analysis Template No. 3 is the initial template generated. After the investigator triangulation, both lecturers argued that "4. Future use of MMOG for Architecture" in Template Analysis Template No. 3 was not relevant to the whole thesis. Therefore, "Future use of MMOG for Architecture" was deleted to form Appendix Four: Template Analysis Template No. 4. However, the non-professional end-users' experience using virtual architecture to become better involved in early-stage design was still relevant to the main storyline of this research, and therefore should not be deleted. The process of investigator triangulation proved that the coding process used in the template analysis is rigorous and trustworthy.

In this thesis, investigator triangulation is also used to check the validity of the reporting process of the findings. After the initial data collection and analysis from D1: interviewing 30 practising architects, D2: 20 architects who are using *SL* for real-world architectural design, D3: 20 *SL* users who become more involved in the architectural design process as non-professional stakeholders, and D4: 48 end-users of the hub, a guidance is proposed in Section 7.2.2 to assist architects to use MMOG at early-stage design. This interim result was validated through interviewing five of the most experienced real-world architects and Construction IT specialists who were using MMOG to augment their real-world architectural design process. The way that five experienced architects and Construction IT specialists were allowed to see and discuss the interim findings, enabled additional information to be collected from the interviews (see 7. 3 Findings From The Validation). New points were put forward, while some initial points in the guidance were deleted, edited or expanded to guide architects to better use MMOG at early-stage design. All of these changes were incorporated into the final guidance of this research, which helped to further strengthen the validity and reliability of the findings.

#### 3.3.4.5 Member Checking

Member checking is widely used in qualitative research to enhance the validity, reliability and accuracy of the data collected (Barbour, 2001; Byrne, 2001; Coffey and Atkinson, 1996; Doyle, 2007; Lincoln and Guba, 1985; Harper and Cole, 2012). It is also called feedback checking (Kaplan and Maxwell, 1994), and respondent validation (Guba and Lincoln, 1989).

It allows participants in the research the opportunity to approve particular aspects of the interpretation of the information they give (Doyle, 2007; Merriam, 1998). In the data collection process, member checking means that the researcher consistently restates, paraphrases, or summarises the information received from a participant to ensure that what was recorded is correct. The respondents can edit, clarify, elaborate or delete the information taken by the researcher, to reflect their views, feelings and experience (Doyle, 2007). If the data collected are approved by participants as accurate and complete, the research is said to be valid (Creswell and Plano Clark, 2007; Lincoln and Guba, 1985). During the data collection process, member checking involves "cross checking interim research findings" (Barbour, 2001: 1117) with respondents who participated in the research (Kaplan and Maxwell, 1994). The feedback from respondents is then incorporated into the final findings (Lincoln and Guba, 1985) to enhance the credibility of the research.

Member checking is considered as one of the strongest techniques to ensure credibility of the research findings (Kaplan and Maxwell, 1994). There are many advantages of member checking. For example, it gives participants the opportunity to help to reduce the incidence of incorrect data collected and the data interpreted (Harper and Cole, 2012). It also enables additional information to be added to the data collected through the validation process by participants. The researcher can then verify the accuracy, fairness and completeness of research findings, to improve the overall quality and validity of the research (Moustakas, 1994).

However, there are also issues that need to be addressed to ensure effective validation through member checking. Some are worried that respondents tend to raise individual concerns in the process of member checking, while researchers prefer a holistic view of the issue studied to highlight the central topic (Bloor, 1997. Also, the views of participants on the issues may change as a result of new experience after the interview. Furthermore, respondents may not always agree with the interpretation of the researcher, then what criteria should be used to justify which interpretation is accurate becomes an issue (Morse, 1999 Angen, 2000). Therefore, accepting respondents' feedback at face value can affect the rigour of the findings (Atkinson, 1997).

In this research, data triangulation was used to ensure different types of stakeholders at the early-stage design process of construction were collected to cover a wider range of perspectives in the AEC industry and answer research questions in this thesis. This can help to enhance the validity and reliability of the data collected. According to Table 3.8, at the interview process, to ensure the data collected truly reflected the views of participants, member checking was used. To avoid the issue that interviewees might change their mind about the issues they discussed, member checking was conducted as part of the interview, rather than after the interview. At the end of the interview, the researcher summarised all the key points participants put forward to answer each interview questions. Each participant was asked to check if the summary of the key points accurately reflected their views on every question in the interviews. Additional points and changes suggested by the participants were made during this stage to improve the quality of data collected.

To validate the methodology and the findings of this thesis, three types of validation methods are used: data triangulation, investigator triangulation, and member checking. In the data collection process, data triangulation is used to collect information from different kinds of stakeholders in the early-stage design process, who have different levels of expertise in using MMOG to assist this process. This helps to give a better understanding to answer research questions in this thesis. Also, member checking is used as part of each interview conducted in this research, with participants verifying the key points summarised by the researcher for each of the questions they answered. This helps to provide a complete, accurate, fair interpretation of data. In the data analysis process, investigator triangulation was used to reduce the bias caused by using only one analyst to interpret the data. Two lecturers experienced in template analysis and interested in the research topic of this thesis were invited to produce an initial template for six transcripts. Each transcript was chosen randomly from six different types of data collected in this research. The templates produced by the investigator and the researcher were compared. Changes were made to form a more robust analysis of the data. In the reporting process of the finding, investigator analysis was also used to validate the initial guidance produced to guide architects to better use MMOG to augment the early-stage design process. Through the combination of the three validation methods used, the validity, reliability and credibility in the data collection, data analysis, and reporting of the findings process can be achieved.

## 3.4 Summary of the Chapter

The chapter has explained the selection, planning and implementation of the research design. Various research designs are compared and justification is presented for the selection of the research design, philosophical basis, and choices of method. Difficulties that arose in the course of work and data collection are discussed. The basic philosophical position for this research is introduced, indicting a critical realism based, objectivist interpretivist, subjectivist, emic, yet a mixed methods research design. The data collection and analysis process are discussed and defended. The selection of semi-structured interviews in real world and virtual world is presented. Issues on validity, reliability, generalisability are discussed; the research methodology is also defended through using data triangulation, investigator triangulation, and member checking to ensure quality of this qualitative research.

# Chapter 4

# 4.0 Architect Interviews

This chapter examines part of Research Objective 3 of this thesis to identify any deficiencies in supporting early-stage design decisions. In order to achieve this aim, 30 real-world architects who have not used MMOG for architectural design are interviewed to explore the following two research questions of this thesis:

> Q1: What are the issues which negatively impact early-stage design.
>
> Q2: What forms of visualisation are used in early-stage design and what are their limitations.

The first section of this chapter discusses the various activities architects undertake during early-stage design. Analysis from this section answers the research question Q1 of this thesis, identifying issues at early-stage design. The second section discusses the various visualisation tools they use to assist the early-stage design process. Analysis from this section answers the research question Q2 of this thesis, identifying the visualisation tools used at early stage and the limitation of each of them. The third part discussed the overall issues of current tools used in early-stage design, which answers the research question Q1. This chapter concludes with a short summary highlighting the findings in relation to the aim and research questions set out at the beginning of this thesis.

## 4.1 Data Collection and Analysis

Based on the research methodology discussed in Chapter 3, a questionnaire was developed to elicit information from practising architects to identify key issues at early-stage design, which visualisation tools they are using and their limitations. To answer research question Q1 "What are the issues which negatively impact on early-stage design?" the following two questions are included in the questionnaire:

1. What are the design tasks you need to complete at early-stage design?
2. What are the overall limitations of those tools to improve early-stage design?

In order to answer research question Q2 "What forms of visualisations are used in early-stage design and what are their limitations?" the following questions are proposed:

3. What tools do you use to augment the early-stage design process?"
4. At what early stage of the RIBA Plan of Work do you think those visualisation tools you currently use are useful?
5. What are the limitations and advantages of current tools at early-stage design?

Two pilot interviews were conducted with the first two architects who were willing to participate in the research. Feedback gained from those two pilot interviews was used to revise and improve the questions to ensure appropriate questions were asked during the interviews. The final questionnaire is presented in Appendix Five: Interview 30 Practising Architects.

Companies were contacted by telephone to see if they were willing to participate in the study. Forty-seven companies were approached and 30 architects (the response target) agreed to take part in this research. The sample size in this qualitative research is one that adequately answers the research question. Data were analysed immediately after each interview was conducted. When 30 interviews had been conducted and analysed, it was found that new categories, themes or explanations stopped emerging from the data. The data collected from 30 architects reached data saturation. Therefore, the sample size of 30 is appropriate enough to answer this question.

The interviews lasted from one to one and a half hours. All architects were interviewed according to the questions designed in the questionnaire. Most of the architects interviewed are from small or medium-sized architects' firms based in Loughborough or Leicester. Some of them are from large architects' firms in London and other cities. Appendix Five provides details of the backgrounds, experience and other relevant information of those architects interviewed in this chapter.

All the 30 interviews have been recorded and transcribed in written form to be analysed by template analysis. Some initial ideas about what the data implies are listed to be used at the next stage. For example, one initial idea noted during the transcription is that architects use a variety of tools to augment their early-stage design. All of the frequently quoted tools such as 2D sketches, CAD, Google SketchUp, BIM or physical models are used as coding to create the initial template.

# 4.2 The Way Architects Manage Early-Stage Design

For the purpose of this study, early-stage design is referred to as RIBA design stages A-D. It begins with Design Stage A: Appraisal, where a brief is made to identify the clients' needs and potential development constraints through preparing studies to empower the client to decide project direction and procurement methods. The brief can be done jointly by architects and clients in small projects, or by another architect or architects' firm in large projects. This was confirmed in the interviews with 30 architects. Architect H said that, "my main projects are single residential housing, which are quite small. Therefore, most of the time, the client and I will discuss and finalise the design brief together.” Architect T’s company, on the other hand, which deals with big international projects, normally carries out its design brief with other architects or architects’ firms employed by the clients. “Often, we do the brief with our clients. But there are also many times when the project is complicated and huge and we will be dealing with another architect or architecture firm who has been employed by our clients to make the brief for us to design.” The brief should contain the functional requirement of the project, especially the building function and the site location (Lawson, 2006). Therefore, architects need to firstly identify these two key issues in the design. Theoretically, with the help of various visualisation tools, the content of the brief can be demonstrated to the client and further detail and clarity gained. However, according to the data collected in the architects’ interviews, this is not always the case. What is specified in the RIBA stages is not always followed by architects. Many experienced architects interviewed argue that the RIBA stages are too idealised. In real-world architectural design practice, the design process is not restrictively a step-by-step route; rather the brief is developed throughout the process. This view was expressed by nine out of 30 architects interviewed. However, they still follow the RIBA stages in their daily practice as it is the standard in architectural practice, which most clients and other stakeholders in the projects recognise. This issue is discussed and addressed in Chapter 8 Section 8.4.2: Limitations of Tested RIBA Stages. Besides drawings, architects interviewed have also been working on other activities as follows:

- Finding information for the project (such as technical knowledge, positioning the building on the site, building orientation), architectural knowledge, technical constraints, and rules);
- Reasoning: processing all information based on the expertise and knowledge of the architects;
- Brainstorming: key in the sketching process, one of the most effective methods to create analogues and metaphors;
- Looking around: architects search for examples of the work done by other architects, which come throughout the design process;

- ❖ Verify results: test design idea against the brief with technical requirements and rules;
- ❖ Reflection: the architect himself/herself reflects on the results, reactions and opinions of the client and colleagues; and
- ❖ Communicates: The architect often does that with the client through presentation.

Early-stage design is therefore mainly composed of the above-mentioned activities, which are about defining the design idea, concept, shape of the building, and creativity. This finding helps address research questions Q1 and Q2 of this thesis. Architects do not want complicated tools in early-stage design.

## 4.3 Early-stage Design Tools

According to the results from the 30 architects' interviews, it is found that architects tend to use simple tools, which allow them to focus on the process itself, rather than too much on the tools themselves. Easy visualisations tools such as 2D sketches, physical models, Google SketchUp, Basic CAD are mostly used in early-stage design.

### 4. 3. 1 2D Sketches

All 30 architects interviewed have been using 2D sketches with pencils and conversation with clients to find out more about their needs of the design. They prefer to manipulate their ideas with hand drawings. As shown in Table 4.1, this is especially so during RIBA stages A and B when all 30 architects reported that they found it useful to use 2D sketches for appraisal and design brief. When at Stage C: Concept, only nine architects think 2D sketches were useful. When it comes to Stage D: Design Development, only six architects still use 2D Sketches. This proves that, sketching is a dominant tool used in the early-stage designs (Gross and Do, 1996). However, the usefulness of 2D sketches at early-stage design is declining when the details of the design require more accuracy. This is mainly because of the following reasons:

**Table 4.1 How Many Architects Find 2D Sketches Useful at each of the Early-stage Design Stages of the RIBA Plan of Work**

| RIBA stages | No. of architects who find it useful |
|---|---|
| **A Appraisal:** | 30 |
| **B Design Brief:** | 30 |
| **C Concept** | 17 |
| **D Design Development** | 6 |

Firstly, architects are trained to use 2D sketches to solve their design problems. Drawings and especially sketches use an abbreviated two-dimensional sign system to represent three-dimensional visual experience and can contain different kinds of information of the design. Many architects interviewed have recalled the process of how they use drawings to solve design problems. This is mainly because there is a tradition to use 2D drawings throughout the design process in the AEC industry, especially in the early-stage design process. Therefore, 10 out of 30 architects mentioned that they believed that this tradition and relevant training has enabled all architects to have this ability to use 2D sketches to visualise 3D design. As a “must-have” skill for architectural design, most architects have been trained for years to have the best ability to use 2D sketches. As a result, 2D drawings and plans are used throughout the whole lifespan of architectural design, from RIBA Design Stage A to Design Stage K. This is echoed by all 30 architects interviewed. For example, architect G (see Appendix Five for more information on his background) mentioned when he drew multiple alternative contour lines and figures on the paper, those suggestive scribbles and wobbly lines, became various 3D shapes of the rooms, walls and roofs of the design in his mind. However, with the advent of various other visualisation tools in the AEC industry, traditional 2D sketches are used by architects increasingly during early RIBA design stages, especially A and B.

Secondly, the selective information contained in 2D sketches is helpful to generate creative design ideas. Ten out of 30 architects interviewed recorded that they only sketch the most important ideas in their drawings to underlie the design, which only consist of some simple elements. Therefore, information contained in the 2D drawings is selective and fragmentary to present initial ideas about the shape of the building. This vagueness and abstraction of 2D sketches can be interpreted in multiple ways (Fish and Scrivener, 1990), which many architects interviewed mentioned that every time they look at their design sketches, something new emerges. “With sketches, I am able to ‘play’ with my design concept and ideas, modifying, adding, or deleting various elements there to generate creativity through visual feedback”, added Architect B (see Appendix One for more information on his backgrounds). Therefore, sketches are ongoing and can be changed and polished repeatedly to influence the design decision-making process. Three architects interviewed echoed this viewpoint through mentioning the quote from Bryan Lawson, “the drawings can talk back to the designer enabling a problem to be discovered and a solution created” (Lawson, 2006: 280). In sum, sketching is useful to help architects to inspect ideas, themes, plans and concepts that have been put down on paper, discovering new features and relations between them to refine and revise their ideas (Suwa and Tversky, 1996). However, as shown in Table 4.1, the ambiguous information contained in the 2D sketches becomes less and less useful when it comes to Stage C: Concept and Stage D: Design Development, when the details of the design need to be detailed and accurate enough for implementation. That is why after Stages A and B, fewer and fewer architects use 2D sketches to assist their early-stage design. Besides using sketches to create their own design ideas, architects also use sketches to share their ideas with other stakeholders in the architectural projects.

Thirdly, architects use drawings to share ideas with colleagues working in the AEC industry. This is mentioned by all 30 architects interviewed. However, the difference between the first two points and the third point is not clearly shown in the interview results. Drawings done to inspire architects to find design solutions, are rough, vague, abstract, and most likely only the designers themselves can fully understand and visualise what is written down on the paper. According to the result, this is mostly done at Stages A and B. However, drawings to be shared with other stakeholders of the projects, have to be standardised and presentable, so that not only professional AEC practitioners, but also non-professionals like the clients may understand it. This is mostly done at Stages C and D. For one thing, 2D drawings presented to other AEC professionals have not been much of an issue to architects who have been interviewed. All the drawings are normally based on industry standards and therefore other professionals in the projects, such as quantity surveyors, mechanical engineers, or civil engineers can read them easily. For another, 2D drawings presented to stakeholders who have no professional knowledge of the AEC industry, especially end-users and clients, have been reported by 25 architects as having different level of difficulty in understanding the design.

This is the main drawback of sketches. Sketches are limited to two dimensions and not all ideas can be represented by sketches. For very complicated geometric shapes, it is difficult to use 2D drawings to help clients to understand what is proposed. For example, architect H (see Appendix One for more information on his backgrounds) used the example of Sydney Opera House. Sydney Opera House has a complicated geometric shape, which cannot be easily explained through 2D drawings alone. Other 3D visualisation tools must be used to allow clients to understand fully what is suggested. The vagueness and abstraction conveyed in the 2D drawings provides limited information about the design. Therefore, unlike architects who are trained for years to use 2D drawings to visualise design in 3D in their minds, most clients and end-users do not have the same visualisation ability and therefore cannot see in the same way what architects propose in the design, through drawings. Many architects interviewed mentioned that some clients cannot read drawings, some of them do not visualise the 3D buildings through 2D drawings at all. In order to solve the problem, many architects interviewed mentioned various other tools to help their clients understand the design. For example, some will use photorealistic images, 3D CAD flythrough, or refer to similar real buildings, to help clients understand the design.

In summary, 2D drawings are widely used by architects for early-stage design, especially RIBA Stages A and B, because they help to visualise design concepts, generate creative design ideas and communicate with other professionals stakeholders in the projects. However, due to the fragmented information in the 2D sketches, at Stages C and D, it is increasingly become difficult for architects to use 2D sketches to communicate with clients and end-users who cannot understand the 3D design concept of architects through 2D information. Therefore, other design tools should be used to help address this issue.

### 4. 3.2 Physical Models

Due to the limit of 2D sketches, architects also use other methods in conjunction with drawings in early-stage design, for example, a physical model. According to the architects interviewed, 20 out of 30 have used physical models for a range of different purposes such as 3D visualisation for the inside or the outlined structure of one building, or for surrounding models, for landscapes, and for urban planning. Most of the models are built using clay, cardboard and wood. The reasons that architects use physical models are as follows:

**Table 4.2 How Many Architects find Physical Models Useful at each of the Early-stage Design Stages of the RIBA Plan of Work?**

| RIBA stages | No. of architects who find it useful |
|---|---|
| **A Appraisal** | 3 |
| **B Design Brief** | 4 |
| **C Concept** | 10 |
| **D Design Development** | 10 |

Firstly, physical models are used to communicate the design ideas to non-professional stakeholders such as clients and end-users (15 out of 20 architects). Eight of them use it at RIBA Stage D to give clients a 3D view about the outline design. They showed the shape and aesthetics of the design and get idea approved by clients. Three of them use it at RIBA Stage C to show clients the landscapes, checking all relative dimensions around the buildings. In two other cases it was used in RIBA Stage C as a tool for urban planning of the project, to see how the design fitted in the surrounding buildings. Another two cases used them at RIBA Stage D as a demonstration tool to clients so as to win the tender of the construction project, where shading and lighting of the design is also tested as part of the demonstration. Secondly, physical models are used by architects to try out complicated shapes, which are difficult to visualise through 2D drawings (five out of 30). This is all done at RIBA Stage C. In three out of five cases models were used to test the overall shapes of the design, while two used models to try out part of the interior design of the building. Generally, as shown in Table 4.2, many architects find it more useful to use physical models at Stages C and D to communicate with non-professional stakeholders such as the clients. From the 20 architects who find using physical models useful at early-stage design, ten of them used it at Stage C: Concept Design while the remaining ten preferred to use it at Stage D: Design Development. Some architects also used physical models at Stages A and B. As shown in Table 4.2, at Stages A and B, only three and four architects have used it to as a tool to quickly test out their own design idea before communicate it to the clients and other professional stakeholders involved in the design. This result reflects that physical models are useful in the early-stage design process for a variety of reasons and audience.

However, there are also problems with physical models. Of all the 30 architects interviewed and for all the 20 architects who have used physical models, their physical models are constructed before 2006. Architect H said, “most of the physical models you see in our studio were construction [*sic*] five years ago. It is not so often now that we build a physical model to show our clients how the design will look like”. Only eight of them are still using physical models in early-stage design now, unless the clients demand it. Most of them are used to showing clients the design in 3D. Only one is still using models to try out his design idea. Architect C said, “I still enjoy using clay to quickly test out my design idea. I find it convenient; however, it is not always the case with most of my fellow architects in the same firm”. The main reason for that is because to construct a physical model can be time-consuming and expensive. To build outline structure physical models to show the clients can takes days or weeks, depending on the precision of the model, with an estimated cost of £2,000 to £3,000. For example, architect J said that “we always work our best to strike a balance between cost, time and quality of the design. The time and cost needed to construct a physical model with much details does not always worth it, especially your client just want to get the design [*sic*] “as soon as possible”. Another reason is that the model is static and can be only used for specific project. When the project is finished, there is little use for the scale model, except to be displayed at the office of the architects or the clients. Also, with the popularity of Google SketchUp which has become freely available since 2006, more and more architects have turned to SketchUp which can quickly achieve the goal of scale models, including to visualise the inside/outlined structure of one building, or for surrounding models, landscapes, and urban planning. Architect K said that, “it is not because physical models are not useful, it is just that with Google SketchUp, we can also quickly and easily show the clients. In comparison with Google SketchUp, physical models seem to become less popular among us now.” Because of these reasons, physical models have become less popular with the advent of Google SketchUp.

### 4.3.3 Google SketchUp

Basic 3D tools are also used in early-stage design. Of these 3D tools, Google SketchUp is the most popular. Google SketchUp, according to most architects, is the best and most widely used 3D early-stage design tool. Of the 30 architects interviewed, 28 of them are using it as an early-stage design tool. The two that do not use it cited the age of the architects (more than 65 years old) and the nature of their practice (a small two-people architectural firm) as the reason. As shown in Table 4.3, Google SketchUp is used by most architects throughout the whole early-stage design. At Stage C: Concept, 28 out of 30 architects interviewed find it useful to use Google SketchUp. From Stages A through C, the usefulness of Google SketchUp increased with 17 (Stage A), 24 (Stage B) and 28 (Stage C) architects finding it useful at each Stage. After Stage C: Concept, the popularity of Google SketchUp drops slightly with three out of 28 architects preferring to use other form of visualisation tools.

**Table 4.3 How Many Architects find Google SketchUp Useful at each of the Early-stage Design Stages of the RIBA Plan of Work?**

| **RIBA stages** | **No. of architects who find it useful** |
|---|---|
| **A Appraisal:** | 17 |
| **B Design Brief:** | 24 |
| **C Concept** | 28 |
| **D Design Development** | 25 |

There are several reasons for the popularity of Google SketchUp. Firstly, it is quick and simple. The interface of the program is easy for people to use. It can take architects only a few minutes to get a building visualised in 3D. Architect C said, “it is really convenient to use SketchUp to model, it is almost as quickly [*sic*] as using a pencil for sketching. There is no doubt why it is called ‘the pencil of digital design’.” Also, the globally accessible 3D warehouse also makes the visualisation process quicker. Models created by Google SketchUp can be shared globally through Google 3D Warehouse and be put at any location with Google Earth. Therefore, architects do not need to create everything from scratch, but can download any model created by other architects around the world. This can accelerate the design process. Architect D gave an example for the online 3D warehouse, “I really like the online 3D models database enabled by Google SketchUp. Last time, I was doing a construction design near the British Telecom tower of London. Instead of creating it myself, I went to Google 3D warehouse and found various buildings models around that area, including five models of the London BT Tower in different scale and just download them and added to my design model”. Secondly, SketchUp is also easy to learn. Unlike most CAD models which take weeks or even months of professional training, the acquisition of the SketchUp takes a few days and for some, just a few hours. Most architects interviewed were impressed by the short training period needed to acquire the necessary skills to model their design in SketchUp. “The time spent on training architects to use new design program is a cost we need to consider. The great popularity of Google SketchUp lies in the fact that it takes us a short time to be able to use it. That is attractive to us architects”, said Architect Y. Thirdly, the interoperability between Google SketchUp, other CAD models and BIM are good. IFC is the open and neutral specification, which is commonly used for BIM and CAD. Five architects interviewed mentioned that they has been using a free plug-in to import BIM and CAD models into SketchUp for editing and rendering. Since June 2008, a free plug-in IFC2SKP (Industry Foundation Classes to SketchUp) has been available to enable the import of IFC format models from CAD/BIM into SketchUp. Architects interviewed have used this plug-in to transfer models from Revit, ArchiCAD and Microstation into SketchUp. This plug-in enabled the transfer of both the geometry and object data. Also, the BIM data of each imported object can be shown with this plug-in. With the popularity of Google SketchUp, more and more BIM and CAD model developers have enabled the import function of SketchUp models into other BIM software. For example, since June 2009, Revit allows the import of SketchUp model, which four architects interviewed have found convenient. “I can transfer the model from Sketch up to Revit at a later stage of the design without wasting time to rebuild a new model in BIM”, said Architect U. Meanwhile CAD software such as Autodesk 3D Max 2010 enabled “Connection Extension SketchUp Importer” which has not only enabled Google SketchUp scenes into 3D Studio Max, but also functioned to allow 3D Studio Max to read all the SketchUp models from the online 3D Warehouse. These are the views expressed by most architects interviewed who think highly of SketchUp as a quick early-stage design modelling tool.

However, there are also some limitations to SketchUp. Firstly, the rendering of the model visualised is not realistic. Google SketchUp is designed for quick visualisation purposes, therefore, the detail of the models is not as high as in CAD models. “Google

SketchUp is really good, but my colleagues and I only use it for early-stage design modelling. For detailed design modelling, SketchUp is too crude and is not precise enough in comparison with various CAD models", said Architect X. Secondly, the free 3D models available online at the 3D Google Warehouse are limited. This online database of 3D free models was created at the same time when Google made SketchUp free to the public in April 2006. However, at this moment, the 3D Google community is limited. According to the website of the Google 3D Warehouse Search, only about 500 3D models are available at the online Warehouse. Also, on the website of official Google 3D Warehouse Community, there are only 1,815 topics discussed among the community of people who are interested in sharing 3D SketchUp models online. Therefore, five out of 28 architects who are using Google SketchUp are not satisfied with the limited number of free online models available at this moment. However, three of them believe that with more and more people interested in sharing their models online, this problem can be solved. Thirdly, although the interoperability between SketchUp, CAD and BIM can be achieved technically, only five out of 28 architects are using SketchUp beyond early design stage. After the early stage, most architects prefer to design the model in more advanced systems such as CAD or BIM because they believed that CAD and BIM are more mature tools dedicated for later stages of the design. Google SketchUp still only stands as a convenient tool suitable for the early stage of designs.

### 4.3.4 Basic 3D CAD

According to the Table 4.4, about one-third of the 30 architects interviewed use various basic 3D CAD models in conjunction with 2D sketches in early-stage design. Architects mainly used CAD at RIBA Stages C and D. At Stages A and B, no architects interviewed had been using basic 3D CAD at all. This is because of two reasons: first, to reduce the time needed to transfer early-stage design based on 2D drawings to detailed design using computer visualisation; second, to communicate more easily with engineers who mostly use CAD in their projects from the beginning. According to the interviews, CAD is already widely accepted by the industry as a visualisation tool, but it is only recently that various CAD tools have developed for early-stage design.

**Table 4.4 How Many Architects Find Basic CAD Useful at each of the Early-Stage Design of the RIBA Plan of Work**

| RIBA stages | No. of architects who find it useful |
|---|---|
| **A Appraisal:** | 0 |
| **B Design Brief:** | 0 |
| **C Concept** | 10 |
| **D Design Development** | 11 |

There are several reasons for this. With definitive and precise drafting and modelling tools, CAD is mostly developed to assist the later design stages (Suwa and Tversky, 1996), which require precision and functionality. However, the early architectural design process is mainly about generating design ideas based on the brief. This process can be accidentally or deliberately vague, abstract or fluid so that the most creative design ideas suitable to the project are revealed. At this stage, the accuracy and functionality of CAD may be counterproductive and may hinder the right design idea from emerging. This opinion was expressed by most of the architects who do not use CAD at early-stage design. For example, Architect A said that, "I like sketching with pencils on paper. Different lines and shapes I draw on the paper can be interpreted in different ways, which can inspire me with different ideas for the design". Architect G added that, "I don't feel comfortable using CAD models to precisely define my design idea at the very beginning. It is less playful, and also stops me from generating creativity through flexible and vague visual representation". This supports the argument raised by Lawson that the use of very precise CAD in the early design stage may limit the creativity of the design and result in poor design (Lawson, 2006).

However, the ten architects who use basic 3D CAD at RIBA Stage C also make a point. For most architects interviewed, CAD is frequently used at a later stage to assist with the more detailed design. As a result, most of them have to transfer 2D drawings developed at the early stage into the CAD systems for detailed design. In order to reduce the time spent on the transition from the conceptual stage to detailed stages, some of the architects use various CAD programs at the early stage so that they can reduce the time spent on the transition period. Also, as early-stage tools do not need precision, architects only use very basic tools in the CAD systems at this stage. For all the 11 architects who use basic 3D CAD at Stage D, it is only a tool that they picked up in recent years, when various CAD companies identified this increasing need, and developed added tools or plug-ins to help architects to use basic CAD at early-stage design. Architect E gave the example of AutoDesk. “Companies like AutoDesk have introduced CAD tools that are intended to support the early stage of design and that can be used together with more advanced tools for the later stages of the design. This is convenient for our company to shorten the transfer time from 2D drawings to more detailed CAD models.” Of these 11 architects, mostly they are using basic Archi CAD in early-stage design; some used AutoCAD and 3D Studio Max.

However, even though CAD is frequently used after early-stage design, none of the architects interviewed have developed detailed 3D visualisation modelling skills themselves. The detailed visualisation models are most likely to be outsourced to external IT companies who are specialised in 3D visualisation. Of all the 30 architects interviewed, 24 of them have mentioned that, as architects, they do not do detailed visualisations themselves because it is too specialised or takes too long to be processed, or because clients don’t ask for it. “Most of our offices are mainly using 2D drawings, only one office in Newcastle has a visualisation team, but it normally takes eight weeks for a detailed CAD model of part of the design model to be created and polished. Therefore, we will not ask external IT companies or our Newcastle office to do a detailed CAD model or flythrough unless clients are willing to wait such a long time and pay for it”, said Architect H.

### 4.3.5 Useful Tools Used at Early Stage

The interviews examined what tools architects currently use for early-stage design decision-making. The results of the interviews are summarised in the following Table 4.5. The criteria used to select six categories of tools are based on the frequency they were mentioned by the 30 architect's interviews. Tools that were considered useful at early stage by more than three architects are included in the table. Therefore, visualisation tools such as Augmented Reality, which was considered as useful by one architect, were not included. The number in the table shows the number of architects who consider each tool as useful at early-stage design. BIM and Virtual Reality are also considered useful by a small number of architects. The additional data collected on BIM and Virtual Reality are shown in Table 4.5.

**Table 4.5 Best Use of various tools at early stage of RIBA plan of work**

| RIBA stages | 2D sketches | Physical models | Google SketchUp | 3D CAD | BIM | VR |
|---|---|---|---|---|---|---|
| **Useful** | **A,B** | **CD** | **A-D** | **CD** | **B-D** | **CD** |
| **A Appraisal** | 30 | 3 | 17 | 0 | 0 | 0 |
| **B Design Brief** | 30 | 4 | 24 | 0 | 3 | 0 |
| **C Concept** | 9 | 10 | 28 | 10 | 6 | 3 |
| **D Design Development** | 7 | 10 | 25 | 11 | 9 | 3 |

To simplify the table and make it easy to be analysed, each of the six types of visualisation tools was rated from "less useful", to "useful", "very useful" and "highly useful".

- Tools are rated "less useful" (marked as "1") if they are considered useful at a specific RIBA Stage by between 3 and 9 architects interviewed.
- Tools are rated "useful" (marked as "2") if they are considered useful at a specific RIBA Stage by between 10 and 16 architects.
- Tools are rated "very useful" (marked as "3") if they are considered useful at a specific RIBA stage by between 17 and 23 architects.

- Tools are rated “highly useful” (marked as “4”) if they are considered useful at a specific RIBA stage by between 24 and 30 architects.

The simplified version of the table is shown in Table 4.6

**Table 4.6 Best Use of Various Tools at Early Stage of the RIBA Plan of Work (Simplified)**

| RIBA stages | 2D Sketches | Physical models | Google SketchUp | 3D CAD | BIM | VR |
|---|---|---|---|---|---|---|
| **Useful** | **AB** | **CD** | **A-D** | **CD** | **B-D** | **CD** |
| **A Appraisal** | 4 | 1 | 3 | 0 | 0 | 0 |
| **B Design Brief** | 4 | 1 | 4 | 0 | 1 | 0 |
| **C Concept** | 1 | 2 | 4 | 2 | 1 | 1 |
| **D Design Development** | 1 | 2 | 4 | 2 | 1 | 1 |

1: less useful, if considered useful by 3-9 architects.
2: useful, if considered useful by 10-16 architects.
3: very useful: if considered useful by 17-23 architects.
4: highly useful: if considered useful by 24-30 architects.

To make it easy find which tool is most useful at each stage of early design, colour coding was introduced with grey representing 1, less useful; blue representing 2, useful; yellow representing 3, very useful; and red representing 3, highly useful. The colour-coded table is shown at Table 4.7

Table 4.7 Best Use of Various Tools at Early Stage of the RIBA Plan of Work (Colour coded)

| RIBA stages | 2D sketches | Physical models | Google SketchUp | 3D CAD | BIM | VR |
|---|---|---|---|---|---|---|
| **Useful** | **AB** | **CD** | **A-D** | **CD** | **B-D** | **CD** |
| **A Appraisal:** | 4 | 1 | 3 | 0 | 0 | 0 |
| **B Design Brief:** | 4 | 1 | 4 | 0 | 1 | 0 |
| **C Concept** | 1 | 2 | 4 | 2 | 1 | 1 |
| **D Design Development** | 1 | 2 | 4 | 2 | 1 | 1 |

Less useful (1) Useful (2) Very useful (3) Highly useful (4)

According to Table 4.7, it is shown from the results that 2D sketches, physical models, Google SketchUp and basic 3D CAD are mostly used by architects at early stage to assist design decision-making. BIM has been discussed several times among the architects, as a tool, which is supposed to be used throughout all design stages starting from RIBA Stage B. However, most architects tend to use BIM from Stage E onwards, which is after early-stage design. It is mainly because not until the detailed stages, is there enough design information to make it worthwhile to use BIM to manage the whole design project effectively. Virtual Reality as a modelling tool was only mentioned three times among all the 30 architects interviewed and therefore is less popular in comparison with other tools. Table 4.7 highlights the most common tools used at early RIBA Stages A-D.

## 4.4 Limitations of Current Tools

From the interviews, it is clear that many architects are satisfied with the current design tools used in the AEC industry. However, some architects also mentioned problems with current visualisation tools. For example, not so many tools are available to effectively empower non-professional stakeholders to better understand the design process and contribute more to it. Also, most of the human interaction enabled by the tools used at early-stage design cannot effectively mirror the real-world, immersive experience of the occupants.

For one thing, few tools can effectively engage non-professional stakeholders at early-stage design. Many architects interviewed argue that clients and architects are always competing for more control with each other during the design decision process. Architect O argued that, traditional architectural practice is a top-down approach where so much emphasis is put on the leading position of the architects that create signature designs or masterpieces. Other stakeholders especially the non-professional ones, such as clients and end-users have limited involvement in the design decision-making process.” Therefore, the tools developed in the AEC industry also cater to this architect-led design process. Most of the tools currently used during the design process are to help the design decision-making process by specialists, such as architects and engineers. Architect H said, “there are hundreds of different software tools in the AEC industry. The vast majority of these tools are developed for architects and engineers who have years of architectural design experience. Those tools are so well-developed now that most architects are very satisfied with the option of tools they can choose from.”

However, a successful architectural design project will not only require tools to help professional stakeholders such as architects to design, but also for laymen stakeholders such as clients and end-users to contribute to the design process. This architect-centred design approach can only be effective in some parts of the life cycle of a construction project, argued by many architects interviewed. Increasingly, architects have started to call for a more participatory approach in the architectural design process for all stakeholders, especially for clients and end-users to actively engage in the design process to improve the quality of the outcome. However, very few tools are effective in engaging non-professional stakeholders such as clients and end-users in the design process.

For example, 2D sketches and drawings are effective tools used by architects at early-stage design. It is difficult for one architect to understand the 2D sketches done by another architect. It is more difficult for clients and end-users to see what the architect sees from a 2D sketch. 2D drawings on floor plan or shape of the building are often shown to the clients. However, not all clients can imagine and understand how the 2D design looks in 3D. Physical models can help non-professional stakeholders to have a better idea about how the design looks in 3D. With the smaller scale of the model representing the design, the physical model can only be appreciated and evaluated from a general perspective, to see if the overall shape, outline, and layout of the building work well. It is difficult to go into detail to see if any specific part of the design works unless a separate model is constructed to demonstrate it.

CAD is useful to generate 3D flythrough of the design. The 3D models generated by CAD are normally mathematically and scientifically accurate to simulate the real-world buildings. With this high level of detail, the computing power required to smoothly produce and operate those visualisations is demanding. These visualisations require advanced hardware, high-resolution graphic cards and great processing power. A few minutes of visualisation produced with high levels of detail can range from a few hundred megabytes up to a few Gigabytes depending on the resolution of the video. It also takes a few days or weeks to render. It is often that architects who decide the flythrough route and how the building is visualised and demonstrated to the clients, and who commission an external IT company to produce the 3D flythrough. If the route is changed, the whole visualisation needs to be re-rendered. When architects show that visualisation to clients, clients are only allowed to view the design based on the perspectives decided by the architects. Clients are not allowed to view other details of the building from a different angle unless it is included in what the architects are willing for them to see. In more recent development of CAD software, clients can be given more flexibility to explore freely within the boundaries set up by architects. But normally, this boundary is confined within specific key areas of the project. Therefore, even with very detailed, photo-realistic visualisation generated by CAD, the 3D information non-professional stakeholders can access is still limited.

Further, the human interactions simulated by most of the early-stage design tools are not yet a true representation of real-world, immersive human interaction. 2D sketches and physical models can help architects to test out design ideas, but are less effective in predicting how group interaction of end-users will be conducted in the actual space proposed by architects. With computer animation, 3D flythrough simulated by CAD can give a dynamic view about the design and some of the group interactions take place in the design project. However, given the length of 3D flythrough animations, this kind of human interaction demonstration is very limited, cannot really give a holistic analysis about how the whole space will be actually used by its occupants. Google SketchUp can provide quick and easy 3D visualisation at early stage for architects. However, its function simulating group interaction of occupants in the virtual space needs to be further developed. BIM is useful as a tool to manage architectural design when all the information about one project is managed in one model. However, the human interaction element in BIM is not yet well developed. Virtual Reality can provide great human interaction in the virtual environment. It is immersive. However, the cost to develop and purchase such powerful machines to simulate those virtual environments is not easily affordable by many small and medium-sized architecture firms. Also, the time and training needed to adjust relevant participants to get used to the human-computer interface and make the best of the virtual interaction experience is not easy. Generally, current tools used at early-stage design have not effectively addressed the issue of helping architects simulate real-world human interaction in virtual space to help early-stage design decision making.

## 4.5 Summary of the Chapter

This chapter examined Research Objective 2 of this thesis on the features of MMOG and their suitability in early-stage design. In order to achieve this aim, 30 architects who have not used MMOG for architectural design were interviewed to explore the following two research questions of this thesis:

Q1: What are the issues which negatively impact early-stage design.

Q2: What forms of visualisations are used in early-stage design and their limitations.

The first section of this chapter discusses the various activities architects undertake during early-stage design. To produce the briefing for the design with clients in small projects or with other architects commissioned by clients in large architectural projects, was found to be important in the early-stage design process. However, some architects interviewed argue that the briefing is not only produced at the early-stage design stage, but throughout all stages.

The second part discusses some of the major tools used at early-stage design, including the pros and cons of various visualisation tools. These tools include 2D sketches, physical models, Google SketchUp and Basic CAD. All the tools that are often used by architects at early-stage design, from RIBA Stage A to D, are discussed and summarised into a table.

The third part highlights various issues that current early-stage design tools fail to achieve. For example, most design tools used in the AEC industry can effectively support professional stakeholders such as architects in the decision-making process. However, not so many tools are available to better engage and support non-professional stakeholders to contribute to the design process. Also, the human interaction simulated by most of the tools available in the AEC industry are not yet a true representation of the real-world immersive interaction of the occupants. A new tool, which could address those issues, and augment current early-stage architectural design process is needed. Analysis from this section addressed the research question Q1 and Q2 of this thesis; issues in early-stage design, the visualisation tools used at this stage.

# Chapter 5

# 5.0 *SL* for Architecture

This chapter examines two of the research objectives of this thesis on the features of MMOG and their suitability in early-stage design. In order to achieve these two objectives, 20 real-world architects who have used MMOG for architectural design were interviewed to explore the following two research questions:

Q3: Can MMOG complement existing visualisation techniques?

Q4: How can MMOG such as *Second Life* be used to better inform building design?

In this chapter, *SL* is discussed from both the perspective of the professional stakeholders such as architects, and the perspective of non-professional stakeholders such as clients to explore what are the benefits and challenges using MMOG such as *SL* to augment the architectural design process. The first section of this chapter presents the data collection and analysis process of this dataset. The second section presents the findings that architects consider MMOG as a useful early-stage design tool. The third part discusses the potential *SL* has over current visualisation tools. The limitations of using *SL* as a tool to augment the current architectural design process are also identified.

## 5.1. Data Collection and Analysis

Based on the research methodology discussed in Chapter 3, a questionnaire was developed to elicit information from architects who have been using MMOG to augment real-world early-stage design in architecture.

To answer research question Q3, “Can MMOG complement existing visualisation techniques?” the following five questions are included in the questionnaire:

1. How long have you been using *Second Life* and other MMOG to augment your real-world architectural design process?
2. At what stage of design will this form of visualisation such as *Second Life* be useful?
3. Can *Second Life* augment the early-stage design process? If yes, how? If not, why not?
4. Does *Second Life* complement other existing visualisation techniques?
5. Can the social interaction formed in the virtual building have any influence on people’s use of the real-world building? If so, in a positive way or in a negative way? If not, why not?

To answer Research Question Q4, “How can MMOG such as *Second Life* be used to better inform building design?” the researcher aimed to find out the limitations and advantages of *SL*, with the introduction of question 6 in the questionnaire. Also, based on question 6, one further question on the barriers that limit the industry uptake of MMOG such as *SL* is proposed as interview question 7 to elicit more about whether MMOG can be better used to inform early-stage design.

6. What are the limitation and advantages of using *Second Life* to augment the early-stage design process?
7. What do you think are the main barriers for the AEC industry/university to use *Second Life* to enhance architectural practice?

Also, to ensure participants can give other useful information relevant to answer these two research questions Q3 and Q4, the following question is also included in the questionnaire:

8. Do you have any other comment?

Two pilot interviews were conducted with the first two architects who were willing to participate in the research in the virtual world of *Second Life*. Feedback gained from those two pilot interviews was used to revise and improve the questions to ensure appropriate questions are asked during the interviews.

Real-world architects who are using MMOG to augment real-world construction design were contacted by *Second Life* Instant Messaging to see if they were willing to participate in the study. A total of 60 real-world architects were approached using various real-world architects' *Second Life* groups and 20 architects (the response target) agreed to take part in this research. All these 20 architects have been interviewed using avatars in *Second Life*, recorded and transcribed into word documents for template analysis. The interviews last from one hour to two hours. In the first part, the architect interviewed in *Second Life* normally gave the researcher a virtual tour to show what they had been doing in *Second Life*, with the virtual models of various real-world architectural projects shown by those architects through the interaction of the avatars of both the architect and the researcher. Issues on designing and constructing those virtual models were discussed in the process and showed to the researcher. Then, all architects were interviewed according to the questions designed in the questionnaire.

After the result from the 20 real-world architects interviewed was analysed, it was found that it would also be helpful to interview non-professional stakeholders who are using MMOG to get better engaged at the early-stage design process. Therefore, another questionnaire was developed to test how non-professional stakeholders are using MMOG to become better involved at the early-stage design process.

To find out more information about this issue, the following questions were developed:

1. How long have you been using *Second Life* and other MMOG to design your own virtual architecture?
2. Why are you interested in developing your own virtual house in MMOG?
3. How does the design and development of architecture in the virtual world influence your involvement in real-world architectural design projects?
4. What are the limitations and advantages of using MMOG to engage you in the architectural design process?

Also, to ensure participants can give other useful information relevant to provide other useful information as they want, the following question is also included in the questionnaire:

5. Do you have any other comment?

Two pilot interviews were conducted with two *Second Life* users who were willing to participate in the research. Feedback gained from those two pilot interviews was used to revise the questions to ensure the questionnaires were well designed to elicit the most useful information. The questionnaire is included in Appendix Six.

Non-professional stakeholders were contacted at the sites of various *Second Life* Virtual Architecture competitions, when the researcher used the avatar to meet other residents who were designing the virtual architecture for the competition. A total of 40 *Second Life* residents who had virtual architecture design experienced were approached and 20 *Second Life* residents (the response target) agreed to take part in this research. All these 20 *Second Life* residents have been interviewed using avatars in *Second Life*, recorded and transcribed into word documents for template analysis. The interviews last from one hour to two hours. In the first part, the resident interviewed in *Second Life* normally gave the researcher a virtual tour to show what they had been doing in *Second Life*, with the virtual models of various real-world architectural projects showed by those residents through the interaction of avatars, both between the residents and with the researcher.

Issues on designing and constructing those virtual models were discussed in the process and showed to the researcher. Then, all residents were interviewed for the questions according to the questions designed in the questionnaire.

## 5. 2 Useful Early-stage Design Tool

Most of the 20 architects interviewed in *SL* agreed that *SL* could become a useful construction design tool at the early stage. That is mainly because of three reasons: it is a simple design tool, it enables quick architectural design, and it is especially useful to use *SL* at RIBA Stages C and D.

Firstly, *SL* is a simple design tool. Architects prefer simple tools at early stage so that they can be more focused on generating new design ideas. As a 3D immersive virtual world where creativity is only limited by imagination, *SL* presents unbounded opportunities for architectural design (Ondrejka, 2006). With a range of simple tools, architects can "build items with a limited palette of primitive objects" ("PRIMS") including cubes, spheres, and cones (Kemp and Livingstone, 2006: 13). These geometric objects can be "dragged off a template then stretched, positioned, sized, textured and combined to form anything imaginable". This provides a powerful modelling tool for architects, who can rearrange the whole place overnight without incurring extra expenses or consequences (Rose, 2007:23). According to Architect C, "it was really simple to produce the floor plans from *SL*. We can easily produce a module layer by layer that we can measure and we can use this module to relate to our blueprint." With these easy tools, architects are able to "constantly make changes, leaving behind a 3D sketch more than a presentable product," added Architect N. "And then we are able to have all the floor plans" said Architect I. In comparison with traditional Virtual Reality and Augmented Reality technologies, which are based on highly specialised computing languages, the modelling in *SL* is straightforward and easy to master. All the tools provided are so easy to acquire that architects without any advanced IT expertise can learn the skills quickly to construct a complicated virtual environment. The time-consuming training and re-training issue incurred by other ICT models is no longer a problem in *SL*. Accordingly, the easy design process in *SL* may "represent new possibilities for building engineering analyses" (Aouad et al., 2007: 288).

Secondly, the easy design tool enables quick architectural design in *SL*. In the past, architectural simulations were mainly developed by special software tools, which demanded special computing expertise. Mostly they were not developed by architects themselves, but were commissioned from external IT companies who specialised in 3D visualisation. The design process was complicated, time-consuming and expensive, which made the visualisation work a demanding job. If the clients were not happy with the design, architects had to ask the special IT experts they commissioned to re-render the 3D flythrough, which can take days or weeks depending on the quality of rendering and availability of the IT experts. However, with *SL,* any design change can be done quickly in-house. Architect J said that,

> … in my architect firm, architects never do the 3D flythrough ourselves. If clients want it, we will find an architectural IT company and commission them to create the 3D simulations for the clients. However, it still takes a long time, normally one week or two if the IT companies are not busy with other visualisation projects. The problem is that as architects, I don't have the programming skills to create such visualisations.

For example, two of the architects interviewed have both been commissioned to design a shopping centre of 130,000 square metres. They had been using traditional industry visualisation tools for the design. However, they find them time-consuming and expensive. It took them nearly one year with a design team of 20 people collaborating in two countries, but still they have not produced a design impressive enough to satisfy the customer. Because of that, they tried *SL* and they both have been designing the virtual prototype together a couple of hours every day in *SL*. In less than five weeks, this virtual model has been fully finalised and approved by the client. Architect D added that, “I was surprised how quickly the first part of design actually went, as compared to working with 3D Studio Max”. With the quick design enabled by *SL*, the architects’ building plans of this project were produced with great efficiency. In less than six weeks, they were able to produce the blueprint for this whole project. Therefore, *SL* has the potential to accelerate early-stage design and therefore improve the efficiency of design projects in real world.

Finally, it is found that *SL* is most useful at Stages C and D in the RIBA Plan of Work. Of all the 20 architects interviewed, three of them believe that MMOG should be used as early as possible to assist early-stage design, all the way from Stages A, B to C and D. Architect C for example used *SL* as a fast prototyping tool as early as Stage A: Appraisal. Four of them used it at Stage B. “I often use *SL* from the beginning of the design project”. After chatting to clients and finding out what they want, Architect C often used *SL* to quickly create a variety of models to demonstrate optional shapes and outlines of the design and showed them to the clients to assist the preparation of feasibility studies. “The clients do like looking at the various 3D shapes of designs I quickly created in front of them. *SL* fast prototyping helps me to instantly get feedback from clients and change it immediately to suit their requirement”. Five of them believe that MMOG could also be used during post-occupancy to help effectively managing the building environment after its completion at stage L, especially in terms of sustainability, and re-design of the place. For example, Architect H recorded his experience help to convert an office building into a hotel. “I think MMOG can be really useful to convert old buildings with new functions”. In the project when he was commissioned to convert an office building into a hotel, it took him quite a long time to get feedback through from all the end-users of that space. “I sent out about two hundred questionnaires; in three weeks’ time, I only got 30 back, not effective at all”. He did another conversion project in real life to change a library into a gallery. That time, he used *SL*, invited all of the current staff of the library and other *SL* residents to participate in the reconfiguration. 10

library staff and 10 *SL* residents spent two hours with him, moving around inside the virtual prototype to test various options for the conversion and the consultation process turned out to be engaging and effective. He did tests like this three times and then he used all the feedback he got from the virtual conversion to re-configure the real-world conversion project. The majority of architects interviewed think MMOG is most useful at RIBA Plan of Work Stages C and D. 18 architects use *SL* at stage C while only 15 architects use it at stage D. The reason for that is mainly because at these two stages, the level of details *SL* needs to effectively engage professional and non-professional stakeholders are not high enough. All the advantages *SL* have, can be maximised at RIBA Stages C and D. When the design process goes beyond stage D, the crude representation of *SL* cannot meet the need of professional architects any more. Architects prefer to use more precise visualisation tools to augment their practice. As a result, none of the 20 architects thinks *SL* is useful between Stages E to K, the more detailed design stage and construction stages.

**Table 5.1 How Many Architects Find MMOG Useful at each of the Early-Stage Design Stages of the RIBA Plan Of Work?**

| RIBA stages | No. of architects who find it useful |
|---|---|
| **A Appraisal:** | 3 |
| **B Design Brief:** | 4 |
| **C Concept** | 18 |
| **D Design Development** | 15 |

# 5. 3 Potential Advantages of *SL* over Current Practice

Architects interviewed identified the following three main areas where *SL* has the potential to augment other visualisation tools. The real-world, real-time, multi-user human interaction in MMOG is better because it is similar to real-world interaction.

Also, as a non-specialist social platform, *SL* can be useful to engage non-professional stakeholders in the design process, such as clients and end-users. Besides, the Internet-based *SL* enables easy access to the virtual design, which improves global collaboration at early-stage design.

## 5.3.1 Real Time, Multi-user Interaction

Most of the architects interviewed believed that the real-time, real-world, multi-user interaction in *SL* is the most prominent advantage that most current AEC visualisation tools fail to achieve. They believe that the human interaction in *SL* mirrored closely real-world interaction for the following reasons: the use of avatars gave more sense of being in the space, the demonstration of the space is not pre-recorded, but free to be explored; the multiple-user experience is more realistic than the single-user experience simulated by other software.

### 5.3.1.1 Immersive Interaction

The interaction in *SL* is immersive through use of acoustic simulation and avatars. It is not only visual, but also acoustic. The whole spectrum of scripts and sound effects enabled in *SL* can be used to simulate various sound environments in the virtual space based on different real-world scenarios to improve the design acoustically. In comparison with other professional AEC visualisation tools, this is not new. But easy access to allow massive numbers of non-professional stakeholders such as clients and end-users to fully experience the virtual space in a more immersive way is beneficial. Three of the 20 architects interviewed in *SL* have reported their success in working with acoustic experts in using *SL* virtual models to improve the sound environment for real-world architectural projects. They imported various noises recorded in real-world office environments, had them mathematically adjusted by the acoustic experts and then put them in different parts of the virtual buildings, and then used various scripts to trigger those noises in different scenarios to test the acoustic environment for the design. Besides this, the ability of controlling avatars to move around in the built environment gives the user a more engaging experience to appreciate the design before construction. 11 out of 20 architects like the idea of using avatars to represent the users in the virtual space, because, as they argued, "it created more real sense of being there", which make users feel more immersed into that space. According to Architect J, "*SL* provides the opportunity to see the design representation with a moving avatar actually seeing various electronic representations on the computer screen, hearing the sound of splashing fountains, touching various objects in the virtual world, allowing the viewer to have a more immersive experience than a 3D rendering could ever portray". Architect P argues that, the use of the avatar to explore the virtual space can evoke physiological and emotional reaction towards the space and therefore assist in better design decision making. The opinion of Architect P was echoed by six out of 20 architects and five out of 20 users interviewed in *SL*, who argue that with the avatars, it is a more effective way to get accurate feedback from various stakeholders to improve the design. Architect L, who is also a Construction IT specialist, mentioned that research already proves that the third-person view commonly used in computer games actually has a psychological impact on the behaviour of long-term users of the games.

However, the third-person view in *SL* is not what many architects are used to. Most architects do not use computer games as a design tool and are more used to visualisation which is viewed from the level of the eye in real life. Most computer games set third-person view as the default perspective for users. While this third-person view allows more immersion of the users into the virtual environment, it creates different viewing perspectives from most of the industry-standard visualisation tools. Most industry visualisation tools use first-person view which most architects are familiar with. Some architects raised the issue of how *SL* could adjust the view to become a more "eye-level" view to help architects to make the right decision about the space. It is possible to switch *SL* into first-person view, which is at eye level so that architects find it easier to evaluate their design in the virtual world. However, some of them find it difficult to manoeuvre around in *SL* with “first-person” view when they are used to the third-person view. It takes time for architects to find out an effective viewing experience in *SL* for architectural design, either in third-person view, which is the default setting, or in the first-person view, which architects can choose to use.

#### 5.3.1.2 Free Walkthrough of the Space

The walkthrough in *SL* is not-pre-determined. This is beneficial to architects, clients and end-users. All the building tools available in *SL* are useful to create a dynamic building model in 3D for AEC-industry stakeholders to view in all possible perspectives and routes. This is better than the pre-decided routes and perspectives used in many 3D flythrough animations of the AEC industry. The free walkthrough makes architects more confident about their design. Architects can use the feature to virtually experience the design and make necessary changes before it is constructed. Six out of 20 architects interviewed confessed that, although being professionally trained to have the ability to visualise their own design through 2D drawings, sometimes, architects themselves are still not 100% sure how the actual design will look and feel when the design is put into practice. With the free walkthrough enabled by *SL*, architects feel more confident about their design and can make modifications based on their own experience exploring the virtual space.

It is also useful to help clients and end-users to understand the design. Non-professionals who want to find out more about what the architects really propose can fully explore the design as they wish. There is no limit to the way in which they can explore the space unless architects set up boundaries for restricted access. Within the virtual space, permitted laymen stakeholders in the design projects can explore the space as freely as they want, unless they are happy for their avatars to be animated in certain ways to follow the routes and perspectives pre-decided by the architects. Therefore, their experience about the space will be more diverse and realistic in comparison with the pre-recorded 3D flythrough visualisation generated by CAD. It can empower non-professional stakeholders to give more feedback about the design to the architects.

#### 5.3.1.3. Multi-user Experience

Another advantage that *SL* has is its ability to create a multi-user experience for participants to interact in the built environment. This impressed most of the architects interviewed. Eighteen out of 20 architects said that they saw the biggest advantage of *SL* over previous design tools in its ability to allow multiple users to have group interactions in the design space. No other design tools can achieve this at this moment. Many architects interviewed argue that the actual use of the space is not only influenced by the interaction between individual end-user with the space, but also, the individual end-users with each other, and how the collective group interaction of the users affect the actual use of the space. "Some of the architectural designs seem to offer great solutions to projects before they are constructed. However, all kinds of design issues start to occur after a large number of end-users start to occupy the architecture and interact with each other in the built environment.… With most of the current visualisation tools, it is not easy to predict how the actual space will be used by groups of end-users", said Architect H. "The most exciting thing about *SL* is that, in the virtual environment, there is a real-world person who controls every avatar. The avatar can behave in the same way as if they are in the real world. If you could get hold of many of your end-users and ask them to do this multi-user interaction in *SL*, it will be very useful to engage them and get feedback for better early-stage design", said Architect I. Therefore, the architects interviewed argue that *SL* may fill this gap to help architects to find out more about group interaction based on actual use of the proposed design before it is put into practice.

#### 5.3.1.4. Evacuation Simulation

Many architects want to use *SL* as a tool for designing for emergency evacuation. All 20 architects identified the potential for *SL* to be used in all kinds of scenarios among end-users, especially for evacuation experiment. Many specialised evacuation tools have been developed to help the design for the space, for emergency evacuations especially in the event of fire, for example, STEPS and EXODUX, which were mentioned by Architect K during interviews. However, their simulation is based on computer-generated crowd movements. Groups of people are mostly represented as little dots on the computer screens. Different dots represent different types of stakeholders who are occupants in the built environment. Those stakeholders react and move around in the computer-simulated emergency situation. With these kinds of crowd evacuation simulations, architects can roughly know how the crowd will react and evacuate themselves in the given design space of the emergency. However, human behaviour is very complicated and unpredictable during an emergency. When people panic, their behaviour does not necessarily follow normal routines. Therefore, it puts the result of those computer-calculated simulations into doubt. This is where architects anticipate *SL* being useful. In *SL*, behind every avatar, there is a real person. To get a group of real people to test out a dangerous scenario with their avatars on the computers screens can help to get results that are more accurate for evacuation considerations in their architectural design. There is no concern about how accurately a computer can predict the complicated reaction each person may have in a panic situation, based on their individual personality. However, some architects are concerned whether participants will behave normally in the virtual environment of *SL*. To solve that issue, some architects get their design visualised in *SL* and then ask all participants to react to it as if it is in the real world. In this way, *SL* may offer a greater potential to understand real human behaviour over previous computer generated human interaction. However, architects have also raised some issues here. The quality of representation of *SL* is not high enough. Therefore, this poor rendering may affect the behaviour of users, as the space does not look as real as it could be. Also, the experience in *SL* is not yet that immersive, people can only see, hear, and touch. Unless architects set up some scripts beforehand that if avatars caught fire or are choked with smoke, they will die, the result from the simulation may not be accurate enough either. What is suggested by architects is that, in the near future, *SL* can be linked to Augmented Reality, where participants will have other sensors put on their body, such as heat sensors or smoke sensors. If users catch on fire, they will feel the heat, the pain, as well as the smoke, and have a truly immersive experience, then the result of the evacuation can be accurate.

## 5.3.2 Better Client/End-user Engagement

According to the interviews with 20 users of *SL* and 20 architects who are using MMOG to augment real-world architectural design in *SL*, *SL* is effective in engaging non-professional stakeholders in the design process. The following are the main reasons. Firstly, *SL* enabled non-professional stakeholders to experience the architectural design in a holistic, dynamic and immersive way. Secondly, with a holistic, dynamic and immersive experience, *SL* helps professional architects and non-professional stakeholders to fully understand the architectural design before it is constructed. Thirdly, the virtual architecture visualised for real-world construction projects in *SL* becomes useful in its own right. Those virtual architectures in *SL* have been used as a useful marketing tool promoting the products of the clients. Fourthly, most architectural activities in *SL* are not conducted by real-world architects, but average users who are non-professional stakeholders. These non-professional communities design and experiment with their own user-centred architecture in a grass-roots way, which may challenge and change the way traditional architectural design process.

### 5.3.2.1 Holistic, Dynamic, Immersive Design

From the interviews, it was found that *SL* enabled non-professional stakeholders to experience the design in a holistic way. The less detailed representation in *SL* makes it technically easier to accommodate a holistic design model. In comparison with traditional AEC industry visualisation tools, which require high-end computers for smooth production and operation, the less-detailed models created in *SL* require less computing power and resources. A normal standard home computer with good Internet access can ensure the smooth operation of *SL* without the fear that the program is too demanding and will crash the computer. Therefore, technically, it is much easier to create a complete model of the architectural design with less detail in *SL*, rather than create a model of highly accurate details, which only shows part of the design. For clients, who are non-professional stakeholders in the architectural design process, to see the holistic design visualised with fewer details is much easier to understand, rather than to see the highly detailed models that only reflect part of the design, leaving the clients struggling to imagine how the whole design looks in reality.

#### 5.3.2.2 Understanding the Architectural Proposal

With a holistic experience, *SL* can assist non-professional stakeholders to fully understand the architectural design before it is constructed. Therefore, many architects who are using *SL* for their real-world architectural projects argue that virtual-world modelling is found to be more effective than traditional CAD or BIM applications in sharing ideas with non-professional stakeholders such as clients and end-users.

In addition to this, and unlike most industry-standard design tools, *SL* was not developed to assist architects. Therefore, using *SL* for architectural design does not require users to have years of professional training and industry experience. This could help clients who are struggling to understand architectural design through AEC industry visualisations. However, there remains the issue of "engagement", for example, encouraging the clients to use software, which is probably unfamiliar to them.

It is reported by all 20 *SL* architects interviewed that they have experienced different levels of difficulty with current visualisation tools in fully demonstrating their design to clients. When all the current tools available fail to communicate architects' design ideas to clients, 18 of 20 architects interviewed have turned to *SL* visualisation for solutions. Two of them have only been in *SL* for less than half a year and have not found appropriate real-world architectural projects to try out *SL* visualisation yet, but both of them have stated that they will do so once appropriate projects becomes available in real-world architectural practice. After inviting clients to virtually inhabit the house, to freely explore the virtual space as much as they want, 16 of the architects interviewed in *SL* have received clients' feedback with clearer instruction of modifications and improvements to their design. Therefore, most architects interviewed argue that they have found *SL* visualisation have been effective to allow clients with no professional expertise to fully understand the design before construction.

For example, Architect D spent two years trying to win the project to design a million-dollar real-world shopping centre in Egypt, with designs using traditional architectural methods, such as paper-based 2D drawings and 3D Studio Max. However, the client of Architect D was not able to understand the design produced by industry-standard visualisation tools. As a result, Architect D met and discussed the design with the clients many times over two years but was still not able to convince the client to approve the design. After virtually inviting the client to join him in exploring the virtual model he created in *SL*, the client eventually understood his design and approved him for the million-dollar contract. "I built the space in 3D Studio Max and produced several renderings to show the client," recalled Architect D. However, the client still did not understand the design Architect D proposed and therefore had not approved the design project to be undertaken. Architect D said, "I came to realise that this client, like so many clients don't really understand architectural drawings". He "seemed to have difficulty understanding the space". However, the problem is that many clients do not always tell architects that they cannot see what an architect sees from a 2D drawing or a flythrough of the 3D CAD animation. If clients cannot see what an architect sees, they will just keep on requesting change in the design until they are satisfied, which may take a long time for the design to be agreed. With the design imperilled, Architect D and Architect A created the whole project in *SL* and showed it to the client. Using avatars, these architects and their client visited the shopping centre virtually. "We walked through into the building and he said to me and pointed at the screen, the distance is not right". Conversely, when satisfied, the client "pointed at the model and said this is what I like", said Architect D. With the immersive experience to actually feel the space with avatars, clients with no expertise of architectural design can fully understand the design proposed by architects, "see what the architect sees" as Architect D puts it, and therefore give accurate feedback to improve the design. With the success of using *SL* as a design tool to engage the client, within three days, Architect D was given the opportunity to design the shopping centre for the client in the real world. "The client was happy and we were on our way back to Cairo", said Architect D.

There are many similar examples mentioned by architects working in *SL* for real-world architectural projects. All the 20 architects interviewed in *SL* argue that, among the community of real-world architects working in *SL*, the most predominant use by real-world architects is to use *SL* models to engage non-professional stakeholders, especially the clients to help them fully understand the architect's design propose

#### 5.3.2.3 User-Generated Architectural Design

*SL* provides a more user-centred design environment for the AEC industry. Most architectural activities in *SL* are not conducted by real-world architects, but average users who are non-professional stakeholders. As an online social networking platform, *SL* is open to the public, rather than just only available to highly specialised professional experts in the AEC industry. The visualisation tools available in *SL* are also designed to make it as easy as possible for average users to pick up quickly without the need for years of professional computer program training. The access to easy design tools empowers non-professional stakeholders, who can have more control in the design process, and therefore can contribute actively, rather than passively depending on how much design information professional architects are willing to share with non-professional stakeholders. As a result, the non-professional stakeholders such as clients and end-users are empowered to explore the virtual design architects proposed in all possible details. Some of them start to design and experiment their own user-centred architecture in a bottom-up way, which may challenge traditional architectural design processes.

According to 20 users interviewed in *SL*, the majority of people who are building architecture in *SL* are not real-world architects, but people from non-architectural backgrounds. For example, at the *SL* Architecture Island, one of the most popular *SL* venues for real-world architectural design solutions, most active members there are people who are not real-world architects, but interested in architecture. "More and more clients come to my island and ask their architects to design their real-world architectural projects in *SL* so that clients themselves can walk around and feel the space before it is constructed," said Architect A, who is the owner of the *SL* Architecture Island. Fourteen out of 20 users interviewed in *SL* confessed that, with the easy visualisation tools in *SL*, they would like to design their own house in *SL* and turned to real-world architects to make it workable in reality. For example, User A said that, "in the past, if I want to design my own house, I will most likely turn to professional architects for help, telling him what I roughly want through showing him some pictures of the architecture style I like. Now, with the skills I have for visualisation in *SL*, I can build the virtual model myself. I do not like the 2D drawings architects normally showed to people. It is boring and difficult to understand. I could prefer to actualise my ideal house in 3D in *SL*, play with the idea till I am happy, and then come to the real-world architect to ask them to help me to transfer the design from *SL* into real life." The view from the users is widely echoed from the architects interviewed in *SL* as well. Most architects working in *SL* (14 out of 20) for real-world architectural projects reported that, the initial reason that drove them to turn to *SL* is mainly because their clients wanted them to. "I don't want to try *SL* at all initially", confessed Architect Q, "because I don't want my clients to know too much about the design details to ask me to work even harder to make them satisfied". However, many architects interviewed in *SL* argue that after Anshe Chung's success of virtual estate development captured the attention of the media globally in 2007 (*Business Week*, 2006), more and more non-professional stakeholders have demanded their architects to visualise their real-world projects in *SL* to be freely explored and improved by clients. Architect K mentioned that most of his business designing virtual-world architecture is at the request of clients who would like to see their own real-world design being explored and accessed by more users in the virtual environment. Many of his projects are commissioned by real-world universities who wanted to set up a virtual campus in *SL* to explore more education-related activities, such as teaching, learning and research.

Because of this, more and more architects entered *SL* to explore best use for real-world architectural solutions. Some of them used the virtual world as a selling point to attract more real-world and virtual-world clients, while other architects are working with other construction IT specialists to develop easier end-user engagement design tools in *SL*. For example, Architect A hired an IT specialist to design a community architectural design tool called WikiTree, to help generate grass-roots interest among average people to contribute as much as possible to the highly specialised architectural design process. WikiTree is an open-source architectural design tool, which has enabled public engagement with traditional architectural design processes (Chase et al., 2008). By using some specially scripted building primitives, any building design created by WikiTree can be shared with the whole public community. It allows both professional architects and non-professional clients and end-users to contribute to the same projects in a variety of ways. For example, it can be used to submit ideas to the design project in both 3D and 2D (2D web comments and votes of the design snapshots are automatically updated in *SL* to the 3D WikiTree). Both holistic and specific submissions of the design can be accepted. Virtual buildings created without these special primitives could be submitted to the WikiTree after adding the special scripts in the tree. In order to effectively engage end-users in the design project, public votes are used to decide the best designs. Many real-world and virtual-world based projects have been designed with the help of WikiTree, in which real-world architects lead the project with contributions coming from non-professional stakeholders in the AEC industry. This project proves that architect-led user-centred architecture design is plausible and effective.

Therefore, many architects believe that there is lots of potential in *SL,* because it can really allow end-users to actively participate in the design process. “Opportunities to involve non-professional stakeholders in the architectural design process are endless in SL”, said Architect T. 12 out of 20 architects interviewed in *SL* echoed what Architect T said. They believe that architects should not be required to work on their own to find a perfect design solution for clients and end-users. Instead, architects should use an easy tool such as *SL* to effectively engage non-professional stakeholders, such as clients and end-users in the design process. Ten out of 20 architects argue that many companies from other industries are already using *SL* to empower their consumers to become actively involved in the design of their products. For example, Starbucks, the café chain recently bought an idea store in *SL* (Kaplan and Haenlein, 2010), offering a site for people to contribute ideas about how the space of the café can be better designed to cater to the needs of the end-users. “I see there is no better way to engage clients rather than in *SL*”, argued many architects interviewed.

Clients have already requested architects’ firms to start using *SL* for real-world architectural design consultation. Three out of 20 architects mentioned the great success of Starwood (owners of the Westin, Sheraton, and W hotels chain) who created an Aloft-style hotel model in 2006. In general, *SL* is designed for average users from all kinds of backgrounds to use. Many modelling features in *SL* are easy for non-professionals such as clients and end-users to learn, understand and utilise. Therefore, it has the potential to empower non-specialists such as clients and end-users in the architectural design process.

### 5.3.3 Early-stage Design Collaboration

*SL* can enhance early-stage design collaboration. It can be achieved in several different areas. *SL* can be accessed globally to enhance the early-stage design collaboration. The virtual models generated by *SL* are not as computing-resource-consuming as those created by traditional industry standard CAD models are. Therefore, all the models can be put online and accessed globally with the Internet. Stakeholders do not need powerful computers to access *SL*. If stakeholders have a high-speed Internet access and a proper computer, they can assess the model anytime anywhere they want. An issue is also raised by most architects interviewed (12 out of 20). The very reason architects do not need powerful computer to access *SL* is because the model generated there is not detailed enough. That is also the reason it can be easily put online in comparison with many other 3D visualisation models. Many 3D models have very detailed representation of the design, therefore it takes a large amount of computing resource to render those detailed representation online. To make that happen, it requires every stakeholder involved in the project to have a very powerful computer to support those heavy models, or the central online servers most be powerful enough. For the time being, the capacity of online servers are still not yet advanced enough to support all the heavy models created by industry visualisation models with detailed representation. However, at early-stage design, the model of the design does not need to be too detailed. This made *SL* model a good tool for early-stage design collaboration.

One of the findings is increasing efficiency of cross-time-zone collaboration at early stage. According to 12 architects interviewed in *SL*, they have been involved in using *SL* for various international architectural projects. They have found this virtual world collaboration more effective in supporting the early-stage design. *SL* is an online platform. With the Internet, stakeholders from around the world can access *SL* to collaborate in architectural projects. Four out of 20 Architects mentioned that they used *SL* in international projects to enable architects, engineers, quantity surveyors from different countries to meet, discuss and change the design virtually together. Three out of 20 architects explored how to use *SL* to accelerate the design process.

For example, in one project, architects from three different countries, based in three different time zones in real world are using *SL* to collaborate on the same real world project for concept design. The way they work is unique, besides trying to meet a few hours a day to discuss the progress of the design, most of the time, all three groups of architects make up a team that are able to work on a 24 hours non-stop basis because of the three different time zones they are based in. In that sense, the efficiency of the whole project can be three times better than any of the three groups of architects to working on their own.

However, this situation may be too ideal in real world. The real-world architectural design process conducted by a team of international architects based in different countries is not always as smooth as it planned to be. Also, the project is still ongoing, and therefore it is difficult for all the architects involved to quantify the actual improved efficiency over previous collaboration methods and working patterns, but it has been confirmed at this stage that they have shortened the early-stage design process by two months. The quality of the design produced is well received by clients, because of the international collaboration through *SL*. Therefore, Architect L, one of the architects based in the American team said, *SL* is useful to international architectural projects because it "enhances the collaboration and experience from different parties from different part of the world". In that sense, using MMOG for international collaboration has the potential to improve early-stage design, and therefore enhance the efficiency of the whole project, but it still depends on how smoothly the whole collaboration goes. If problems occur, such as the loss of power, or the Internet, or the computer of any of the architects involved, the overall performance is affected.

Another advantage is that *SL* can transcend the boundary of cultural difference in international architectural collaboration. This also brings about a better understanding of design from different cultures at early stage. Additionally, virtual interaction and collaboration make it possible to overcome religious barriers, which cannot otherwise be solved in real world. For example, in some Muslim counties, women who want to work outside home must strictly follow Islamic laws. According to the Islamic laws, Islamic women should not be alone with men in the workplace. A woman should not work in a non-Muslim environment unless there is an extremely compelling reason for her to do so; the compelling reason mainly refers to financial needs for survival. *SL* transcends religious constrains and allow people from different religious belief to work together without challenging the current religious practice. Reported by two architects interviewed in *SL*, it is possible to use the virtual platform to transcend religious barriers for female Muslim architects to work with wider community while obeying their religious laws.

A further advantage enabled by *SL* design collaboration is on Cost Effectiveness. With the possibility to collaborate globally without incurring the travel cost for stakeholders to meet and work together physically, *SL* has the potential to provide a better interface to allow stakeholders who are geographically dispersed to collaborate better on the design. Some architects interviewed are using *SL* to test out more effective design collaboration among stakeholders based in different countries using avatars at early stage. In the past, international collaboration between architects can be "hectic" when they are not based in the same countries. This point was mentioned by seven out of 20 architects interviewed in *SL* who have real world experience collaborating on international architectural projects. In all the data collected, one prominent example is an ongoing project to use *SL* to co-ordinate a big regional development plan for the west region of Egypt for the Egyptian government, which involved architects from over three countries. With *SL,* instead of bringing all the architects based in three different countries physically together in the same country at early stage, architects collaborate in *SL* on a daily basis to design the project virtually in front of their own computer screens across three different time zones. For big projects like this, involving many stakeholders and big design teams, meeting physically to discuss and collaborate is expensive. According to Architect M, "it will cost 5% of the overall budget if we try to bring all the people together to work in one place as before". However, with *SL,* it is "easier to be able to discuss the vision together and identify our objectives, while the 5% travel cost can be used to reduce the cost of the whole project".

### 5.3.4 Summary

This part summarises three areas where architects consider *SL* have potential over current tools to be used at early stage. For example, the human interaction in *SL* is better because the use of avatar gives participant a greater sense of being in the space, the demonstration of the space is not pre-recorded but freely explored; the multiple-user experience is more realistic than the single user experience. *SL* also has advantages to be used to engage non-professional stakeholders in the design process, such as clients and end-users. The Internet based *SL* enables better international collaboration, which can be used to accelerate and improve the early-stage design, transcend cultural differences, reduce cost. Besides, it can be used as a powerful tool for specific applications such as emergency evacuation simulations.

## 5.4 Issues of Using *SL* for Real-world architecture

Despite all the advantages *SL* offers to help professional architects and non-professional stakeholders such as clients and end-users, there are various issues need to be addressed to allow effective use of *SL* to assist early stage architectural design.

- Various IT limitations of *SL* :
  - Access to the Internet
  - The computer hardware
  - The online servers
  - The low representation details
  - No real-world environments
  - Interoperability with other visualisation tools
  - Other MMOG

- The AEC Industry: Issue of Innovation
- Find the right project and client is not easy

- ❖ Non-professional stakeholders Engagement is a Challenge
- ❖ Time consuming to explore *SL* for architecture
- ❖ Lack of *SL* Architectural Education

Each of all these limitations is discussed in more details in the following sections.

## 5.4.1 IT Limitation of *SL*

### 5.4.1.1 Access to the Internet

*SL* requires a computer with three-dimensional graphics capability and a broadband Internet connection. However, according to the latest UN statistics, only 28.7% of the world population has access to the Internet (Internet World Stats, 2010). Therefore, online immersive interaction for the public is no more than a privilege for a small fraction of the world, which puts the validity of the interaction in *SL* into question. Besides, even in the developed world, the population of *SL* is not representative of the general population. *SL* users are ‘younger, more educated and more likely to be male than the general population’ (Yellowlees and Cook, 2006: 536). Therefore, architects who want to use *SL* to engage stakeholders at the early-stage design process through global collaboration, they must acknowledge and address this issue.

Also, the global collaboration enabled through the Internet sometimes can be a problem. Of the 30 interviews with architects, it occurs three times that Internet access required by *SL* becomes a barrier. In order to achieve ideal performance, it is recommended to use wired high-speed Internet connection for *SL*. However, this is not always easily available. In one case, architects only have wireless Internet connection at their office. *SL* cannot be connected with the wireless Internet connection because gaming platforms generally were blocked by the corporate firewall set up by that company. The architect interviewed had to go to their IT support to ask for inclusion of *SL* in their Internet firewall system before *SL* can be access with the company wireless Internet. In another case, *SL* can be accessed through wireless Internet access, but the performance of *SL* through Wireless network was pool. It took a long time for the whole virtual model to be rendered in front of the architects. Also, the movement of avatar in *SL* was not smooth at all. The third case, *SL* just cannot be started because the wireless Internet connection was too slow to run *SL*.

One suggestion came from architects interviewed is that *SL* should not rely too heavily on high-speed Internet connection, but with more flexible choice of access to models. For example, all three architects interviewed who experienced difficulty accessing *SL* suggested that it would be more convenient if *SL* allowed the virtual building model to be downloaded to the hard drive of their computer to be viewed and modified. Besides, six of 30 architects interviewed also echoed the need to have the flexibility on offline modification. The good thing about this off-line modification and interaction could give architects more flexibility, control and enhanced security of their own model.

Some architects were worried about the security issues of putting their business sensitive design models online. They were not sure how secure *SL* was to ensure commercially designed project would not be accessed to other organisations, especially their competitors. Twenty-one out of 30 architects asked the question on how they can control who can see the virtual model they put in *SL*. When they knew landowner could restrict the access to the virtual land and buildings to only invited visitors, they were still not sure about the security for an online platform, which was in the public domain. They argued that online data was more likely to be hijacked, that was even worse for *SL* which had been increasingly gaining media attention. Seven of 30 architects expressed their concern on the issue of Internet security. "All the virtual models built in *SL* are based on the public online servers. Those servers had once in the past being hijacked, which means the design information I put on *SL* may be revealed to a third organisation," said Architect M. Therefore, instead of having all the models based on the central online servers of *SL*, architects would prefer to have those virtual models being based on the hardware of their own computers. Besides security of information, flexibility to manage their own design off-line is also emphasised by many architects interviewed. “High speed Internet access is not always available, it will be really convenient if I can download the model to my computer and for example, modify it on my way taking the train to meet the clients”, said Architect K. If the off-line model becomes available, architects can view and change the model as much as they want. They can put the model online to share with the public or within their own regional network should a need rise. This is currently not available in *SL*.

However, *OpenSim*, an open source platform, enabled all the functions mentioned above, which is discussed in more details in Charter 5 in how architects using other MMOG platforms to augment their current design process. Some architects proposed the solutions to MMOG on its security issue is to choose MMOG which allows more flexible online and offline structure and put them at internal network of the organisation , rather than the Internet to avoid potential attacks from hackers.

#### 5.4.1.2 The Computer Hardware

In order to run *SL* smoothly, the computers of the users have to be geared for supporting online computer games, which normally requires high quality graphic cards. However, for the average user, without high quality graphic cards, occasionally *SL* will crash those computers. This has caused some problems for architects who have to work hard to ensure clients are not worried that *SL* could damage their computers. One UK architect sent a link to his client based in Canada for an online exploration of the design virtually in *SL*, but the hardware and graphics card of the client’s computer was not advanced enough. As a result, *SL* crashed the clients’ computer several times and the exploration was not able to run properly, until the client tried *SL* at the laptop of his younger son, a computer game fan whose laptop configuration is advanced enough for *SL*.

#### 5.4.1.3 The Online Server of SL

Everything created in the virtual world of *SL* is called an “asset”. This includes all the basic 3D geometry “PRIMS” (which can be used to create all other objects in *SL* with complex shapes), the 2D visual based “textures” (which also takes up the number of “PRIMS” but are used to decorate those 3D “PRIMS” based items) etc. Currently, the maximum size of one virtual island in *SL* is 65,536 $m^2$, supported by one online server with the capacity to accommodate 15,000 “PRIMS” there. Therefore, researchers need to carefully calculate the area of virtual land they need to purchase before starting the virtual construction to avoid unnecessary expenditure. For example, the replica of Farnsworth House takes about 800 “PRIMS”, including furniture, which requires 400 square metres of land (Rose, 2007: 23). Also, the biggest single “PRIMS” is limited to ten metres in all dimensions. Therefore, if architects want to construct models in *SL*, which are larger than 10 metres, they have to find or purchase specially designed “Mega-PRIMS” or else they may exceed the limit of number of “PRIMS” allowed on their land. This online server supports those “PRIMS” and for each island, it simulates everything on that island through calculating and transmitting image and sound data of objects and land to the client at 45 frames/second. If there are too many “PRIMS” or avatars on the same island simultaneously, the speed for the server to simulate everything on the island will be delayed. Most of the time, this delay is almost un-noticeable to users. However, sometimes, the users have to wait for a long time for all the objects, avatars and area around them to be simulated. If the number of “PRIMS” exceeded the capacity that the online server could simulate at the same time, the whole island sometimes crashed and all the users on the islands are forced to log out of *SL* until it is restored. This has been a problem for those architects interviewed. In another unsuccessful case, the architect invited too many end-users (more than eighty at the same time) to explore the community centre design based on his *SL* Island. The server supporting his island in *SL* reached its full capacity. As a result, the 200 square metres virtual community centre designed by the architect was rendered at an incredibly slow pace. It took more than 15 minutes for the whole virtual community centre to be displayed in front of all the participants. When a few more end-users tried to enter this island, they were not allowed to teleport to that Island by the *SL* system. The whole island crashed soon after one more end-user arrived at the community centre, and all eighty clients who were already there were forced to log out. When they tried to log in again, the number of participants has to be kept below seventy. However, most users still experienced a clear rendering delay.

#### 5.4.1.4 The Low Representation Details of *SL*

Due to the limitation of the online servers, the representation details of *SL* are also limited. In *SL,* objects are composed of two parts, primitives and texture. Primitives are basic shapes used to create the objects. They include all basic geometrical shapes, such as circle, sphere, square, cylinder etc. Texture is the representation of the materials used for the objects, which can be pasted onto the surface of primitives in a way similar to wallpaper, as oppose to actually what the materials is of the object. There are problems with primitives and textures in *SL* that impede the visualisation from allowing the high quality required for architectural design. The problem of *SL* is that "the primitives are very primitive" said Architect N, who has 24 years real-world architect experience "If you really want to get some high quality shadows, you cannot use primitives, you need more sculptured objects", said Architect V. In order to ensure the smooth running of the *SL* program, the maximum texture size is set with the limit of 1024x1024 pixels. Even if some textures may have a resolution as high as 2048x2048 pixels due to a previous limit that was higher, this is not detailed enough for high quality architectural rendering. Nevertheless, with that resolution, *SL* will require too much memory and take substantially longer to load. As a result, with the limitations of both primitives and texture in *SL,* real-world architects "can only go so far with the rendering quality. That is bottom-line", said Architect Z4. The resolution of *SL* rendering is not yet good enough to be used for real world construction plans. Although, with the help of professional design programs such as Photoshop, the quality of rendering produced by *SL* can be good enough to demonstrate the design to the clients, however, for the final construction rendering, *SL* is not good enough. According to Architect H, "the resolution of *SL* renderings on a laptop screen is one thing, but blown up to that scale is quite another. It remains to be seen whether this will have to be rebuilt in 3D Max in order to produce sufficient quality renderings. We're all a bit nervous about how that is going to turn out." As a result, most architects working in *SL* have to use traditional CAD model to produce the industrial standard drawings for their construction plan. For example, Architect Z1 said that "I enjoyed using *SL* to augment my real-world architectural design, but at some point, I still have to model my design in Revit so that you can represent things in a sharper way".

*SL* is not the exact representation of real-world architecture. The powerful construction tools in this digital universe enable the easy and vivid incarnation of architectural design. However, unlike the real world, there are no physical rules to follow. Architects do not need to consider the problems of physics, gravity, and weather in *SL* design. According to real-world architect Lester Clark, the owner of the virtual replica of Farnsworth House, 'I don't have to bleach the decks every couple of weeks, nor worry about the ventilation or flooding' (Rose, 2007:23). This poses difficulty in transforming virtual world designs into real-world architecture, and arouses doubts within the architectural industry on the value of virtual building design. Is it worthwhile to invest time and money in *SL,* if the virtual world designs cannot be applied to reality? This is one reason why the architectural experiments in *SL* are mainly conducted by individual architects, rather than big construction companies. As a possible solution, many architects are working on introducing CAD models into *SL* to counter this limitation.

#### 5.4.1.6 Interoperability with Other Architectural Visualisation Models

The interoperability between *SL* and other current design tools is a major issue for architects. Rather than create everything in *SL,* all the architects interviewed would prefer to import current standard 3D models or 2D drawings into *SL* and then get clients feedback. Architect B said that "the thing that interests me is not about constructing things in *SL* or MMOG, but bring them in to allow better end-users and clients' engagement after our designs have been constructed in traditional CAD models". Architect C echoed what Architect B said, "I prefer building a model in Revit and import it into *SL,* as opposed to actually building things in SL". The reason for that is discussed below.

It takes time to acquire building skills in *SL*. It is a big learning curve for architects to master the skills to design buildings in *SL*. "It is relatively complex to explain, too much information in a very short time. It takes a lot of time to understand it," said Architect I. To use *SL* and other MMOG for architectural design, architects have to register with *SL,* create an avatar, become familiar with the interface, learn all the building skills, scripts, communication functionality etc. There is also an equally steep learning curve for other stakeholders.

Architects prefer to import traditional models with higher quality rendering and intelligence, rather than create the less detailed and intelligent models in *SL*. In real world, there are many visualisation tools, most of which can produce high quality models that are mathematically correct, high-detail rendered to meet the need of architects. "All sorts of technology such as Laser scanning can make models in real environment with great accuracy," said Architect C. Many architects discussed software such as Google SketchUp, which offer a wide range of ready-made building components as well as furniture online for free. Architects do not want to replicate the same model again in *SL* if they can import a ready model from the online Google Warehouse. Also, architects want to keep the intelligence of traditional 3D models in *SL*. In these tools, "when architects draw a wall in 3D, the system knows it's a wall, a door knows it is a door, a chair is a chair. That is the way you construction your model and you don't want to lose that intelligence" said Architect Z2. Therefore, transferability of the high quality rendering and intelligence of traditional visualisation models to the virtual environment of *SL* is a key concern for many real-world architects. "There is no real port for you to import and export 3D information. The interoperability with industry standard 3D models are now what we absolutely need in virtual world in order to make it become truly effective tools", Architect P confirmed.

To meet the increasing need of architects for better interoperability with traditional visualisation tools, several IT companies or experts have developed various plug-ins to be used in the *SL* platform. With these plug-ins, *SL* can accommodate a very limited range of 3D model imports and export between *SL* models and standard industry 3D models. It is more often that architects prefer to import Models and drawings created in AEC industry into *SL*. Currently, 2D drawings created in most traditional visualisations tools can be imported directly in *SL*. With some special plug-in, some 3D models created in traditional AEC visualisation tools such as Google SketchUp can be imported into *SL*. This is the standard practice of real-world architects who are using *SL* to better engage clients in the design process. Also, there are several IT companies based in *SL*, which provide commercially developed IT plug-ins to enable models built in *SL* to be exported to traditional visualisation tools. However, it is not often that architects export the models they build in *SL* to external virtual environments. "Very few of us architects using *SL* will want to export models created here to real world. That is because the main purpose we use *SL* is to demonstrate our design to clients who normally cannot be easily engaged with real-world architectural tools, especially 2D drawings", explained real-world architect F. Besides Google SketchUp, there are still issues of *SL* on interoperability because *SL* does not support direct import of the models created by many traditional visualisation tools. "Sometimes, we have to build everything one "PRIM" at a time, and we end up recreating everything in SL", said Architect R, a real-world architect who has been in *SL* for just 6 months. "If we don't want to pay for the plug-in, and want to export the model built in *SL*, we have to build it again inside a 3D architectural application, that is not convenient," recalled Architect H.

Although some architects find it inconvenient that *SL* has these interoperability issues, most of them are confident about its potential. Many architects interviewed argue that *SL* was never intended to be an architectural design tool. Therefore, they argue that architects should not be frustrated that *SL* currently does not support direct import and export of AEC industry standard visualisation. "*SL* only happens to be found useful by architects. Therefore, we should not blame Linden Lab for not allowing direct import and export into AEC industry tools", argued by many architects interviewed. However, there is increasing demand in the *SL* community to ask for better interoperability with standardised models. "Although *SL* has not come that far, it is gradually becoming an expectation," said Architect T when talking about the interoperability issues. As a result, Linden Lab did respond to the increasing needs of the community on interoperability issue. At the *SL* Community Convention, the official annual event held by Linden Lab on the 16th August 2009, many architects were excited by the announcement of SL's plan to introduce 3D mesh imports to improve the interoperability issue of *SL* and other traditional AEC visualisation tools. Linden lab has been developing *SL* to support 3D Mesh imports since then. On 13th Oct 2010, *SL* has officially launched the *SL* viewer, which enabled Mesh imports, inviting any interested public community in *SL* to test the functionality and stability of Mesh imports and exports in some designated areas. This has greatly inspired many architects working in *SL*. "Sculpty came, *SL* survived. Mesh is coming. *SL* will thrive", said Architect G. Many other architects interviewed agreed with Architect G, they believed that, with Linden lab working on improving SL's interoperability with industry 3D models, the potential for architects and other industry designers for real world professional applications will be immense.

However, the ability to import and export other industry models is also a double-edged sword. *SL* does not support direct import and export of all AEC industry design models. It is a big concern for many architects. Although *SL* has officially announced that Mesh imports, a key IT element that will enhance better interoperability between *SL* and other AEC industry design models, was launched with the latest *SL* client installed at the computers of the users. However, it is not until the Mesh imports function is fully enabled, that the AEC industry will not start to widely adopt *SL*. Low interoperability with traditional CAD is also where opportunities are created for AEC professionals to better engage average users with no expertise of architecture in the design process. Architect R argued that "the way we build everything one "PRIM" at a time is what makes the collaboration possible. For people don't own a 3000 dollar professional architectural application, they can use the simple tool in *SL* to collaborate with us architects". However, most architects interviewed still want better interoperability with other AEC design tools so that architects and other professionals can import models made from all AEC industry visualisation tools. With the test of the Mesh imports and exports going on in *SL* at this moment, architects and non-professional stakeholders in the design process will have more options about how they want to use *SL* to augment their current RIBA plan of work.

Despite all the debate and development on the interoperability issue of *SL,* architects are working hard to make *SL* models viable in real-world architectural design. Architects have been using *SL* to evaluate various architectural parameters to make the *SL* model viable in real life. For example, they have used *SL* to test the space, materials, interior design, natural light, ventilation, noise, cost etc to help make their virtual building transferable to real world. *SL* provides some of the measurements. For example, the latest viewer enables the dynamic shadowing of the virtual buildings, which many of architects interviewed, found useful. "I used the new shadow function to test the lighting of my design to see how the natural light affect different parts of my design at different time of the day", said Architect D. Individual IT specialists have developed other real-world architectural measurements. Architect A developed tools to transfer *SL* Architectural Design into Real world to help design decisions. For example, they created a special script to be attached to their virtual model, which can automatically calculate the energy consumption of the design based on the change of the space. Another script was developed to help the quantity surveyor to estimate the actual cost of the design. Other special software were created and added to the virtual models in *SL* to help different stakeholders to perform their real world tasks in a collaborative way. In another project, an *SL* model was developed to simulate a real world shopping centre in Egypt, Architect D used *SL* to incorporate the souks (it is a commercial quarter in an Arab or Berber city) element- a unique characteristic of Middle Eastern open markets into the design of the shopping complex. "This narrowed shopping streets with the visual simulation of product displays made for a much more interesting experience", said Architect D. With *SL* being able to measure all the real-world architectural measurements to meet the standard of real architect design, many architects interviewed (12 out of 20) are confident that with professional IT support, it is possible to produce designs in the virtual world which could become viable in real-world architectural designs.

#### 5.4.1.7 Other MMOG

Many of the IT issues of *SL* are not necessary representative of other MMOG. Some of the other MMOG may not have the same problems as *SL*. For example, *OpenSim* uses entirely different mechanisms for its online servers, which allow architects to save the virtual buildings on their own computers hard drive. Architects can put their virtual building onto the Internet to be shared globally if they want to use it to engage other stakeholders in the design process. Otherwise, it can remain in their own computers. *OpenSim* does not entirely rely on the central online server provided by the MMOG developers. There is no limit of the number of "PRIMS" or the size of "PRIMS" allowed on *OpenSim*. The decentralised IT structure of *OpenSim* can support more than eighty people to interact simultaneously on the same area without the online servers crashing due to overload of information flow. Therefore, researchers who are interested in future work exploring how MMOG can be used in conjunction with other visualisation tools to augment the current RIBA stages should not only look at *SL*, but also explore other platforms of MMOG, to find the most effective MMOG for RIBA architectural design stages.

### 5.4.2 The AEC Industry: Issue of Innovation

The majority of architects interviewed in real world and virtual world, argue that the AEC industry is not driven by innovation and technology, but tradition and regulations.

The construction industry is not like the IT industry where people are enthusiastic about new technology. It is also highly regulated. Arguably, these regulations actually restrict the development of the industry. Architect Z5, one of the most experience architects interviewed in real world, with experience of working in over 20 different countries said that, "if you go to different parts of the world, and look at different buildings, and you know the regulations of that country or region. You will then understand why the buildings in those places are so different. It is the regulations that control what the built environment actually is like". However, sometimes, some of the regulations are out of date. However, architects still have to design buildings following those out-dated rules.

Because of all the regulations, there is not that much innovation in the industry. It often takes the whole industry a longer time to adopt the latest technology. According to the interviewees, the industrial wide application of the CAD model also takes a long time. When CAD was firstly introduced, there has been argument that it will never take the place of 2D drawings by pen. Architect W said, "I remember when I was in architecture school, everyone was sketching with pen and papers. There was huge debate about whether computers could be allowed to be part of the architectural process; it will never become a part of the professional architectural practice". Many architects using *SL* as part of their design argue that the same happened to the virtual world. Architect F said, "People are reluctant to use it, and I will say it will be at least five years before lots of architects are practising it". Because of the highly regulated nature of the AEC industry, the adoption of new design tools such as *SL* takes time.

### 5.4.3 Difficult to Find the Right Projects and Clients

Due to the highly regulated nature of the AEC industry, it is not always easy to find the right projects and right clients who are supportive of architects using *SL* for real-world architectural projects. According to the results from *SL* interviews, clients of big projects, which need to engage many end-users, are more likely to try *SL* for real-world architectural projects. It is rare to see real-world architects using *SL* for single small real world residential housing, because of the time and cost incurred. There are several cases when *SL* prototypes have been built for real world hospitals, hotels, university, group residential housing where the needs of a large number of end-users are considered. For example, the success of the Reflection Project is partly because the client is an adventurous billionaire who is always energetic to try something new. According to Architect D, his client "has built a ceramics empire selling products all over the world, flies his own Gulf stream jet, works two cell phones at the same time, one for each ear, never seems to lack for energy, and loves the idea of pioneering in the virtual world".

For all the real-world architects interviewed who are working in *SL* on real-world architectural applications, they have to get the approval from their clients before they progress any further to produce the model in *SL*. As a result, for clients who are too busy to get involved in the design process or not IT savvy at all, it is difficult for real-world architects to move any further in *SL* for real architectural solutions. *SL* Architect G said that, "it took some time to work up the nerve to actually try it and to find a client willing to go along for the ride". Most of the architects interviewed in *SL* have to wait for a long time for real world projects or design challenges that truly justified using *SL* as opposed to other 3D modelling programs, such as 3D Studio Max, which they normally use.

### 5.4.4 Non-professional Stakeholders' Engagement

It is not easy to effectively engage non-professional stakeholders at the early-stage design. Architects want to ensure they can effectively engage end-users and clients, while they do not want to give up too much control to non-professional stakeholders in the design process, who are increasingly empowered by new IT such as *SL* to better understand the design process and therefore demand more.

Architects need to think of ways to attract enough visits to their virtual architecture for public consultation. For one thing, using *SL* within the architectural design process does not guarantee active feedback from all its 20 million users. *SL* is a "boom-town and a ghost-town" in one. *SL* declares itself as a virtual world with over 20 million registered users, but there are rarely more than 90,000 people 'in world' at any one time. According to the research conducted by Elin Paajarvi, a student in LOL Architects, huge numbers of registered users never return to *SL*. The reason for that is because it is easy and free to become a resident in *SL*, but it is impossible to unregister one's account (Ring, 2007). Despite some popular locations, *SL* is mainly a lonely world, with few people "hanging around" while about 2 million dead bodies of the avatars taking up actual space in (Ring, 2007). Therefore if architects plan to use *SL* to engage the widest population in their community project, it is not possible to have all 90,000 *SL* users to all visit it and interact with each other at the same time. For another, residents in *SL* can simply "teleport" to wherever they want. It seems as if "there is no need for streets, paths, motorways, signposts, tunnels, and transportation such as trains, cars, air planes or any of the things that order the real-world landscape" (Rose, 2007: 23).

Besides, architects are not sure how many end-users can actually commit to the training and test time of *SL* group interaction. Five out of 20 architects mentioned that, if they want the best performance of the *SL* interaction, they have to spend time to train their clients or end-users to be proficient enough to use *SL*, or else, the interaction within the space may not work. If they want to train their client and end-users, it may be difficult to ask them to commit lots of time to for the training and experiment. For architects who are involved in a variety of construction projects, how to design a possible visiting route and attract enough feedback on their design becomes a challenge.

Besides issues on ineffective engagement of end-users, architects interviewed in *SL* reveal that the slow adoption of *SL* in the AEC industry is also because some architects do not want to give up control in the architectural design process. They find it difficult to cope with the trend that their clients and end-users can have more control in the design process empowered by new IT such as *SL*. Architects are used to the design process where they have complete control over what the clients can see and what the clients cannot see with other visualisation tools. Because of that, the visualisation created by other design tool normally only shows part of the whole design. All 20 architects interviewed echo this point. Nine out of 20 architects argue that in traditional ways, only 30% of the design is shown to clients. With *SL* models, clients can walk around the entire design 24 hours a day. Architects have to work very hard to make the complete design well defined. This is mainly because when clients are allowed to see everything, they will raise more issues for architects to address for the design. "I don't want my clients to know every single detail of my design; I only want to show them the good part of my design, not the part that I am not confident about. Or else, they will demand that you to work harder and make it perfect for every little bit of the design. To make your clients satisfied with the least design work is what most architects would like to do", said Architect O. Architect H echoed the opinion of Architect O, "*SL* enables clients to have full access to the design. Now, everything has to be of high standard or else your clients will never be happy". This is what concerns some architects because they have to work far harder to ensure the other 70% usually non-viewable elements are also of a high standard in order that the clients will approve them.

Therefore, not all architects interviewed are willing to enable non-professionals, such as clients and end-users to have full access of the design they visualised in *SL*. Most architects interviewed (16 out of 20) would like to have full control on what they allow clients and end-users to see in the *SL* model as they normally have in traditional 3D flythrough. As a result, the freedom enabled by *SL* to allow non-professional clients and end-users to walk around without restrictions is not always easily available, depending on how much power architects are willing to share with the clients and end-users.

Many architects interviewed in *SL* (12 out of 20) believe that in *SL*, there is a pressure that forces architects to design architecture in its entirety. However, at the same time, ten architects interviewed in *SL* also agree that this holistic and decentralised design approach will in the long-term enhance the industrial practice of architecture. They argue that this is mainly because enabling clients and other non-professional people to fully understand the design in its entirety before it is constructed helps to bridge the communication gap between professionals and non-professionals in the architectural design process. Therefore, it helps to improve the quality of the whole design process. They summarised that some architects may not feel comfortable giving up too much control initially, to allow non-professionals such as the clients or end-users to thoroughly understand the design. In the long run, architects will all be required to communicate their design to non-professional stakeholders in its own entirety and allow all stakeholders, especially non-professional stakeholders to understand and contribute as much as they can. This holistic and collaborative design process will greatly improve the efficiency and quality of the design process.

Clients and end-users are not always given full access to the virtual building designed in *SL*. Some of them therefore start to explore opportunity to generate their own virtual design in *SL*. This user-generated architecture in *SL* and other MMOG can become another challenge to real-world architects. This is mainly because with no professional training of architecture, non-professional stakeholders such as clients and end-users can use *SL* and other MMOG to build whatever house they want in 3D and improve it till they are satisfied. Because of this, average clients and end-users may no longer need (or need less support from) professionally trained architects to help them to design their projects in the near future. This client-driven architectural design may undermine the top-down role of traditional architects. This worries the architects interviewed. Eight out of 30 architects interviewed argued that everyone who can build in *SL* and MMOG are becoming their own architect. At the *SL* event “Architectural Design and International Collaboration in Virtual Worlds” held by the American State School, a question was asked to the panel of four leading experts in *SL* architecture “Will real-world architects start to lose work because people are beginning to build building in *SL* themselves? Many of the architects interviewed argue that this clients/user driven bottom up design process has the potential to bring about a huge change for the professional architects, and that this is the main reason architects are not willing to see it happen (supported by 18 out of 30 architects interviewed).

However, the possible change brought about by clients/end-users driven design process is not only about architects having to give up more control to clients/end-users. Some architects are not so worried about the change and its potential impact on the industry. Thirteen out of 30 architects interviewed remained confident about their practice. They argued that clients and end-users might still need to turn to architects requesting help to make their *SL* or MMOG design buildable in reality. This change will instead create new opportunities for an IT savvy architecture firm to flourish. Other architects (11 out of 30) believed that this will result in more outsourcing from the USA, EU to other parts of the world because currently the majority of users of *SL* and MMOG are from USA and EU. Therefore, many architects interviewed argue that if this is to happen, architects should take their initiatives to learn *SL* and MMOG to keep competitive in the market.

In summary, the architects interviewed, are not sure how long it will take for mainstream architects to accept this client driven architectural design practice. But many of them believe that architects are the last people who will drive this bottom-up approach, instead, clients will. According to architect Z3, the AEC industry will not start to use *SL* or MMOG until the clients demand for it and are willing to pay for it. If they lose clients and lose business because their main competitors are using *SL* and they are not, they will start to use it. Similar views were expressed by several architects involved in *SL,* "if the clients want innovation such as *SL* they will get it, because that is what architects are paid for". In general, slightly more than half of the architects interviewed (16 out of 30) believe that the bottom-up clients centred approach enabled by *SL* and MMOG will enrich the architectural profession through involving more input from the traditionally less engaged stakeholders. Therefore, it could strengthen the roles of the architects as the leader of the construction project, but the time frame for this to happen, no one is yet sure about it.

### 5.4.5 Time-Consuming to Explore *SL* for Architecture

As an emerging technology, it takes time to persuade architects and architecture academia to join and play an active part in *SL* to explore its potential for early-stage design. Some university members are sceptical of the digital world's value. They think *SL* is merely a game- for fun, for children, for cybersex or gambling - it cannot be used for serious matters such as for architectural development. Traditionally, games are labelled as unproductive (Huizinga, 1955) entertainment for kids (Pearce, 2006), and saddled with negative images. Although real-world architects interviewed in *SL* (16 out of 20) believe that the numbers of real-world architects and AEC industry professionals entering *SL* is "accelerating at an alarming rate", many architects eventually give up their exploration in *SL* for various reasons. One reason is that it takes them too long to find the best use of *SL* to augment their real world design process. Some architects interviewed in *SL* argue that, for people who used 3D CAD, learning *SL* for architectural design is not a deep learning curve. However, as it is new, there are not enough reference materials produced to guide architects to best deploy it in the architectural design process. As a result, it is frustratingly time consuming and easily dismissed.

### 5.4.6 Lack of *SL* Architectural Education

Besides the highly regulated nature of the AEC industry, there are also other barriers, which stop architects from trying new design IT tools such as *SL*. This includes a lack of education for relevant tools for architectural students. As early as 2005, only a few universities in the US, Australia, Sweden pilot the use of *SL* for architectural learning and teaching. But now, more and more universities around the world start to explore the use of *SL* to train architectural students to design, including University of Auckland in New Zealand, Newcastle University, RMIT, Sydney University in Australia, Montana University, MIT, Stanford University, Harvard University in the USA, Royal Institute of Technology in Sweden, Ain Shams University in Egypt and etc.

However, it is often one professor of architecture, who becomes interested in using *SL* for architectural education. Most of their colleagues do not always get involved in this innovative approach of teaching. Academics who start to use *SL* and other MMOG for architectural teaching and learning often consider MMOG as promising as those traditional architectural tools taught in the curriculum. For example, Architect H (see Appendix Two) interviewed, who is a professor of architecture at university said that, "our students have been using physical models, sketches, 3D Max in the past, and students are now learning how to build in *SL* and other MMOG. It proves to be easier, cheaper and most importantly participatory". Eleven out of 30 architects interviewed suggest argue that more and more architectural professors are beginning to use *SL* and other MMOG for architectural teaching and learning. However, it is not yet adopted by their architectural schools yet. There is still limited number of architectural Schools in the world, which are teaching students to using MMOG for real-world architectural design.

This is because, *SL* is still new and not many architectural Schools are picking it up into their curriculum. There has been lots of debate about the educational value on *SL* in the past few years and some negative issues about violence and adult content in *SL*. This has put off many academics at architectural Schools from exploring the educational and research opportunities in *SL*. Also, *SL* is not a platform dedicated for architectural education, therefore, architects interviewed argue that some academics specialised in architecture are waiting for the platform to become more architecture design friendly before they want to spend time educating their students using it. "It is still in its infancy for architectural education and there are many challenges for using *SL* to teach students for architecture", said architect R (see Appendix Eleven).

One of the challenges is that many people associate MMOG with computer games, entertainment and leisure, rather than serious business and professional tools. Architect F (see Appendix Eleven) said, "I try to avoid using the word 'computer games' to describe all the work I have done in *SL*, because I am doing them for serious professional business, not for fun". However, 14 out of 20 architects suggested that *SL* would be adopted by the AEC industry as a gimmick, rather than a serious tool. For example, Architect Q, an expert in Construction IT said that, "Years ago when I was working in a company, the guy got a palm computer, this is about 1992. He took it to the meeting. Everyone was fascinated with his computer. Whether it added to anything to the process, I am not sure, but it is a gimmick, it got people to talk what he was doing and get people interested in what he was doing. New technology is used as gimmick, there is nothing wrong with that. People will adopt the technology as a gimmick, not as a serious tool".

Therefore, as raised by many architects interviewed, unless more and more architectural Schools around the world begin to engage in virtual world and understand how the virtual world could affect the future architecture training, the whole AEC industry will not quickly accept MMOG platforms despite all its potential.

### 5.4.7 Summary

Although more and more architects are exploring the potential of *SL* and MMOG to augment their real-world architectural design process, there are issues need to be dealt with. *SL* is developed to engage users from all backgrounds, rather to be used by architects for architectural design. Therefore, there are various IT limitations architects need to address in *SL* for architectural designs. These limitations include access to the Internet, the computer hardware, the online server, the low representation details, no real-world environments, interoperability with other visualisation tools. Also, there are other issues architects need to be aware of, such as industry uptake issue of innovative IT platform such as SL; how to find appropriate projects and clients to use *SL,* challenges to engage non-professional stakeholders in *SL,* the time it takes to explore best architectural application in *SL,* as well as the issue on the lack of *SL* architectural education in universities.

## 5.5 Summary of the Chapter

This chapter examines all of the architectural activities conducted by real-world architects and the *SL* community who assist real-world architectural projects.

In a user-generated 3D virtual world, the design tools provided by *SL* have been found useful at early-stage design. The reasons are because *SL* is a simple design tool, it enables quick architectural design, it is especially useful to use *SL* at RIBA stages C and D.

*SL* is considered to have potential over current tools to be used at early stage. For example, the human interaction in *SL* is better than other current tools because the use of avatar gives participant a greater sense of being in the space, the interaction between occupants in the virtual space can be freely explored, the multiple-user experience in the virtual environment is more realistic than the single user experience. Also, it is more effective to use *SL* to engage non-professional stakeholders in the design process, such as clients and end-users. *SL* is based on the Internet, which enables better international collaboration. It can be used to accelerate the process of early-stage design, improve the efficiency and quality of the design, transcend cultural differences, and reduce the cost of the project. Besides, it can be used as a powerful tool for specific applications such as emergency evacuation simulations.

Despite all the advantages *SL* have to augment current early-stage design, *SL* is a general social networking platform, developed to engage users from all backgrounds, rather than to be used by architects for architectural design. Therefore, there are various IT limitations need to be addressed before *SL* can become more useful for architectural designs. These limitations include the issue of Internet access, the resource-consuming computer hardware, the online server, the low representation details of the models, no real-world environments, and interoperability with other visualisation tools. Also, there are other issues, such as the industry uptake of innovative IT platform such as SL; how to find appropriate project and client to use *SL*, challenges to engage non-professional stakeholders in *SL*, the time it takes to explore best architectural application in *SL*, as well as the issue on the lack of *SL* architectural education in universities.

This section shows that *SL* is suitable for early-stage design (Research Objective Three of this thesis), if its negative features can be overcome. This chapter therefore answers research questions Q3 and Q4. Due to the various limitations *SL* currently has, it can complement other tools to better inform building design if its limitations can be addressed. This discussion helps to answer research question Q4 “How can MMOG such as *Second Life* be used to better inform building design?” The answer to that question is that MMOG such as *Second Life* can be used to better inform building design if it is used at an early stage in projects where an accurate simulation of massive end-user interaction within the virtual space decides the success of the design.

# Chapter 6

# 6.0 The Virtual School Test

In this chapter, a virtual model mimicking the real-world School of Civil and Building Engineering, Loughborough University was created in *SL* as an example to test how realistic the virtual environment and the human interaction in MMOG is for early-stage design.

## 6.1 Rationale for Model Choice

The findings from Chapters 2, 4 and 5 show that MMOG have potential in augmenting early-stage design. This is mainly because its feature of simulating real-world human interaction and the virtual environment. However, the comparative realism of the virtual environment and virtual human interaction between its occupants is having a big impact on how useful MMOG are at early-stage design. Therefore, it is important to find a real-world construction project to test this feature of MMOG to validate its value. The School of Civil and Building Engineering, Loughborough University was chosen as the model to test how a realistic and accurate MMOG model could be used as a tool in the RIBA design stages. Choosing this School as a model can help to achieve Research Objective 4, "To test the effectiveness of MMOG in simulating real-world environments". The reasons for choosing this building are as follows. Firstly, the researcher has easy access to all design information for this building, which can be used to replicate the model in *SL* in accurate detail. At the time of this research, there were no other architectural design projects available on campus that the researcher had easy access to the design information and plan of work to be used to test how MMOG can be used to augment early-stage design. Secondly, most of the end-users of the School are known to the researcher, which makes it easier to engage end-users in the testing of the virtual model. Also, most of the end-users in the School have professional experience or in-depth knowledge about the AEC industry and the RIBA design process. Therefore, the data collected from involving them in the test could potentially reflect the views of AEC professionals on the architectural potential of MMOG. Thirdly, most professional stakeholders involved in the design and construction of the School are still in touch with the School. Therefore, the researcher can easily involve professional stakeholders of this School project, and seek professional feedback on the potential of MMOG to augment the architectural design process at the early stages. Due to the above-mentioned reasons, the School of Civil and Building Engineering of Loughborough University was chosen as the model to test the usability of MMOG to augment RIBA design plan of work at RIBA Stage L: Post-occupancy. How realistically the virtual representation of the building can mimic the real-world equivalent and the resulting human interaction in the virtual environment can still be used to assist early-stage design process.

**Figure 6.1. Screen Shots of Virtual School within *SL***

## 6.2 Data Collection and Analysis

To ensure the model can help to achieve Research Objective 4, "To test the effectiveness of MMOG in simulating real-world environments", the data collection includes five phases:

- To create the virtual model in *SL*.
- Presentations about the virtual School.
- Re-configuration test of the virtual School.
- Interviews of participants.
- Interview professional stakeholders who re-designed the School.

Based on the research methodology discussed in Chapter 3, a questionnaire was developed to elicit information from both professional stakeholders (who were involved in the redesign of the School) and end-users (who inhabit and use the hub on a daily basis), to test Research Question Q3, "Can MMOG complement existing visualisation techniques" and Research Question Q4, "How can MMOG such as *Second Life* be used to better inform building design". Based on the results analysed in Chapter 4 and 5, the questions designed to answer Research Questions Q3 and Q4 are structured around how realistic the model created in *SL* is and how the human interaction in the virtual environment of *SL* is.

To find out "Is the model created in MMOG realistic enough to better engage different stakeholders at the early-stage design process", the following questions are included in the questionnaire:

1. Can you recognise which real-world building this virtual model represents? If so, name it.
2. How realistic is the virtual representation?
3. How are the representation details of this model in comparison with models

generated through other forms of visualisation tools?

4. Have you identified any issues or advantages of using MMOG models to represent real-world architectural design?

To find out “Is the interaction in the virtual space sufficiently realistic to be used to mimic real-world group interaction in early-stage design”, the following questions are included in the questionnaire:

5. What is your impression about using an avatar to experience the space in the virtual architecture created in MMOG?
6. How far do you consider *Second Life* human interaction as real-time human interaction?
7. How far do you consider *Second Life* human interaction as real-life human interaction?
8. How far do you consider *Second Life* human interaction as truly immersive human interaction’?
9. Can the social interaction formed in a virtual building have any influence on people’s use of the real-world building? If so, in a positive way or in a negative way? If not, why?
10. Do you think *Second Life* provides better human interaction than other visualisation tools used to be used at early-stage design?
11. Do you think MMOG have the potential to support architectural design?

Also, to give participants an opportunity to comment on these two research questions Q3 and Q4, the following question is also included in the questionnaire:

12. Do you have any other comment?

Concerning the potential of MMOG as a complementary technique for visualisation and its potential to be used to better information early-stage design, two pilot interviews were conducted with the first end-user who was willing to participate in the research and the first professional stakeholder who participated in the re-design of the School. Feedback gained from those two pilot interviews was used to revise and improve the questions to ensure appropriate questions are asked during the interviews. The final version of this questionnaires included in Appendix Eight.

All of the end-users in the School, which includes one hundred and 20 PhD students, 30 postdoctoral researchers and 60 academics, were contacted by School group email to see if they were willing to participate in the study. A total of 210 end-users were approached and 42 end-users (the response target) agreed to take part in this research. The 42 end-users of the School include 24 PhD students, 15 researchers and three academics working in the hub. All these 42 end-users were allowed to choose to participate in either the presentation in Section 6.2.2 or the reconfiguration in the virtual hub as in Section 6.2.3. Six out of seven professional stakeholders who were involved in the re-development of the hub were also interviewed using the same questionnaire.

The reason for choosing 48 participants is mainly due to sample size considerations. All the interviews were transcribed and analysed after the data was collected. When 48 interviews had been analysed, no new themes or findings were discovered. The data had reached saturation. As a result, 48 interviews in the hub was an adequate sample size to ensure that rich information was elicited to achieve Research Objective 3, “To test the effectiveness of MMOG in simulating real-world environments”. All of them have been interviewed face-to-face, recorded and transcribed into Word documents for template analysis. The interviews lasted from one hour to one and a half hours. In the first 20 minutes, the virtual model of the School of Civil and Building Engineering School and various features of MMOG in augmenting early-stage design were shown to practicing architects. Then, all the participants were interviewed for the questions according to the questions designed in the questionnaire.

### 6.2.1 The Design and Development of the Virtual Model

To develop the virtual model, a 2D drawing of the actual real-world School design was obtained from the client organisation. 400 photographs of the real-world School, including details of the furniture, room distribution, rooming and other design related information were taken from various perspectives. In addition, using this design, simulations of the real building were prepared using “PRIM” (*SL* Primitives) in order to fully understand the functionality and capability of the “PRIM”, a thorough study of them was conducted via online tutorials.

The development of the virtual School reflected the purpose of the test. For example, more detailed representations were created for places and venues in the virtual School where most human interaction takes place on a daily basis. In the real world, most social interaction in the School takes place in the hub on the first floor, where most of the PhD students and postdoctoral researchers work. Therefore, the representation of this part of the School is very detailed. All the furniture, plants, buildings of this part have been given many details to mimic the real-world School. It is the same with the main entrance and the back door of the School where very detailed representations are created to ensure users find it realistic. Also, to ensure participants recognise and identify the virtual School immediately, the overview of the virtual model is also detailed.

After the completion of the virtual model in *SL*, three steps were taken to develop this test. This is shown in Table 6.1. Firstly, six pilot interviews were conducted with two end-users, two visitors, two design-team members of the School hub to ensure quality questions were asked in the questionnaire. Secondly, six out of seven professional stakeholders who designed the hub of the School were interviewed to gain feedback about using MMOG from the perspectives of the professional stakeholders. Finally, various initiatives were used to engage and elicit feedback from the end-users and visitors of the hub in the School to explore the value of MMOG from the perspectives of the non-professional stakeholders.

**Table 6.1 The Design and Development of the Virtual Model**

| **The Design and Development of the Virtual World** | |
|---|---|
| **Step One** | Pilots of the study |
| **Step Two** | Design Team |
| **Step Three** | End-users, Visitors |

## 6.2.2 Presentations about the Virtual School

Step One: open invitation to researchers and PhD students (occupants), academics (visitors) and design team (professional stakeholders) were sent out, with pilot interviews conducted first to ensure quality questions of the questionnaire. The participation was on a voluntary basis. Step Two: two presentations were given to engage stakeholders in the School. Table 6.2 gives a breakdown of the total number of participants (19) who attended the presentation of MMOG. Of all the 19 participants, 16 of them only watched the virtual interaction as part of the presentation. Three of them created their avatars and took a virtual tour around the School in *SL*.

In order to attract enough participants from the School to participate in the test, the researcher did two presentations promoting the study on the virtual School in *SL*: one real-world presentation, the other a virtual-world presentation. The first presentation was conducted in a real-world lecture theatre in the School, giving all the participants a holistic view on MMOG's application on architectural research. The second presentation was conducted virtually in *SL*. Three real-world PhD students (including the researcher) created their individual avatars in *SL* and visited the virtual School. Their avatars were shown around the virtual School. Then, the three avatars met the avatar of another PhD student who participated in the test from home. In the virtual room mimicking the real-world School seminar room nicknamed "Fire Engine"; these four PhD students participated in a virtual seminar on MMOG Architectural Research and Anti-terrorism. Meanwhile, all the virtual interaction was shown on the big screen at the "Fire Engine" School seminar room to three academics (visitors of the hub), seven PhD students and six researchers who are end-users of the School.

Table 6.2 outlines the different types of participants who attended MMOG presentation. The selection criteria of the participants are: they are end-users of the School; their research interest is about the built environment so that they are more likely to become participants for the follow-up tests of MMOG in the virtual School.

**Table 6.2 Participants who Attended MMOG Presentation**

| **Participants who Attended Presentation of MMOG's Architectural Potential** | | | |
|---|---|---|---|
| **Participants** | **Academics** | **Researchers** | **PhD students** |
| 19 | 3 | 6 | 10 |

### 6.2.3 Re-configuration Test of the Virtual School

Step Three: participants accessed the reconfigured model virtually. They used their avatars to navigate around the model to see the reconfiguration. They also gave feedback on the proposed changes in real time.

To elicit valid information about how realistic the virtual environment and the virtual human interaction are in MMOG, a well-structured test to enhance the better use of the real-world School is needed. During Christmas 2009, there was a re-configuration planned for the space of the School hub to accommodate the increasing number of research associates and the inefficient use of the free desks for PhD students. This need to re-configure the current space created an opportunity to achieve the goal of the test needed in this research.

Therefore, before Christmas, a re-configuration of the space was demonstrated in the virtual School to inform end-users about the potential changes to the space and seek feedback from them. Twenty-three PhD students and research associates, who were actually working in the School on a daily basis, participated in the virtual reconfiguration. Twenty-one participants used their working laptop at the School of Loughborough University. Two of them took part in the re-configuration remotely, one PhD student accessed the virtual School at home in Leicester, and the other one participated in Italy. After a one-hour tour and re-configuration of the virtual hub, ten participants did a focus group interview to give more feedback about their virtual experience in the re-configuration. All remaining participants were interviewed individually after the re-configuration. Table 6.3 outlines the different types of participants who attended the reconfiguration of the virtual School.

The selection criteria of the participants are: they are end-users of the School; their research interest is about the built environment so that they understand the issue of architectural design. It was planned for the sample size to be the same for the two studies mentioned in 6.2.2 and 6.2.3. Due to non-attendance at both events, the sample sizes were different. However, they were both large enough for the purpose of the studies.

**Table 6.3 Participants who Attended Reconfiguration of the Virtual Model**

| **Participant who attended Reconfiguration of the Virtual Model** | | | |
|---|---|---|---|
| **Participants** | **Academics** | **Researchers** | **PhD students** |
| 23 | 0 | 9 | 14 |

### 6.2.4 Interviews of Participants

Although the invitation was sent out to the whole School, a total of 48 attended who are the occupants (39 end-users), visitors (three academics), and design team (six professionals) of the hub. The selection criteria of the participants were: they were end-users, visitors, design team of the School building and their expertise of using MMOG at early-stage design are different. The profile of the respondents is contained within Appendix 13. According to Table 6.4, 48 participants are put into three phases based on the level of expertise of using MMOG at architectural design.

- ❖ Phase One Presentation of MMOG: demonstration of MMOG for design.
- ❖ Phase Two Participants Avatar Navigation: avatars of participants were created, touring the School building virtually.
- ❖ Phase Three Reconfigure the Virtual Hub: avatars of participants reconfigured the space of the hub virtually.

Each of the phases contains 16 people. Phase One includes three academics/professionals, six researchers, seven PhD students who only attended the virtual presentations of the School. Most of the academics participated only in the first phase of the project, which discussed the potential of MMOG at early-stage design. Phase Two includes 10 end-users and six professional design team members who created their avatars to navigate in the virtual building of the School (three researchers and seven PhD students). Phase Three includes 16 end-users who re-configured the School virtually (six researchers, ten PhD students).

The reason for these three phases is to test whether stakeholders of various level of expertise of using MMOG may affect the result of how they perceive this virtual model and interaction experience as realistic.

**Table 6.4 Virtual School Participants Breakdown**

| **Virtual School Participants Breakdown** | | | |
|---|---|---|---|
| **Participants** | **Academics/professionals** | **Researchers** | **PhD students** |
| **Phase 1: 16** | 3 | 6 | 7 |
| **Phase 2: 16** | 6 | 3 | 7 |
| **Phase 3: 16** | 0 | 6 | 10 |
| **Total: 48** | 9 | 15 | 24 |

### 6.2.5 Interview Professional Stakeholders

This virtual model was shown to professional stakeholders involved in the design and construction process (six out of seven: the only one who was not interviewed was because he no longer worked in the AEC industry) of the School of Civil and Building Engineering. This includes one facility manager, three civil engineers and two architects. In-depth interviews were conducted to find out how MMOG such as *SL* could be used by professional stakeholders in the RIBA process to complement other visualisation tools.

## 6.3 Results from the Interviews

Of all the participants in the interviews, they mainly discussed the following issues. Firstly, how realistic is the virtual School to represent the real-world School. Secondly, how realistic it is for them to use avatars to interact with other avatars in the virtual space, in comparison to their daily interaction between colleagues in the real School space. Thirdly, how MMOG could inform better design. Fourthly, how they compare *SL* and other architectural visualisation tools. The detailed findings are listed as follows.

### 6.3.1 Virtual Representation

All 48 participants recognised the virtual School immediately. They clearly knew the *SL* model represent the real-world building of the Civil and Building Engineering School, Loughborough University. This shows that the virtual representation of MMOG can be realistic enough for stakeholders to recognise and identify. However, in terms of the details of the visual representation, opinion differed between participants with different levels of experience using construction visualisation technologies.

Firstly, participants who had no experience or less experience of using visualisation software, were more likely to be satisfied with the details of representation of the *SL* virtual models. For example, of all the 24 PhD students interviewed (see Table 6.4) who had no real-world construction industry related work experience, 14 of them thought the visual representation of the virtual building was good enough for architectural design. However, all participants who have used other architectural visualisation tools, considered the details of the *SL* model of the School as crude, not as good as other industry-standard CAD models. For example, of all the 24 participants who are research associates, academics or professionals with years of experience working in the construction industry, 19 of them considered the detail of representation of the *SL* virtual model too crude to be used as a better architectural design tool to replace current industrial-standard CAD tools. The only experienced participants who were satisfied with the representation of *SL* model was a lecturer previously teaching Technical Drawing for Civil Engineering students for five years, who has no experience using industry CAD.

From this result, the level of details *SL* can provide for architectural design is good enough to satisfy end-users who have no professional experience of design. However, if it is for professional experts in the AEC industry, who are familiar with a whole range of detailed visualisation modelling tools, the detail *SL* can go into is still not enough. In summary, the virtual representation of *SL* is realistic to non-professional stakeholders (such as clients, end-users) in the design process, not realistic enough to professional stakeholders (such as architects, civil engineers or quantity surveyors) in the design process. Therefore, an *SL* model can be useful to engage non-professional stakeholders in the design process. For professional stakeholders, more detailed representation is required.

For experienced participants, they also spot other problems of the model. Firstly, the scale of the model does not feel right. They think the scale of the whole model is smaller than it feels in real life. Five out of 24 experienced participants in the interviews expressed this view. These five participants argue that the default perspective in the *SL* model – the third-person view – makes participants feel as if the whole building is smaller than it should be in real life. All the furniture looks smaller than in the real world and the space within the virtual model is less spacious than it should be in real life. This is true. Besides the issue of the third-person perspective, there is also another issue, which causes the smaller scale of the model. The whole virtual model of the School is built to exactly the same size as the real-world building with all the furniture allocated at the same positions according to the real-world ones. However, the average height of avatars in *SL* is 1.5 times bigger than in the real world. The researcher only knows this after this whole virtual model was constructed. Therefore, what the researcher did was to make the avatar of the creator one-third smaller than the original size so the whole space looked like the right scale. However, when the group interaction happened in the virtual School, all of them were the original avatar size, which is 1.5 times bigger than real-world persons are. Therefore, some participants find the environment is not the right scale for them.

Secondly, they thought the details of the interior of the virtual building were far better than the details of the building itself. This view was expressed by three out of 24 experienced participants who have been working in the industry as architects. They argue that for real-world architects, unless they are specialised in interior design, most of the visualisation they do will put more emphasis on the structure and details of the building itself, rather than all the interiors of the buildings. This is true as well. The representation of the visuals in *SL* mainly depends on the details used in the textures. Most of the furniture used in the School is free items shared by professional *SL* content creators. They are often design experts in real world who have advanced design skills in using Photoshop and other professional design software to create the detailed texture for items. Researchers in this study are not design experts, with little or no experience in Photoshop. Therefore, the texture used to represent the exterior of the building is not through creating the exact texture and mimicking the real-world building through a professional design program, but through collecting similar ready-made textures created by other content designers in *SL*. As a result, the level of details between the furniture and the School building are not on the same level of accuracy.

### 6.3.2 Evaluate Human Interaction

As discussed in Section 4.4 of Chapter 4, with current tools it is a challenge to engage non-professional stakeholders at the early-stage design of architecture. Most of the human interaction enabled by other tools used at early-stage design cannot effectively mirror real-world immersive experience of the occupants. Therefore, it is important to establish participants' views about the interactions in the virtual hub test. How realistic professional and non-professional stakeholders consider the human interaction is in the virtual environment can prove how useful MMOG are at early-stage design. Both architects and Construction IT specialists who are designing software to assist early-stage design of architecture can learn from these findings to develop better process and tools to effectively engage non-professional stakeholders at early-stage design.

Theoretically, a great value of *SL* over previous AEC industry visualisation tools lies in its provision of enabling very large numbers of users to interact with each other and the built environment in a real-time, real-life, immersive way. However, according to the data collected, the theory is not exactly true. According to the result, most people consider the human interaction in the virtual built environment in *SL* as real time; half of them find it an immersive experience while only one third agrees that it is real life. In general, most participants consider the group interaction in the virtual environment of MMOG is more realistic human interaction than simulated by other visualisation tools at early-stage design in the AEC industry.

Firstly, most participants consider the interaction in the virtual space as real time. The reason they consider it is real time is because all the activities involved virtually are time consuming. According to Participant S, "virtual interaction is time consuming. If I take an hour in *SL*, it takes an hour in real life". Also, another main reason is because participants can see what other people are doing around them in *SL* and interact with them simultaneously. All the activities people are doing in *SL* are streamed live with people around them in that area. There is no delay or elapse of time for people to respond to the interaction around them. Because of this reason, they think *SL* interaction is real time. For the opposition, their arguments are also worth discussing. For example, Participant H argued that "whether the interaction in *SL* can be considered as real time or not, it is more to do with human nature rather than the computer design model itself". Some participants argue that, human beings are social animals; social interaction is a key part of their daily life, but not the whole life. *SL* can only represent the social interaction side of the real world; therefore, it is not real time. For example, Participant J argue that, "in real life, I sit at my desk for most of the time, reading, writing journal articles, giving phone calls, replying emails and etc. The interaction with other people in my workplace is only about 10% of the time for my daily work. *SL* stimulates only a small part of my daily work. If in *SL,* I can do all the rest of my daily work, then I will consider it as real time. But it cannot". From this, it is clear that the hub may not be the ideal test bed. Real-world buildings, which involve lots of interaction between end-users, should be considered for further research. In sum, how participants consider virtual interaction as real time or not, is entirely depending on how they interpret "real time". Most participants agree *SL* interaction is real time because they are spending real time interacting virtually, or the interaction is happening simultaneously. Some of them disagree by arguing that the social interaction only forms part of their real-time interaction. Therefore, they do not consider virtual interaction as real time.

Secondly, only one third of participants agreed that virtual interactions in *SL* are "real life". Half of the participants agree that, "to a certain extent', *SL* interaction can be "real life", while the rest one third simply said "no". People consider *SL* interaction as real world, based on the fact that behind every virtual avatar, there is a real-life person, rather than the traditional simulation controlled by the computer. "Yes, of course, it is real life communication: two people talk to each other via the computer games", argued by Participant K. "it is similar to Yahoo Messenger: people chat to each other with the help of the computers", added Participant N. One-third of the people who argue *SL* interaction is not real life do so mainly because of the following reasons: the anonymity of virtual identification and people's old concept about human interaction.

For one thing, the ability to become anyone one prefers in *SL* put the trust building between residents in question. Participant D argued that, “with fake ID, people are more likely to use *SL* as an opportunity to become a different person”. There was great concern among participants that people do not behave exactly the same virtually as in reality. Therefore, one of the people who hold cautious views about *SL* interaction, emphasised that the instructions of the platform also have an influence on people’s behaviour in a virtual environment. If participants are asked to take it seriously and behave/react to things as if it is in real life, it is more likely that the interaction in *SL* will mimic real-world interaction. This was echoed by people from the same group who argued that *SL* interaction can become real-world interaction, depending on people’s attitude and personality. If participants take it seriously, it can be a real-world interaction. If they take it as a computer game, then it is only entertainment for them, it is not real-world interaction.

For another, it is difficult to change people’s concept of real-life interaction. For many people who are not IT savvy, human interactions in a virtual world cannot become real life at all. This view is supported by one third of the participants. Participant G answered that question with a definite “No”—“We want face-to face human interaction”. Participant D, who “has not got lots of experience in computer aided architectural design”, explained this reluctance to accept computer-aided human interaction as human interaction, “I find the interaction in digital world artificial, because the human and buildings there are computer generated. It takes me a long time to get used to this new form of interaction”. However, for people who are IT savvy or used to computer-aided architectural design, the interaction in *SL* is real life. They argue that, for people who are used to chatting via the computer, *SL* is better real-world interaction because it adds the avatar, which gives participants more sense of being in the space, interacting with others. It is supported by Participant M, “I want to learn this software and build a villa in the mountain for my family. It is interesting to invite my wife, all the kids to create their own avatars and then come to interact within the villa, edit it until everyone is happy. You cannot do better human interaction in any other visualisation tools rather than in

*SL*”.

Thirdly, participants were almost equally divided on whether *SL* virtual interaction can be considered as “truly immersive”. For the supporters, one immersive feature of *SL* is the application of using an avatar to represent the individual user in the virtual space. Ten out of 48 interviewees recommend the use of the space through an avatar as something offering distinct advantages over other forms of visualisation. Most of them argue that it creates more sense of being in the space and helps the users to have a better feedback about the built environment. Participant C further explained that point: “people can emerge themselves in the environment, easily change the layout and structure of the space and see the alteration immediately”. Therefore, many of them consider this interactive immersion as an effective way to engage all the stakeholders in the construction projects. An example was given by Participant N, “when we go to the hub as a construction project team, each member of the team can contribute as much as they can. It is easier to get your ideas across to others because all of us can see it, feel the actual space and layout, and then evaluate it. There are more opportunities in *SL* to contribute to the project than in real life”. Therefore, the interactive immersion in *SL* can help to enhance the collaboration of all the stakeholders of the project globally, without the limit of time and geographic locations.

For the opponents, they interpret “immersive” as a holistic sensuous experience, which is composed of at least the five basic senses – the sense of sight, sense of touch, sense of hearing, sense of smell and sense of taste. However, *SL* only enables its users to experience two senses – the sense of sight and sense of hearing. Many participants pointed out that interaction in *SL* is a narrowed experience of interaction. *SL* experience is only a visual and verbal simulation, it lacks of all the other senses. There is no smell, touch or taste. Also, some argued that the first perspective of people is not default in *SL*. Because of that, the experience in *SL* is not very immersive.

However, even that is the case, some supporters refuted this argument by pointing out the current immersive technology available still remains only visual and audio, or at most feeling, not yet taste and smell. "Of all the so-called immersive environment, *SL* has done a great job for creating these high quality visual and audio effects", argued Participant J, "You can also touch the building in *SL* if connected with external sensors". Participant J added, "most mainstream immersive environments available now only entail the senses of sight, hearing and touch because these three can already create a perfect immersive experience for people". Accordingly, it is not yet necessary in *SL* to create an holistic immersive experience with all five senses. As half of the participants expect a holistic immersion experience, it may be a direction that MMOG developers need to explore in the near future.

Many participants made the comparison between *SL* interaction and interaction which took place in Virtual Reality. What they argue is, Virtual Reality can provide more realistic interaction experience than *SL* in a traditional sense. However, *SL* is a lot cheaper, easily available and accessible to engage non-professional stakeholders while providing realistic interaction between groups of people. In that sense, *SL* is a better tool for human interaction than Virtual Reality. For example, Participant U said that, "In Virtual Reality, the details of the representation of the virtual environment are a lot better than that of *SL*. Various electronic equipment can enable participants to have a better sense immersed into that virtual space". In that sense, besides Virtual Reality, *SL* is another tool to achieve more realistic human interaction than most visualisation tools in the AEC industry. However, those powerful machines are not easily accessible to the large number of small and medium-sized architects' firms. They cannot afford it. Participant J said that:

> The cost, training, time required to achieve optimal results using Virtual Reality to simulate massively interaction between people in the virtual environment doesn't meet the need for architects to finish their early-stage design in a quick, easy and cost effective way. It can be difficult to use Virtual Reality to engage professional stakeholders, it can be more difficult for architects to recommend non-professional

stakeholders to engage in it to test the design.

Therefore, considering the lesser accessibility of Virtual Reality, *SL* enables globally accessible interaction between non-professional stakeholders who do not need to pay for anything, but access the virtual design remotely through their own personal computer, interacting simultaneously with other participants. Therefore, in comparison with other visualisation tools, *SL* can provide better group interaction of real-world people in the virtual environment to assist early-stage design.

Due to the IT skills of individual participants, experience with other visualisation tools, perception about what can be considered as "real-time, real-life, immersive experience", and current IT constraints, not all 48 participants agree that the virtual group interaction in the *SL* virtual environment is real-time, real-life, truly immersive human interaction. However, the vast majority of the participants agree that the avatar-based group interaction in the virtual environment of *SL* is a better human interaction simulation tool than that of many visualisation tools to be used at early-stage design. Of all the 48 people interviewed, 40 of them agree that the group interaction in *SL* is more realistic human interaction than other visualisation tools used at early-stage design in the AEC industry. For example, Participant H, who does not consider *SL* interaction as immersive, said that "I don't feel comfortable interacting with people virtually through an avatar; I prefer to talk to them face-to-face in the real world. That is the reason I do not consider the interaction in *SL* immersive. However, I do agree that, in comparison with other visualisation tool, *SL* provides a cheap and easily accessible tool to enable large number of participants to interact with each other in a more realistic way". His view was echoed by Participant P, "not so many visualisation tools available now allow a large number of real-world end-users or clients actually occupy the virtual environment, to freely interact within that space and each other to test its functionality before construction. *SL* has advantage enabling this group interaction. That is most needed in the visualisation tools at this moment for early-stage design".

This is the view of the 48 participants of the virtual hub test, including six professionals in the design team of the hub, three academics who are visitors of the hub, 39 end-users of the hub (15 researchers and 24 PhD students) in the School of Civil and Building Engineering. This sample can well represent the view of both the professional design team (six out of seven were interviewed) and end-users of the hub in the School. The School has a population 120 PhD students, 30 postdoctoral researchers and 60 academics. The regular occupancies of the hub are as follows:

- ❖ Only about 40% of the 120 PhD students are regularly around in the hub of the School.
- ❖ Most of the 30 postdoctoral researchers are using the hub on a daily basis.
- ❖ A small number of academics use the hub on a regular basis.

Therefore, the sample is representative of the School population and their view can effective represent the view of the end-users, visitors and design team of the hub.

### 6.3.3 How can MMOG Inform Better Design?

Generally, professional stakeholders consider *SL* to have potential for architectural design. However, due to various IT and culture barriers, it may take a long time for *SL* to be used widely for architectural design. In all the 48 people interviewed, 23 of them hold positive views about SL's ability to enhance construction design, 6 unsure while 19 negative. The detailed figures in all three groups are also different. There is a clear divide between members of Groups A, B and C in their confidence to use *SL* for architectural design. It is more likely that people will doubt the validity of *SL* and other MMOG in architectural design when they have not participated much in it. For example, eight people in Phase One (who only attended the presentation on the use of *SL* and MMOG for architectural design) argue that *SL* holds no future for architectural design. Five are confident, while three are not sure about its potential and said it is for future architectural design, not currently. According to Participant L, who has never used any MMOG "Why *SL*? It will not make any difference for architectural design". However, with more time immersed in the virtual world, more people become interested in using *SL* to explore opportunities to improve architectural design. In Phase Two (who created their own avatars and toured around the *SL* virtual School model), eight of them are confident about virtual architectural design and interactions, two were unsure while six negative. There is slight increase of more confidence in Phase Three (who have used *SL* for architectural activities such as the re-configuration of the space) of ten, with one unsure and five negative. It is clear from Table 6.5 that participants' view on MMOG's architectural potential rise from Phase One (5) to Phase Two (8) to Phase Three (10) respectively. This means when stakeholders become more and more familiar with a new design tool, their views about its architectural application rise accordingly. Participants who are not sure or hold negative views about *SL*'s architectural potential drops from Phase One, to Phase Two, to Phase Three as well: from 3, to 2, to 1 for unsure; from 8, to 6, to 5 for negative views. According to the data, it is clear that similar to other innovations in the AEC industry, it also takes time for people to explore the best use of the new IT, such as MMOG and *SL*. Also, the more people get involved in the virtual experimentations, the more confident they become about its potential and meanwhile being able to explore various ways to make the best of *SL* for architectural applications.

Table 6.5: People's Views on SL's Potential to Support Architectural Design

| **People's Views on SL's Potential to Support Architectural Design** | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Positive** | | **Unsure** | | **Negative** | |
| **Group A** | **16** | 31.25% | 5 | 18.75% | 3 | 50% | 8 |
| **Group B** | **16** | 50% | 8 | 12.5% | 2 | 37.5% | 6 |
| **Group C** | **16** | 62.5% | 10 | 6.25% | 1 | 31.25% | 5 |
| **Overall** | **48** | 47.92% | 23 | 12.5% | 6 | 39.58% | 19 |

### 6.3.4 A Comparison of *SL* and Other Forms of Visualisation

Although 19 out of 48 interviewees don't think *SL* can offer significant impact on current visualisation tools in the AEC industry, many participants interviewed still see the potential of *SL* over other forms of visualisation.

Firstly, ten out of 48 interviewees recommend the use of the space with an avatar to offer distinct advantages over other forms of visualisation. Secondly, the "massively multi-player" interaction within the built environment is what other visualisation tools lack. Thirteen out of 48 participants argue that very few CAD models offer the same level of group interaction within the space, and with other people. *SL* is more engaging, especially with young people. Participant B, a researcher of eight years experience working on construction projects in the public sector further highlights SL's potential to improve public engagement in the design. "If the aim of the construction project is to enhance the public involvement such as the library, primary schools, secondary schools, social care facilities etc., the massively multi-players enabled *SL* architectural design can be a great tool to simulate the public interaction in that place." Thirdly, 16 out of 48 interviewees mentioned the globally easily accessibility of *SL* and its potential to enhance the collaboration of all stakeholders in a construction. Participant D said, "It is suitable for long-distance communication. All stakeholders in a construction project can change the design and see the output immediately even if they are physically far away from each other. All they need to do is to have their PC and Internet ready and then everything is fine".

This is the opinion of 23 out of 48 people who see the potential of *SL* for architectural design. However, the 19 people who doubt the impact *SL* may bring to the AEC industry also have valid arguments. Most participants who doubt the architectural value of *SL* argue that *SL* is not developed specifically for the AEC industry. It creates a completely different model separate from the AEC industry. It is not developed by architects nor construction consultants who have architectural expertise and therefore it does not fit in the AEC industry. Because it is not an architecturally oriented platform, the following drawbacks emerge.

Firstly, buildings created in *SL* do not have physical attributes. As participant F put it, "What will the AEC industry get from *SL* since nothing built in *SL* has physical attributes? You can have one million people stand in the virtual School and it will not collapse, but when it comes to real life, it falls down." Therefore, 14 out of 48 participants argue that design in *SL* is not always applicable or transferable to real-world building. Secondly, it is time-consuming for AEC people to find the best use of *SL* for architectural design. Eighteen out of 48 of the interviewees consider *SL* involvement as "time consuming". Most of them find it difficult to use and time consuming to find the best use of it for architectural design. However, "time is crucially important for construction design," highlighted Participant G. In "an industry not driven by IT, but by procedure", (Participant H, who has been working for Vinci, one of the biggest consultancy companies, for two years), "Architects do not have time to try advanced IT." This is echoed by five participants who are from both developed and developing countries (three UK and two from China). Participant L has worked one year for the China Academy of Building Research, the largest and most diverse research institution in the building industry in China. He said, "Normally, architects have far too many projects to design. They are required to finish their projects in a few days. In the China Academy of Building Research, they used to use no computer models at all, but only drawings, because it is easy and quick. Now, they begin to use some computer-aided architectural design tools. However, their priority is that "the faster, the better". Therefore, if architects try *SL*, there is also a big hidden cost in the long length of time they have to invest. For example, according to Participant H, his boss is paid £120 pounds/hour. If it takes him 20 hours to learn *SL*, that cost also needs to be considered. Accordingly, with those barriers on new IT, time and cost in the AEC industry, it will be long before *SL* can become architecturally specific for architects to use effectively.

## 6.4 Validation

In this virtual test, member checking and investigator triangulation are used to validate the research methodology.

In this Chapter, to ensure that the data collected from 48 participants on the virtual School is accurate, fair and complete, member checking is used. The 48 participants have different levels of experience interacting with each other in the virtual environment of the model created in *SL*. Some of the participants only saw the virtual interaction as part of the presentation, some created their own avatar to tour around the virtual model, while others participated in the reconfiguration of the virtual model. Their experiences and understanding of the virtual model varied greatly. At the end of each interview question, the researcher summarised the key points raised by the participant. The participants were asked to check if the summary accurately reflected their views of the questions. They were encouraged to delete, edit, expand or highlight any points. Changes were made during this stage to ensure the data collection process captured accurate data from a group of people with different levels of expertise and understanding of MMOG.

For example, to answer question 8 in the questionnaire "How far do you consider *Second Life* human interaction as truly immersive human interaction?" Many participants (12 out of 48) initially considered the interaction in the virtual School was not immersive because they considered the immersive experience should not only be seeing, listening, but also feeling, tasting and smelling. When the researcher summarised their points and asked them to confirm the content, 11 of them also added that, in comparison with lots of other visualisation tools available, MMOG is more immersive with the use of an avatar. Some of them started to make a detailed comparison between Virtual Reality and MMOG in its ability to provide more realistic interaction in the built environment.

Besides using member checking to validate the data collection process, investigator triangulation was used to validate the data analysis process. One interview transcript was randomly chosen from 48 interviews for two lecturers to participate in the initial coding. As discussed in Section 3.3.4.2, to reduce the bias of the researcher, two external lecturers were invited to participate in the data-analysis process. The templates developed by the two external analysts were compared with the original coding developed by the researcher. No major changes of the template are suggested except for two points (See Appendix 16). The validation of the template led to the reclarification of some of the information as it was felt more pertinent in other sections than where it had originally been classified. The focus ensured the clarity and robustness of the analysis.

## 6.5 Summary of the Chapter

In this chapter, a virtual School mimicking the real-world School of Civil and Building Engineering, Loughborough University was created in *SL* as an example to test how realistic MMOG such as *SL* can be used as a tool to augment the RIBA design stages. With the completion of this model, 42 end-users of the School of Civil and Building Engineering, Loughborough University together with six professional stakeholders who were involved in the redesign of this School were interviewed. During the interviews, the virtual model and its potential to assist the current architectural design stages were demonstrated and discussed with the interviewees. Presentations were held to demonstrate this virtual model and its potential application to augment architectural design stages. A virtual re-configuration of the space was held with 23 end-users from the School participating.

The final results from the 48 interviews showed that similarly to other innovations in the AEC industry, it also takes time for people to explore the best use of new IT such as MMOG. Firstly, there are currently various barriers that concern AEC industry stakeholders on the potential of *SL* to augment the architectural design process, such as time, training, details of representation and interaction in a virtual environment. Secondly, the virtual representation of *SL* is realistic to non-professional stakeholders (such as clients and end-users) in the design process, but not realistic enough to professional stakeholders (such as architects, civil engineers or quantity surveyors) in the design process. Therefore, *SL* modelling can be useful to engage non-professional stakeholders in the design process. For professional stakeholders, representation that is more detailed is required. Thirdly, theoretically, a great value of *SL* over previous AEC-industry visualisation tools lies in its provision of enabling very many players to interact with each other and the built environment in a real-time, real-life, immersive way. However, according to the data collected, the theory is not exactly true. According to the results, most people consider the human interaction in the virtual built environment in *SL* as real time; half of them find it immersive experience while only one third agrees that it is real life. Nevertheless, most of them consider *SL* as a better tool to simulate real-world human interaction in the virtual environment to assist early-stage design. Fourthly, it is found that the more people get involved in the virtual experimentations, the more confident they become about its potential and meanwhile become able to explore various ways to make the best of *SL* for architectural academic research. Last but not least, in comparison with other MMOG, it is argued that the use of avatars and the possibility to enable “massively multi-players” to interact within the space is what participants considered as advantages that *SL* could have over current visualisation tools. However, as *SL* is not developed specifically for the AEC industry, there are many limitations that AEC industry stakeholders are worried about, such as the lack of physical rules in *SL*, the time it takes to explore the best use of *SL* and other MMOG to augment the current architectural design process. The data collection and analysis process of the virtual test are also validated through investigator triangulation and members checking.

# Chapter 7

# 7.0 Discussion of Main Findings

This chapter examines two Research Objectives:

1. Examine the features of MMOG and their suitability for informing early-stage design.
2. Develop and validate guidance on how and when MMOG should be deployed to best inform early-stage design.

In order to achieve these two research objectives, a discussion is carried out to explore the following four Research Questions of this thesis (See Section 7.5: Summary):

Q1: What are the issues which negatively impact early-stage design?

Q2: What forms of visualisations are used in early-stage design and their limitations?

Q3: Can MMOG complement existing visualisation techniques?

Q4: How can MMOG such as Second Life be used to better inform building design?

This chapter starts with the discussions of the main findings of this thesis. Guidance is proposed to better use MMOG to complement other design tools at different RIBA design stages. Five experienced architects and IT Construction specialists were interviewed to validate the guidance with further findings discussed from the validation of the guidance.

## 7.1 Findings vs. Literature Review

According to the literature review, three main challenges are identified at RIBA early-design Stages A to D, including a complex decision-making process (Cilliers, 1998), communication issues between professional and non-professional stakeholders (Arlati et al., 1995 and Moum, 2006) and lack of innovation (Slaughter, 2000 and Winch, 1998). Based on the three main issues identified at early-stage design, various design tools have been developed to improve the decision-making process between different stakeholders.

### 7.1.1 Manage Early-stage Design

In Chapter 4, the first section reveals that architects manage early-stage design mainly through 2D sketches, physical models, Google SketchUp and basic CAD. 2D sketches remain a dominant tool used in the early-stage design, especially during RIBA Stages A and B, mainly because architects are trained to use 2D sketches to select the most important design information to visualise 3D design in their minds, and to share it with professional stakeholders who have received similar training to understand their 2D sketches. The selective information contained in 2D sketches is also helpful to generate creative design ideas. However, sketches are limited to two dimensions and it is difficult to use sketches to represent complicated geometric shapes or to share design ideas with non-professional stakeholders such as clients or end-users.

Physical models are mostly used at RIBA Design Stages C and D to help architects to test out complicated shapes which are difficult to visualise through 2D drawings (Stage C), or communicate the design ideas to non professional stakeholders in 3D (Stage D). However, the physical models used to show clients sometimes can be time consuming and expensive to build.

Google SketchUp, in comparison with physical models, is simple and quick to learn and use at early-stage design. There is also, good interoperability between Google SketchUp, other CAD models and BIM, which allows architects to transfer the model built through this software to be modified with more detailed CAD models or linked to BIM at a later design stage. Because of that, Google SketchUp is found to be one of the most popular early-stage design tools by architects (from Stages A to D, especially during Stages B to D).

Basic 3D CAD is also used to reduce the time spent on the transition from the conceptual stage to detailed stages. CAD 3D flythrough is often used at Stages C and D. However, it is also found that most detailed visualisation 3D flythrough generated to show clients are most likely to be outsourced to external IT companies specialised in 3D visualisation. Architects do not do it themselves.

Virtual Reality is rarely mentioned as an early-stage design tool due to cost and other issues of the equipment. Therefore, only very few architects use it at early stages of the RIBA Plan of Work (A to D). BIM is a popular topic among architects. Many architects believe that theoretically BIM can be used throughout RIBA stages from Stage B. However, most of them agree that BIM should be used at more detailed design stages starting from Stages E or F onwards. The main reason is that at early-stage design, there is not enough data collected to make the best use of BIM. BIM becomes more useful at a more detailed stage.

It is clear from the findings that most visualisation tools currently used in the AEC industry are developed to assist professional architects to better contribute to the design process. Few tools have been developed to effectively engage non-professional stakeholders such as clients or end-users in the design decision-making process. Therefore, effective collaboration between professional architects and non-professional clients and end-users has been and remains, an issue. Also, many tools used at early-stage design cannot effectively simulate real-world group interaction of the occupants in the virtual space.

The main interviewees in this research are from small and medium-sized architectural companies who are dealing with projects in the local community in the UK: cheap cost of the tool and its ability to produce a quick turnaround at the early stage becomes the main consideration. Besides those four main tools identified, Virtual Reality and BIM have also been mentioned as tools used at early-stage design. Tools which are not cheap enough and with more complicated processing time, reviewed in Chapter 2 Literature Review, including Multi-user Virtual Environment, Game Engine Construction Model and nD models are rarely mentioned in the results for early-stage design.

### 7.1.2. Compare MMOG with Previous Tools: Interaction

In Chapters 5, and 6, the main results prove that the value MMOG have over previous AEC industry visualisation tools lies in their ability to enable multiple participants to have a better interaction experience with each other and the built environment. For example, in Chapter 5, Section 5.3.1, most of the architects interviewed reported that what interested them most about MMOG's architectural potential lies in its ability to ensure massive numbers of real-world people can interact with each other in the virtual space. Also, in Chapter 6, Section 6.3.2, it was found that most participants consider the human interaction in the virtual built environment of MMOG as real time; half of them find it an immersive experience while only one third agrees that it is real life. This is greatly influenced by how much time users devoted to virtual interaction and how familiar they become interacting virtually in MMOG. The more they get involved in the virtual experimentations, the more likely they identify the virtual interaction as part of their real life. Overall, the use of MMOG to simulate real-world architectural design is considered more interactive and immersive. Firstly, the exploration of the space is not pre-ordered, but is free to be explored. Secondly, the multiple-user experience is more realistic than the single-user experience simulated by other software. Thirdly, the use of avatars gives a greater sense of being in the spaces. Finally, it can become a powerful tool for specific issues such as emergency evacuation simulation. Therefore, the virtual interaction in MMOG can be used to overcome cultural, social and gender differences, and enable stakeholders who cannot otherwise get involved to contribute to the design process.

The ability of MMOG to allow very many users to access virtual buildings through real-life, real-time, immersive human interaction was suggested in Chapter 2 Literature Review, Section 2.4.1 as a potential area where MMOG can become useful in early-stage design. This finding points out why this massive human interaction in MMOG is considered real-time real-world human interaction to assist early-stage design decision making.

### 7.1.3 Compare MMOG with Previous Tools: Collaboration

In Chapter 5, it was found that MMOG is most useful at RIBA Stages C and D. It can be used to improve the collaboration between all stakeholders in the architectural design process. Internet-based MMOG provide better accessibility to stakeholders of the architectural projects. The global-collaboration-enabled MMOG are cost effective for international design projects. Also, text-messaging-based MMOG and free translators could transcend language barriers. As a non-specialist social platform, MMOG can be useful to engage non-professional stakeholders in the design process, such as clients and end-users. MMOG enabled non-professional stakeholders to experience architectural design in a holistic, dynamic and immersive way. Also, the virtual representation of MMOG is realistic to non-professional stakeholders (such as clients and end-users) in the design process. Therefore, MMOG helps non-professional stakeholders to fully understand the architectural design before it is constructed. Most architectural activities in MMOG are not conducted by real-world architects, but average users who are non-professional stakeholders. The easy design tools in *SL* empower non-professional stakeholders, transforming them from passive recipients of choosing the design from what professional architects propose, to active contributors who are eager to realise their own design concept virtually and ask professional architects to make them work in real life. This bottom-up approach may challenge and change the way traditional architectural design process is managed.

MMOG's ability on better collaboration between all stakeholders and especially between professional architects and non-professional clients and end-users is briefly mentioned as a case study in literature review. However, systematic analysis about why MMOG can be used to improve the collaborations between all stakeholders at early-stage design is not discovered in the published literature. Therefore, this finding is helpful to provide more insight on why MMOG should be used at early-stage design to engage non-professional stakeholders to contribute more.

### 7.1.4 Compare MMOG with Previous Tools: Limitations

As an emerging tool for early-stage design, MMOG is found to have various limitations. In Chapters 5 and 6, barriers that limit the uptake of *SL* and MMOG by architects have been found. *SL* is not developed to support professional architectural design, but to engage users from all backgrounds. Therefore, various IT issues need to be dealt with to use *SL* to better support architectural design. For example, there are IT issues about access to the Internet, the computer hardware, the online server, the low resolution details, no real-world environment and interoperability issues with other visualisation tools. There are other issues, such as: the highly regulated industry which impedes the introduction of MMOG; how to find appropriate projects and clients to use MMOG; challenges to engage non-professional stakeholders in *SL*; the time it takes to explore best architectural application in *SL*; as well as the issue on the lack of *SL* architectural education in universities.

### 7.1.5 Summary: Better Use of MMOG

Form 7.1.1 to 7.1.4, the following points can be summarised to identify when and how to use MMOG at early-stage design:

1. Currently, it is more useful to use MMOG at RIBA Stages C and D.
2. MMOG require the development of improved IT infrastructure to underpin building design more efficiently.
3. MMOG is more useful to engage non-professional stakeholders and allow them to become more involved in the architectural design process. This is mainly achieved through more realistic group interaction of occupants in the virtual environment and easy access to the virtual model.
4. MMOG is a useful collaboration tool at early-stage design.
5. It is most useful to use MMOG in projects involving large numbers of end-users.

## 7.2 Guidance in Using MMOG

Based on the main findings in previous chapters, guidance for architects was proposed to use MMOG to augment early-stage architectural design. This guidance was validated by interviewing five experienced architects and Construction IT specialists who have been using MMOG to augment real-world architectural design processes.

### 7.2.1 Development of the Guidance

In order to help architects to better use MMOG to complement existing early-stage design tools in architecture, guidance of how to best use MMOG at early-stage design is constructed using the data collected in Chapters 4, 5 and 6. The guidance is composed of two parts. The first part is developed through the key points summarised in Section

7.1.5 on the better use of MMOG at early-stage design. The second part is developed from various tables used in previous sections such as Table 4.7 in Chapter 4 and Table 5.1 in Chapter 5, to find out how to best use MMOG in concert with various design tools at early RIBA stages.

In Chapter 4, Table 4.7 summarised the data collected from 30 architects on the effectiveness of various tools they are using at early-stage design. The criteria to evaluate the effectiveness of those tools are as follows:

- ❖ If the tool is considered useful by 24-30 architects, it is labelled as "Highly Useful".
- ❖ If the tool is considered useful by 17-23 architects, it is labelled as "Very Useful".
- ❖ If the tool is considered useful by 10-16 architects, it is labelled as "Useful".
- ❖ If the tool is considered useful by 3-9 architects, it is labelled as "Less Useful".

Therefore, based on these criteria, the following results are found:

- ❖ 2D sketches are "Highly Useful" at RIBA Stages A, B; "Less Useful" at Stages C, D.
- ❖ Physical models are "Useful" at RIBA Stages C, D; "Less Useful" at Stages A, B.
- ❖ Google SketchUp is "Highly Useful" at RIBA Stages B, C, D; "Very Useful" at Stage A.
- ❖ 3D CAD is "Useful" at RIBA Stages C, D.
- ❖ BIM is "Less Useful" at RIBA Stages B, C, D.
- ❖ Virtual Reality is "Less Useful" at RIBA Stages C, D.

In Chapter 5, Table 5.1, the data collected is from 20 architects who are actually using MMOG at different design stages to augment real-world design practice. The results from Table 5.1 also show that the best stage to use MMOG is also at Stages C and D. This uses the same criteria as those listed in Table 4.7 where 30 architects were interviewed. The 20 architects who find MMOG useful at various RIBA early stages should be multiplied by 1.5 so that the result of Table 5.1 can be evaluated by the criteria set up for the 30-architect sample in Table 4.7. Using this rule, the new Table 7.1 is shown below. According to Table 7.1, MMOG is considered "Less Useful" at RIBA Stage A, B; "Highly Useful" at RIBA Stages C, D.

**Table 7.1 How Many Architects Find MMOG Useful at each of the Early-Stage Design Stages of the RIBA Plan of Work?**

| RIBA Stages | | No. of architects who find it useful | |
|---|---|---|---|
| **A** | **Appraisal** | 3*1.5 = 4.5 | Less Useful |
| **B** | **Design Brief** | 4*1.5 = 6 | Less Useful |
| **C** | **Concept** | 18*1.5 = 27 | Highly Useful |
| **D** | **Design Development** | 16*1.5 = 24 | Highly Useful |

With the model constructed in Chapter 6 to test how realistic MMOG models and the interaction are to various stakeholders at the early-stage design, this further proves the value of MMOG at early-stage design. Combining Table 4.7 and Table 7.1, Figure 7.1 is created. Figure 7.1 summarises the recommended tools architects could use at early stages of the RIBA Plan of Work and how MMOG can be used to augment the early-stage design process in construction.

Based on Figure 7.1, the guidance in using MMOG to augment early-stage design process in Construction is proposed in Section 7.2.2. This guidance should be used by architects at the start of their design project, to assist them to effectively manage their early-stage design process. Architects should read this guidance and develop a plan to use MMOG to complement various tools to better engage clients and end-users at early-stage design.

### 7.2.2 Initial Guidance

The guidance is made up by Figure 7.1: Use of Design Tools at Different RIBA Early Stages and an explanation of how to use MMOG.

#### 7.2.2.1 Objective

The objectives of the guidance are to:

1. Examine the features of MMOG and their suitability for informing early-stage design.
2. Identify how and when MMOG should be deployed to best inform early-stage design.

#### 7.2.2.2 Content

The content of the guidance is made up of the following two parts:

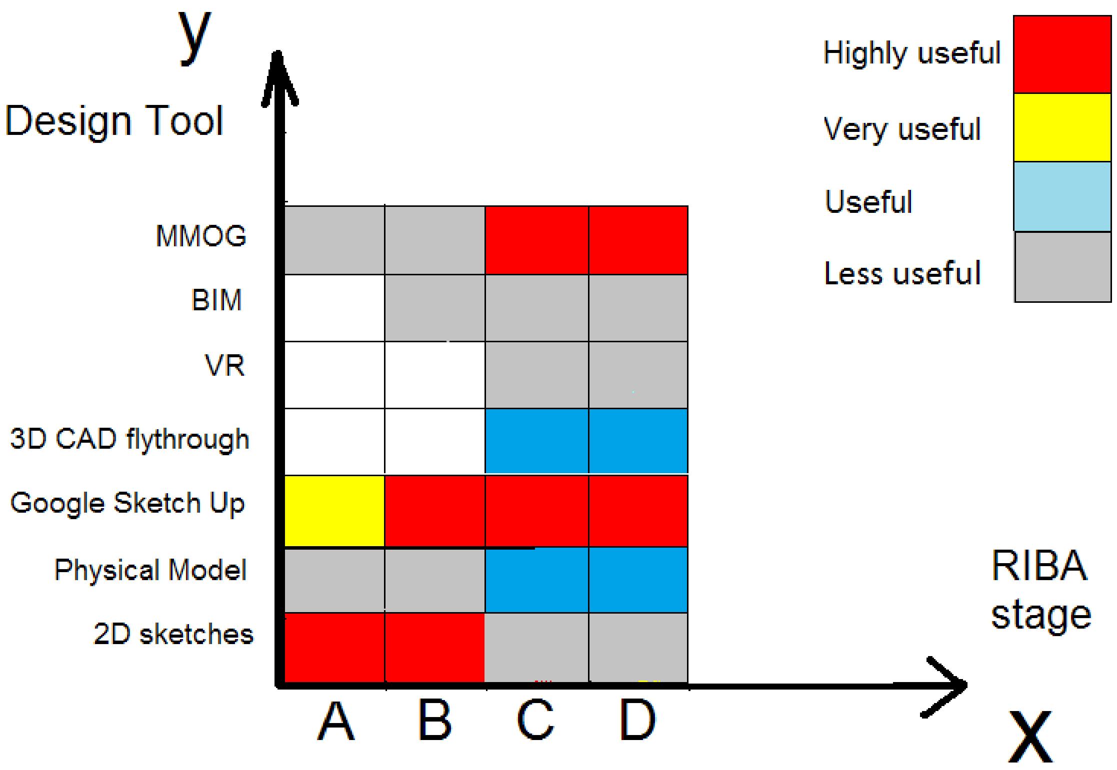
**1. *Useful tools at early-stage design:***

According to Figure 7.1, architects use a variety of tools at early-stage design in construction. Most architects think 2D sketches are used at the RIBA Stages A and B to help architects to have a general concept of the design; physical models are mostly used in Design Stages C and D to try out different design ideas; Google SketchUp can be used throughout RIBA Stages A to D to help quickly visualise design ideas into 3D, while Stages B to D are where architects see Google SketchUp has the biggest advantage. At RIBA Stages C and D, some architects will commission external IT specialists to do CAD 3D flythrough of the building design to show clients what it will look like. Virtual Reality is seldom used by architects due to expense and high requirement for strong computing resources but still, architects said, it is useful in RIBA Stage D. BIM is only just emerging amongst architects. It is a popular direction many architects interviewed want to invest in and develop in the near future. Some architects argue that BIM ideally should be used throughout the whole lifespan of RIBA Stages. Some of them argue that potentially, BIM could be used from Stages B to D, while more of them suggested that it is more effective to use BIM from Stage E onwards because at the early-design stages, there is not enough information to be put into BIM. It is better to use some simple tools such as 2D sketches, physical models, Google SketchUp or 3D CAD flythrough at the early Stages A to D, rather than the big database of BIM.

***2. When and How to Use MMOG:***

1. Currently, it is more useful to use MMOG at RIBA Stages C and D.
2. MMOG require the development of improved IT infrastructure to underpin building design more efficiently.
3. MMOG is more useful to engage non-professional stakeholders and allow them to become more involved in the architectural design process. This is mainly achieved through more realistic group interaction of occupants in the virtual environment and easy access to the virtual model.
4. MMOG is a useful collaboration tool used at early-stage design.
5. It is most useful to use MMOG in projects which involve large numbers of end-users.

**Figure 7.1 Use of Design Tools at Different RIBA Early Stages**




### 7.2.3 Questionnaire to Validate the Guidance

Based on the research methodology discussed in Chapter 3, a questionnaire was developed to validate the guidance, which includes Figure 7.1 and the five points summarised regarding use of MMOG at early-stage design. Five architects and Construction IT specialists who have advanced skills and experience using MMOG for real-world architectural solutions were interviewed to validate the guidance.

These five interviews were constructed to answer the following two Research Questions of this thesis:

Q3: Can MMOG complement existing visualisation techniques?

Q4: How can MMOG such as *Second Life* be used to better inform building design?

To answer research question Q3, “Can MMOG complement existing visualisation techniques?” the following questions are included in the questionnaire:

1. At what stage of design will this form of visualisation, MMOG, be useful?
2. How far do you agree or disagree with the effectiveness of using the various tools listed in Figure 7.1 to augment early-stage design. Why?
3. Does MMOG complement other existing visualisation techniques? If yes, when and how? If not, why not?

To answer Research Question Q4, “How can MMOG such as *Second Life* be used to better inform building design?” the following questions were proposed:

4. What are the limitations and advantages of using MMOG to augment the early-stage design process?

5. What can be done to solve the current issues of MMOG to better support early-stage design?
6. How far do you agree or disagree with the five points proposed in the Guidance for using MMOG at early-stage design?
7. Do you think using MMOG to augment early-stage design can be applied to all types of architectural projects? Why?

Also, to ensure participants can give other useful information relevant to answer four research questions, the following question is also included in the questionnaire:

8. Do you have any other comment?

Two pilot interviews were conducted with the first architect and Construction IT specialist who was willing to participate in the research. Feedback gained from those two pilot interviews was used to revise and improve the questions to ensure appropriate questions are asked during the interviews. The final questionnaire is included in Appendix Nine: Guidance Validation Interview.

Architects and Construction IT experts who are recommended as top experts in using MMOG to augment real-world architectural design were contacted by emails to see if they were willing to participate in the study. A total of ten experts were approached. Three architects and two Construction IT specialists (the response target) agreed to take part in this research. Three of them were interviewed online in *Second Life*, two of them were interviewed by telephone. All the five interviews are recorded and transcribed into Word documents for template analysis. The interviews lasted for one to two hours when all the participants were asked to respond to the questions designed in the questionnaire.

## 7.3 Findings from the Validation

Generally, due to various limitations discussed in previous chapters, it is found that it is not yet worthwhile to use MMOG in all kinds of architectural design projects throughout the RIBA Stages. Most interviewees agree that MMOG should be used at RIBA Stages C and D. Some architects find it easy to combine 2D sketches, Google SketchUp and MMOG at early-stage design. However, with the development of IT, they believe that in the near future, MMOG can become more useful as an interface to access other forms of data rather than dedicated as an early-stage design tool, if MMOG are viewed as a computer interface, rather than a design tool. When and how to use MMOG in architectural design process largely depends on the type of project. For example, as an early-stage design tool, it is more useful to use MMOG actively to enhance collaboration with professional stakeholders and engage non-professional stakeholders in design projects, or projects that need to involve many end-users at early-stage design.

### 7.3.1 Successful Process to Use MMOG with Other Tools

All of the participants agree that it is most useful to use MMOG at RIBA Stages C and D. They also agree with the usefulness of the different tools summarised in Figure 7.1. Most of them suggest that they have found the following way to use MMOG with other tools effective at early-stage design. The consideration is to choose some of the easiest early-stage tools, to develop a quick, easy, cost-effective early-stage design process. In this way, the architect can manage the complex decision-making process in the simplest possible way, effectively engage both professional and non-professional stakeholders, have lots of time and opportunity to generate more innovative design ideas to enhance the quality of early-stage design.

At Stage A, they use 2D sketches to try out various ideas. As soon as they have a general idea of the design such as how the shape of the design will look, they start to use Google SketchUp at Stage B. They often start by looking at the online Google 3D Warehouse to find any similar ready-made 3D model there. If there are similar 3D models, they download it and then use Google SketchUp to modify it to fit the new design idea. If there is no similar model available at the 3D warehouse, they can use Google SketchUp to create that 3D model quickly. Then at Stage C, they can use SketchLife, to export the Google SketchUp 3D model into *SL* to engage with other professional stakeholders in the design process. The professional design team meet virtually in MMOG to discuss the design and modify the design with the tools made available in the virtual world. Then non-professional stakeholders such as clients are invited to give feedback. Clients and end-users are often invited at Stages C and D to come into the virtual world of MMOG. Architects set up a time to meet all the non-professional stakeholders virtually, showing the clients and end-users around in the virtual design. Non-professional stakeholders are often asked to interact with each other in the virtual space to identify any issues in the virtual design. At the same time, architects can easily change it in front of the clients and end-users until they are fully satisfied. Then architects can move on to more detailed design stages starting from

Stage E.

The benefits of this combination of 2D sketches, Google SketchUp and MMOG in early-stage design process are that it is easy, simple and cost-effective. 2D sketches are what most architects normally use as part of their design process. Google SketchUp also increasingly becomes a must-use tool at early-stage design due to its quick, simple and free application. The model downloaded from Google 3D warehouse or created in Google SketchUp can be imported into MMOG with the free software SketchLife. MMOG provides free, easy access to allow clients and end-users to access the virtual building, interacting as a group with each other and with the virtual environment to give architects accurate feedback to improve the design at early stage. Architects also use MMOG to meet virtually with other professional stakeholders to collaborate effectively on the design. It avoids lots of issues when trying to link MMOG with more complicated visualisation tools such as CAD, on the issues of training, interoperability, cost or time.

However, this process suggested by these five experienced architects and Construction IT specialists can only represent the practice of some architects, it does not mean all architects using MMOG follow exactly the same procedure. Also, when dealing with different clients in different types of projects, the procedure can also vary.

### 7.3.2 Natural Interface to Access Other Forms of Data

There is another important finding which arose from all the validation interviews. Instead of saying how MMOG can be best employed at specific RIBA stages, architects and Construction IT specialists argue that in the near future, MMOG could potentially be used throughout all design stages of RIBA as an interface.

According to the five experts interviewed, there has long been a debate in the MMOG

Architects Community about the future development between BIM and MMOG. They want to find out whether BIM is increasingly moving towards MMOG, to have the possibility to be put on the Internet or some other form of network, to allow simultaneous modification of the virtual model by all stakeholders in a more interactive and immersive way. Alternatively, will MMOG increasingly move towards BIM, to have better interoperability with professional visualisation tools to enhance its industry application?

One popular argument raised by all the five experts is that, though BIM has not yet move fast enough to have the better accessibility and interface as a MMOG, in the near future MMOG can become a better interface to access all forms of data stored in the BIM. The very reason for that is because MMOG is a more natural and intuitive interface for people, and therefore it has the potential to become a better interface for stakeholders of construction projects to access data collected from BIM and other design tools at different stages of architectural design. Construction IT specialist D used the example about how Microsoft Windows system replaced Microsoft DOS operating systems to illustrate how the immersive and interactive interface provided by MMOG can help all stakeholders in the construction project to better access and manage other forms of data collected. According to the interview data, Microsoft DOS systems are based on text and programming language, and users need years of training to become competent to use all the abstract and specialised programming language to operate the computers. Because of this, computers using DOS systems were highly specialised and were mainly used by trained computer IT experts. Microsoft Windows systems are based on 2D visual graphics and therefore provide a much more user-friendly interface for average users to access various kinds of data installed on their computers, boosting the global-spread purchase of the personal computer and the rise of the Internet. “With the introduction of Windows systems, everyone changes from DOS to Windows within one year,” said Construction IT specialist E. Architects and Construction specialists argue that things can happen with Windows. MMOG metaphor is stronger than the Windows metaphor because the immersive and interactive nature of the MMOG interface is more natural to people. However, it is argued that it will take at least five to ten years from now to see the change from the traditional interfaces used in the AEC industry, such as BIM and other software, to the more interactive and immersive MMOG-styled interface for design data access and management.

Another argument is that the interoperability problems between different MMOG that many architects current experience, can be resolved in the near future. Architect A believed that market pressure would eventually push for the creation of a standardised avatar, which can walk in different MMOG for real-world architectural design. As a result of that, architects and Construction IT specialists would no longer need to create several avatars, confined by different rules and conditions of various MMOG, but only one avatar, the same rules and conditions applying across the whole spectrum of MMOG platforms.

### 7.3.3 Better Collaboration between Stakeholders

Architects and Construction IT specialists again highlight that design tools in the AEC industry are mainly effective to meet the needs of professional architects rather than engaging non-professionals. Traditional tools developed at early-stage design have not been effective in engaging non-professional stakeholders. The reason for that is because the knowledge, skills and backgrounds of non-AEC-professionals, such as clients and end-users differ widely. To find a universal tool to help non-professionals with different levels of architecture knowledge to fully understand the issue and design challenges in a highly professional practice is difficult. As a result, very few design tools are available to effectively empower non-specialists in the AEC industry, to contribute as much as they can in the design process.

With a more natural and intuitive interface to access and interact with other forms of data stored in a professional architectural design database, MMOG have the potential to empower non-professionals (such as the clients and end-users) to actively contribute to the design process. MMOG therefore can bridge the gap between professional architects and non-professional clients and end-users to allow better contribution. One architect interviewed gave the example of a virtual kitchen in a big office he designed in *SL* for a real-world project. After inviting end-users to virtually inhibit the virtual office building a design problem in the kitchen was identified.

Architect C argued that things like this could be important at early-stage design. More and more computer-generated architectural design tools have some level of intelligence to ensure fewer errors are made by architects at early-stage design. However, errors incurred by the group interaction of end-users in the actual space cannot yet be fully calculated and predicted by computer tools. Allowing end-users actually to occupy and explore the design at early stage, this process itself becomes intuitive. The natural interface provided by MMOG helps most non-professional stakeholders to easily understand the design and therefore become more involved.

### 7.3.4 User-centred Design Environment

All respondents agreed that currently, due to the time, training and resources needed to make the best use of MMOG in concert with other visualisation tools at RIBA early Design Stages, it is not yet worthwhile to use MMOG in all types of construction projects. Rather, at this moment, it is more worthwhile to use MMOG for architectural projects, which need to fully consider the needs of many end-users or clients in a more user-centred design environment.

MMOG are most effective to assist the early-stage design of projects where the success of the design largely relies on full consideration of very many end-users. For example, hospitals, community centres, education facilities (including museums, libraries, colleges or university buildings), shopping centres, train stations, airports, hotels or sports stadia. It may not be useful to small single residential projects.

Architect B gave the example of the great success of Starwood (owners of the Westin, Sheraton, and W hotel chains) who created an Aloft-style hotel model in *SL* as a prototype to engage multiple end-users to improve the design quality in 2006. Various tests have been conducted among the *SL* community to test the design and concept of these new stylish and affordable hotels. For example, they observe how people move around through the virtual space of the hotel; try to find out any specific areas or types of furniture which will be more likely to engage residents of the hotel. One of the interesting findings is that most *SL* residents asked why the bathrooms in the virtual hotels were missing. Because of this feedback, the architect of the virtual hotel added a sliding glass door in the bathroom. This change of design was also applied to the construction of the real-world Aloft hotels. In 2008, a virtual-world prototyped Aloft hotel was completed and opened to the public in New York; all the design of the hotel was based on the public consultation from the *SL* community. It is said that by 2012, another 500 Aloft hotels will be constructed across the USA with the feedback collected from testing end-users in *SL*.

In another example, *SL* has been used to prototype real-world ecological design. Some architects have used virtual architecture competitions to collaborate with others for the best design ideas on eco-missions in their real-world project. For example, Real Urban Planner Z said that he was commissioned by the Chinese Government to design an "Eco-friendly Community" in one of China’s bamboo forests. Instead of doing it on his own, Architect Z replicated the whole construction site precisely in *SL* and then launched an *SL* architecture competition inviting students, architects and anyone around the world to contribute to the design with the requirement that contributions had to be ecological and “promote the use of hybrid materials, with a minimum of 25% bamboo.” The final winner was also allowed to assist in the “real-world construction of the winning green structure”.

The case of the Aloft hotel and the ecological competition are two of the many examples real-world architects mentioned during their interviews in *SL*. They argue that *SL* has the capacity to effectively seek feedback from massive numbers of end-users or clients who cannot be easily engaged otherwise in real life. Therefore, MMOG should be used in big architectural design projects, which are in a user-centred design environment.

### 7.3.5 Quality Rendering of Design

Many architects interviewed in both the real world and in MMOG stressed the importance of the design tool's ability to produce good quality rendering so that when the early stage of design is complete, the renderings of the design can still be used at more detailed design stages. When interviewing 20 architects who are using MMOG to design real-world architecture, many of them are worried about the quality of rendering they can produce with *SL*. According to the interview results from top experts using MMOG for real-world architectural design, it is possible to produce good quality rendering of the architectural project.

All objects created in *SL* are made up of a range of "PRIMS" (primitive shapes that can be linked, twisted, cut and combined in all possible ways) and texture (2D visuals which act like a wallpaper, which can be pasted to the surface of any object). The details of the texture determine the "PRIMS" it needs. The more detailed the rendering is, the more "PRIMS" are required to create it, and the longer it takes for the *SL* online server to render. Therefore, the visual rendering of most buildings in *SL* is not good enough for real-world architects. Two out of five architects and Construction IT specialists interviewed agree that they were initially worried about the quality of rendering for their virtual modelling in *SL* before its production. "We were worried if we could get any decent architectural rendering out of this process", said Architect B, a view echoed by three other experts interviewed.

In order to create a virtual building in *SL*, architects need to create their own 3D geometric shapes and then paste relevant texture onto the surface of the shapes to add more realism to it. The problem is that it takes a long time to create a virtual building in *SL* simply from the "PRIMS" and the basic textures available in a new user's account. However, as a user-generated community, many free objects created by other residents are available in *SL* for new residents to use.

The reason for this is two-fold: the community culture in *SL* is based on sharing and supporting each other in the virtual world. Therefore, many advanced users of *SL* are willing to share the virtual objects they created with the rest of the *SL* community so as to attract more visits for specific virtual venues in *SL*. This is good for architects who want to save time building models in *SL*. They can base their design on a similar virtual building model created by other people and adjust it to become their own virtual model. Or more often, they create the outline of their own virtual building model, but copy and paste different parts of the buildings (e.g. doors, windows, fences, ceiling, floors and walls) created by other people. Many architects interviewed spent lots of time visiting various popular plots in *SL* collecting different types of free furniture and textures to enrich their own collection of materials, to enable them to build virtual models in *SL* quickly. However, most of the time, the rendering quality of those free objects are not high enough to meet the requirement of professional architectural design and therefore architects may need to change the texture of these objects with higher quality details. The good thing is that *SL* also provides a function to allow users to import any JPEG format of photography (a commonly used compression for digital images) to *SL* with the cost of 10 linden dollars. In order to improve the low quality of texture and rendering generated from *SL*, most architects interviewed use external software to generate high-quality rendering to be imported into *SL* for more realistic rendering.

There are three ways architects can enhance the representation details of the texture in *SL*. Firstly, various industry visualisation tools have been used to import high-quality images into *SL*. Maya, Revit and AutoCAD are some of the most popular tools used by architects to achieve better rendering in *SL*. They always produce the various rendering of their projects through such professional design software. Therefore, it is convenient for them to import those ready-made renderings into *SL* and to use them as texture to improve the quality of *SL* rendering.

Secondly, professional design tools such as Photoshop were frequently used to help enhance the texture quality. Many design tools are used to create customised textures. Some of the programs mentioned include: Gimp; Photoshop; Genetica; Filter Forge; PhotoSEAM; ArtRage 2; Context Free; Paint.NET; Texture Maker; AvPainter; Texture Convertor 2 and imageSynth2. However, Photoshop is the most frequently used. Many architects have already purchased the license to use Photoshop in real life, and they are familiar with how to use Photoshop to create customised texturing. The levels of details of the texture can also be easily controlled by architects. For example, Architect B used Photoshop to create a texture, which mimics the reflection of neighbouring buildings to be put onto virtual windows to add more realism to the model.

Thirdly, architects can buy high-quality rendering of texture in *SL* created by other artists. Photoshop and other professional design software are useful to create all the varieties of texture require by architects to make virtual projects more photorealistic. Nevertheless, architects want to make the visualisation process in *SL* faster. Therefore, some architects find it easier and more time-effective just to buy a big collection of detailed textures and use them for various projects. For example, Architect A said, "I once bought a pack of 1,000 highly detailed textures in an *SL* store, it cost me only five US dollars, which I can use for at least several months for various virtual projects. It saves me a lot of time using Photoshop trying to create my own ideal textures,"

Fourthly, architects import photos taken from the real world directly as texture. The high quality of the rendering of the building visualisation is mostly associated with how much it looks like a photo of real-world buildings. Therefore, creating and buying textures, which only simulate the visual attributes of real-world objects, seems to be limited. As a result, some architects use free photos from online databases to create photo-generated textures for their *SL* virtual buildings. Architect B designed a virtual city in Mexico in *SL*, which includes ancient Aztec architecture. Architect B downloaded photos of the columns with detailed Aztec designs from Flicker.com and then used Photoshop to render them into the right scale and import them into *SL* to be pasted onto the virtual columns he created. The result was that “the texture of the Aztec model is rather photorealistic. It looks exactly like the real one it mimicked”.

With all methods adopted to improve the rendering of the virtual architecture, most of the architects and Construction IT experts are satisfied with the quality of the rendering if it is only shown to clients. “The result turned out to be that the rendering produced by *SL* architectural model is good enough to be displayed to the clients”, Architect A said. *SL* “shows some beautiful rendering. You can certainly make some acceptable architectural renderings”, said Architect B. Therefore, through importing rendering into *SL* from other sources, it is possible to create high-quality rendering.

However, there is also a problem. Sometimes, the quality of the rendering is so high it makes the file too big and when imported into *SL* there are resultant hardware or *SL* crashes. The only way to solve it is to make the file smaller so that the architects’ own computers or *SL* software on their computers can accommodate it. However, if they do that, the quality of the rendering has to be reduced. Besides, architects who have powerful computers have also had trouble with the *SL* online servers. The whole virtual world created by users in *SL* is supported by powerful online servers managed by Linden Lab, creator of *SL*. As a result, the numbers of “PRIMS” allowed on each virtual island is limited so that it will not easily crash those online servers whose capacity is also limited. The more detail architects want to go into, the more “PRIMS” will be consumed on the land, and the more pressure it will put on those online servers. Therefore, it is argued by many of the architects interviewed that AEC professionals need to strike a balance of how much detail they want to go into and the level of details should not result in poor performance of the *SL* system on their own computer and the online servers. This might be an issue for using *SL* at the detailed design stages. However, for most architects interviewed, they agreed that early-stage design does not require such level of detail. As a result, a more basic rendering of the models created by MMOG would not compromise their utility at an early design stage.

## 7.4 Revised Guidance

Based on the findings from the validation, the guidance was revised to include extra information identified during the validation process. The first part of the initial guidance Figure 7.1 which summarises various tools used at early-stage design remains the same. The revised part of the guidance is the second part: when and how to use MMOG. The revised part of the guidance can be found in the following:

1. Experienced architects have successfully developed a process to combine 2D sketches, Google SketchUp and MMOG to augment their early-stage design process to better engage non-professional stakeholders. This process has proved to be cheap, quick and simple, which helps to generate innovative design ideas at an early stage, to enhance their quality.

2. The study has determined that MMOG currently satisfy the requirement of stages C and D in the RIBA Plan of Work. This is because these stages are when the concept is developing and the input of a range of extended stages is needed to inform the design decisions. Stage D adds details whilst decisions are still being made; the major part of the design is frozen at this point. Hence, the greatest opportunity for stakeholders' input is during these two stages.

3. Better use of MMOG depends on the development of relevant IT. MMOG

could also become a natural interface to access other forms of data in a BIM to be used throughout all RIBA Stages depending on its interoperability with traditional visualisation tools.

4. MMOG are a useful collaboration tool when used at early-stage design.

5. MMOG have the potential to be a useful way to engage non-professional stakeholders. This is because of their ability to represent complex building data in an easily accessible and understandable manner. Thus, they allow stakeholders to interact more fully in the architectural design process. This is mainly achieved through more realistic group interaction in the virtual environment and easy access to the virtual model.

6. MMOG offer the greatest potential for projects where multiple stakeholders need to be involved and consulted through the design process.

## 7.5 Summary of the Chapter

This chapter examines the main findings of this research against relevant literature review of the thesis. These findings include how early-stage design is managed, MMOG have advantages over other design tools at early-stage design on interaction, collaboration and limitation. Guidance to show how MMOG and other visualisation tools could be used to augment the current RIBA Plan of Work is proposed and validated. From the validation, another finding is identified, that MMOG have the potential to be used throughout all stages of a construction project. This is mainly because MMOG provide a more intuitive and natural interface for both professional and non-professional stakeholders in the AEC industry to access and manage data collected through other design tools. However, as an emerging tool, which is just starting to be explored and utilised by professional architects at early-stage design, it is more useful to use MMOG in projects which are based in a user-centred design environment. With this analysis, this chapter achieves five research objectives:

1. Review current tools used in early-stage design.
2. Review research and practice pertaining to visualisation and the building design process in order to identify any deficiencies in supporting early-stage design decisions.
3. Examine the features of MMOG and their suitability for informing early-stage design.
4. To test the effectiveness of MMOG in simulating real-world environments.
5. Develop and validate guidance on how and when MMOG should be deployed to best inform early-stage design.

Also, four research questions of this thesis are answered. The main issues identified at early-stage design include a complex decision-making process, the lack of innovation, and a communication gap between professional and non-professional stakeholders. These issues have negatively impacted early-stage design. These issues are found in Section 2.1 Early-stage Design and Section 2.2 Visualisation Tools used at Early-stage Design, in Chapter 2; and Section 4.1 How do Architects Manage Early-stage Design, in Chapter 4.

2D sketches, physical models, Google SketchUp and basic CAD are the main forms of visualisations used in early-stage design, with BIM and Virtual Reality also used. This is discussed in Section 2.2 Visualisation Tools Used at Early-stage Design in Chapter 2 and Section 4. 2 The Way Architects Manage Early-stage Design in Chapter 4.

Currently, MMOG can complement existing visualisation techniques; this is discussed in many parts of the thesis. For example: in Section 5. 3 The Potential of *SL* over

Current Practice of Chapter 5; in Chapter 6 where the results of the test are presented with most people considering the MMOG model as realistic, but with divided views on whether this interaction can be considered as real-time, real-life and truly immersive interaction; in Chapter 7 where the guidance is developed, tested and validated to identify how to best use MMOG in concert with other forms of visualisation tools at early stage.

According to the findings, MMOG such as *Second Life* can be used to better inform building design if they are used in user-centred design environments, to improve collaboration between all stakeholders, especially to engage non-professional stakeholders, at RIBA Design Stages C and D. This is identified in Chapter 7 with the development, test and validation of the guidance to identify best methods to employ MMOG and other visualisation tools at early-stage design.

# Chapter 8

# 8.0 Conclusion

This Chapter reflects on the research aim, objectives, research questions and methodology, with the main knowledge contribution identified. Also, the limitations of this research and recommendations for future research are also discussed.

## 8.1 Overview

This research has explored the potential of using MMOG to augment early-stage design in concert with other existing visualisation tools. The review of literature revealed an absence of design tools that could effectively manage the complex decision making at early-stage design, bridge the communication gap between professional architects and non-professional stakeholders such as clients and end-users, and address the lack of innovation. As a result, the aim of this research was to explore the potential of MMOG for informing the early-stage design process. The research objectives are as follows:

1. Review current tools used in early-stage design.
2. Review research and practice pertaining to visualisation and the building design process in order to identify any deficiencies in supporting early-stage design decisions.
3. Examine the features of MMOG and their suitability for informing early-stage design.
4. To test the effectiveness of MMOG in simulating real-world environments.
5. Develop and validate guidance on how and when MMOG should be deployed to best inform early-stage design.

Based on the research aim and objectives, a mixed-methods research design was developed. The research adopts a qualitative approach with both inductive and deductive research process. The methodological position for this study was "Critical Realism", which can help to "deconstruct common sense and empower people to change reality", by collecting data from both real-world interviews and online interviews in the virtual world of MMOG to guarantee a more "credible" results for data collection and analysis (Houston, 2005: 7).

On the ontological level, it used objectivist ontology. On an epistemological level, this research is based on the following paradigms. Firstly, it adopts the position of an interpretivist epistemology, which holds that knowledge of the world is intentionally constituted through a person's lived experience (Weber, 2004). In this research, how useful a MMOG is to support the early stage of architectural design relies on the way different people experience and appreciate MMOG, which is the position advocated by an interpretivist epistemology. Secondly, it adopts the position of a subjectivist epistemology. Subjectivist epistemology postulates that "values are constituted by subjects" (Rønnow-Rasmussen, 2003: 261). The values of using MMOG to augment early-stage design are constituted by the attitudes of different stakeholders in the AEC industry. Stakeholders with different interests, background, knowledge, experience and IT skills in the design process access the value of MMOG differently, which is the position advocated by a subjectivist epistemology. Thirdly, this research is based on an emic epistemology. The emic aims to understand phenomena from the "insiders' view" (Holloway, 1997: 53). This research aimed to elicit information from different stakeholders who were insiders to the architectural design process on whether MMOG should be applied to early-stage design, where using an emic epistemology was useful. This study used qualitative semi-structured interviews. The construction of the questionnaires and the sampling strategy are presented. The selection of the interviewees is described, in terms of both the individuals and the methods of selection. Template analysis is presented as the main data analysis technique.

The methodology is validated through data triangulation, investigator triangulation, and member checking to ensure the quality of this research. In the data collection process, data triangulation is used to collect information from a wide range of stakeholders at early-stage design, who have different levels of expertise using MMOG to assist this process. This helps to give a broader perspective to answer the research questions. Member checking can be used in the data collection process. It entails a process where the researcher consistently restates, paraphrases, or summarises the information received from a participant to ensure that what was recorded is correct. The respondents can edit, clarify, elaborate or delete the information taken by the researcher to reflect their views, feelings and experience (Doyle, 2007). In this thesis, member checking is used as part of each interview conducted, where participants verify the key points summarised by the researcher for each of the questions they answered. This helps to provide a complete, accurate, and fair interpretation of the data. In the data analysis process, investigator triangulation was used to reduce the bias caused by using only one analyst to interpret the data. Two lecturers experienced in template analysis and interested in the research topic of this thesis were invited to participate. The templates produced by the investigator and the researcher were compared with changes being made to form a robust analysis of the data. In the reporting process, investigator analysis was also used to validate the initial guidance produced to guide architects to better use MMOG. As discussed in Sections 7.2.2, 7.3, and 7.4 in Chapter 7, the combination of these three validation techniques ensures the validity, reliability and credibility of the data collection and data analysis processes.

## 8.2 Reflection on Research Questions

The original questions posted in Chapter 1 were:

Q1: What are the issues which negatively impact on early-stage design?

Q2: What forms of visualisation are used in early-stage design and what are their limitations?

Q3: Can MMOG complement existing visualisation techniques?

Q4: How can MMOG such as *Second Life* be used to better inform building design?

These led to the development of both the research objectives and methodology employed during the research. The questions have largely been answered through the course of this research, such as in Section 7.5 Summary. However, other similarly pertinent questions have also arisen. They include issues on training, cost and user-acceptability of MMOG in what is still a predominantly traditional industry sector. These issues need further study if researchers are to address them. However, the research questions postulated for this research provide opportunities for this further study.

## 8.3 Contribution to Knowledge

The extant literature identified in this thesis covers the issues of early-stage design of the architecture (Section 2.1.3, including the complex decision-making process, the lack of innovation, communication gaps between professional and non-professional stakeholders), issues of various early-stage design tools (Section 2.2), the application of MMOG (Section 2.3) and its potential in augmenting architectural design (Sections 2.4 and 2.5). In comparison with the extant literature, the contribution to knowledge of this thesis is as follows:

- ❖ This research reveals the ineffectiveness of current early-stage design tools in engaging non-professional stakeholders. Most of the current visualisation tools used at early stage are developed to assist professional stakeholders. Few of them have proved to effectively engage non-professional stakeholders such as clients and end-users in the design process. It is more useful to use MMOG in a user-centred design environment. This can be defended by the results discussed in Section 4.2 Chapter 4.

- It reveals the potential of MMOG to overcome the weaknesses of existing early-stage design decision supporting tools. MMOG enables a massive number of real-world end-users to interact with each other in the virtual space, at a low cost and with easy accessibility. This can potentially allow a more effective and quick decision-making process at the early stage of design. This is shown by the results discussed in Sections 5.2 and 5.3 of Chapter 5. These findings show that MMOG can be used to augment early-stage design.

- It reveals a set of barriers inhibiting the wider uptake of MMOG by architects. Due to IT issues, industry regulations, education of prospective architects, and the likely changes of decisions being generated by prospective clients, there is still a long way to go before industry-wide application of MMOG at early-stage design can become possible. This is demonstrated by the results discussed in Section 5.4 of Chapter 5. This finding shows various barriers architects need to address to effectively adopt MMOG at early-stage design.

- It identifies the best point at which to deploy MMOG during the early-stage design process. If a MMOG is considered as a design tool, it is found that RIBA Stages C and D are the optimal stages to use a MMOG. In the near future, if a MMOG is considered as a natural computer interface, it can potentially be used throughout the whole lifespan of the RIBA Plan of Work. That is because MMOG can become a more natural interface to access other forms of data to assist the design process. This is proved by the results from Section 7.4 of Chapter 7. This finding shows that MMOG can be used as a useful early-stage design tool at RIBA Design Stages C and D. Also, it is potentially possible to use a MMOG as a natural computer interface to access other forms of data throughout the RIBA Design Stages.

- It highlights a process which architects developed to combine 2D sketches, Google SketchUp and MMOG in supporting the early-stage design process. This process can better engage both professional and non-professional stakeholders and therefore has proved to be a cheap, quick, simple and innovative way to enhance the quality of early-stage design. This is shown by the results from Section 7.4 of Chapter 7. This finding demonstrates an easy process architects can use to deploy a MMOG to augment various early-stage design tools, and therefore better engage non-professional stakeholders.

The contribution to knowledge made by each of the four research questions originally proposed in Section 1.2 is given below:

Q1: What are the issues which negatively impact on early-stage design?

Early-stage design is a complex decision-making process. This has resulted in communication issues between professional and non-professional stakeholders. Without effective interaction, it is not easy to generate innovative design solutions at an early stage. The difficulty in effectively engaging non-professional stakeholders is the main factor which negatively impacts early-stage design. It is postulated that the ability to visualise early-stage design information would significantly help overcome these issues.

Q2: What forms of visualisation are used in early-stage design and what are their limitations?

Due to their simplicity and easy application, 2D sketches, physical models, Google SketchUp and basic CAD are the main forms of visualisation tools used in early-stage design. The limitation of 2D sketches is that non-professional stakeholders cannot always understand them. The limitation of physical models is that they can be expensive and time-consuming to produce. The limitation of Google SketchUp is that the rendering of the model is not realistic. Also, the free 3D models available online at the 3D Warehouse are limited. Not all architects feel comfortable to use basic CAD in early-stage design. They are worried that using basic CAD could limit the creativity of the design and result in poor design. More complex tools, such as the use of Virtual Reality and the emergent use of BIM, are available but are currently limited to large, complex projects due to cost and training issues.

Q3: Can MMOG complement existing visualisation techniques?

Currently, MMOG can complement existing visualisation techniques. The reasons for this are their ability to engage non-professional stakeholders in the design process, and their easy accessibility (for example, anyone with an Internet connection can use a MMOG). They have the ability to enable massive multiple human interaction in a realistic way through the use of avatars. This is an advantage because most current tools cannot accurately predict how effective the virtual design is in a user-centred design environment.

Q4: How can MMOG such as *Second Life* be used to better inform building design?

The work of this study has produced guidance for the use of a MMOG such as *Second Life* to better inform building design, for example:

❖ Experienced architects have successfully developed a process to combine 2D sketches, Google SketchUp and MMOG to augment their early-stage design process to better engage non-professional stakeholders. This process has proved to be cheap, quick, and simple, which helps to generate innovative design ideas at an early stage to enhance their quality.

- The study has determined that MMOG currently satisfies the requirement of stages C and D in the RIBA Plan of Work. This is because these stages are when the concept is developing and the input of a range of extended stages is needed to inform the design decisions. Stage D adds details whilst decisions are still being made; the major part of the design is frozen at this point. Hence, the greatest opportunity for stakeholders' input is during these two stages.

- MMOG require the development of improved IT infrastructure to underpin building design more efficiently. MMOG could also become a natural interface to access other forms of data in a BIM to be used throughout all RIBA stages depending on its interoperability with traditional visualisation tools.

- MMOG are a useful collaboration tool when used at early stage design.

- MMOG have the potential to be a useful way to engage non-professional stakeholders. This is because of their ability to represent complex building data in an easily accessible and understandable manner. Thus, they allow stakeholders to interact more fully in the architectural design process. This is mainly achieved through more realistic group interaction in the virtual environment and easy access to the virtual model.

- MMOG offer the greatest potential for projects where multiple stakeholders need to be involved and consulted through the design process.

## 8.4 Limitations

Despite the contributions to knowledge, there are also limitations this research needs to acknowledge. These relate to methodology, testing of RIBA Plan of Work, the examples chosen to demonstrate the potential of MMOG, and the limitation of the researcher.

### 8.4.1 Limitations of the Methodology

As in all research, there have been several limitations of the methodology. Firstly, the anonymity of the researcher when using *SL* had its limitations. The researcher found it useful to collect data in *SL* without revealing her real-life identify and the purpose of the research. Due to the commercial sensitivity and popularity of anonymity in *SL*, real-life architects who are using MMOG for real-life architectural solutions are not always willing to share their commercial projects with researchers. The researcher registered three different avatars with different names and characters in *SL*. When using the first avatar to collect data, the researcher revealed her real-life identity, but got limited response from the architects' community in *SL*. Many architects working on real-life commercial projects did not want to reveal the designs and the details of their projects for fear that their competitors in real life might use the information to compete against them. As a result, the researcher kept her true identity hidden when using the other two avatars to do interviews on line. This helped the researcher to identify the active architects' community in *SL* and helped to build up links with architects who became the participants of interviews. However, there were also problems with this anonymity. Some architects require people to reveal their true identify before any architectural activities can be conducted. However, hiding one's true identity worked better to help the researcher elicit useful information from participants.

There are also some problems identified in the research methodology. The sampling of participants is a big issue in this research. Firstly, the population studied is a "significantly biased convenience sample". Architects working in MMOG such as

*Second Life* are "not a representative sample of the general population". They tend to be younger, more educated and mainly males (Yellowlees and Cook, 2006: 536-537). Therefore, it is difficult to obtain other demographic populations' views on the architectural use of MMOG such as *Second Life*.

### 8.4.2 Limitations of Tested RIBA Stages

This research created a virtual model in a MMOG and through testing examined how it supported the design decision making at RIBA Design Stage L, post-occupancy. Therefore, the results only reveal some of the potential issues of using MMOG at different RIBA stages. This research is a three-year project to explore the potential of using MMOG to augment the current RIBA design stages in concert with other visualisation design tools in the AEC industry. Due to the limitations of time and real-world design projects available at the time of the data collection, a virtual model mimicking the real world hub of the Civil and Building Engineering School of Loughborough University was created to help test how this MMOG could be used to engage different stakeholders of this building at the post-occupancy stage for the reconfiguration of the space. The research could be more useful if a more user-centred architectural design project of appropriate time scale was available for the data collection process. In this way, MMOG could be tested throughout the whole lifespan of RIBA stages to see how it could augment current visualisation tools.

## 8.5 Future Research

Due to the above limitations, the following recommendations are made for future research.

- ❖ To avoid the issue of anonymity of the researcher, it is recommended that future research should explore the opportunities to work with real-world architectural companies to use MMOG at early-stage design of a real-world project from Stages A to D to test how effective MMOG are. In that case, there would be no issue about the anonymity of the researchers and the architects interviewed. Research participants on both sides could be as open as possible to discuss the benefits and issues involved with using MMOG to augment the early-stage design.

- Most of the 30 architects interviewed in this research are from small and medium-sized architects' firms. Also, the research is not structured in a way to compare how the size of the architects' firms may impact on how new IT applications such as MMOG can be implemented. In future research, it is better to work with different sizes of real-world architects' firms (small, medium, and large) to test whether the effectiveness of using MMOG at early-stage design may differ due to the size of the company.

- The context of this research covers mainly the UK, although it also reflects the international situation in America, Australia, Asia and Europe. Three out of five main datasets in the research such as all 30 architects without MMOG experiences, the 48 professional and non-professional stakeholders, and the five experienced architects and Construction IT specialists are all based in the UK. Therefore, this research domain is the UK. However, most of the MMOG online collect online data mainly covered the UK and America (the USA and Brazil), but also including Australia, Africa (Egypt), Asia (Japan, South Korea) and Europe (Sweden). Recommended future research should also examine the application of MMOG in countries other than the UK, to identify if there is any country-specific issue in making the best use of MMOG at early-stage design.

- This research chooses *Second Life*, a general platform of MMOG, as an example to test the effectiveness of MMOG at early-stage design. *Second Life* is only one of the many MMOG available. Future research should look at using different types of MMOG to compare and find out which MMOG available at this moment is most effective in supporting real-world architectural design process. Researchers who have computer-programming skills could also look at using various tools available to create their own MMOG and customise it to cater to the needs to both AEC professional and non-professional stakeholders.

## 8.6 Final Comments

This research explored the potential of using MMOG as an early-stage design tool in a user-centred design environment with guidance produced to recommend best use, using data from architects from small and medium-sized UK companies. As MMOG are a new area for architectural research, it is hoped that this research will be a starting point for identifying some of the strengths and limitations of such applications. Nevertheless, increased use of MMOG (or any other tool for that matter) does not necessarily imply that they are adding value to the process. Further metrics need to be developed (other than just use) which determine the “value-added” of such tools.

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# Appendices

## Appendix One:

## Template Analysis Template No. 1

| What forms of visualisations are used in early-stage design and what are their limitations? | | |
|---|---|---|
| **Theme** | **Sub-theme** | **Data extracts relevant to each sub-theme** |
| 1. 2D sketches | 1.1 Trained to use | 1.1.1 "Must-have" skill for architects<br>1.1.2 Architecture tradition<br>1.1.3 Effective visualisation tool for architects |
| | 1.2 Creative design idea | 1.2.1 Selective information<br>1.2.2 Sketch most important design data<br>1.2.3 Can be interpreted in multiple ways |
| | 1.3 Share ideas with colleagues | 1.3.1 Should be industry standard to be understood |
| | 1.4 Share ideas with clients | 1.4.1 Difficult for laymen to understand |
| 2. Physical models | 2.1 Share ideas with clients/ users | 2.1.1 RIBA stage C to show clients about the landscapes<br>2.1.2 RIBA stage D gives clients a 3D view of the design<br>2.1.3 RIBA stage E to win the tender of the construction project |
| | 2.2 Test out design ideas | 2.2.1 RIBA stage B to try out various ideas and communicate those ideas to architects themselves |
| | 2.3 Issues | 2.3.1 Cost: expensive<br>2.3.2 Static model: cannot be re-used<br>2.3.3 Time: consuming<br>2.3.4 Google SketchUp: better tools than physical models |
| 3. Google SketchUp | 3.1 Simple and quick to use | 3.2.1 As quick as using a pen<br>3.2.2 Google Warehouse<br>3.2.3 Short training period |
| | 3.2 Good interoperability | 3.3.1 CAD<br>3.3.2 BIM |
| | 3.3 Issues | 3.3.1 Rendering of the model is not realistic<br>3.3.2 Limited free 3D models at the 3D Google Warehouse<br>3.3.3 Most architects only use it at early stage |
| 4. Basic CAD | 4.1 Advantages | 4.1.1 Reduce the time to transfer 2D drawings to computer visualisation based detailed design<br>4.1.2 Communicate with engineers who mostly use CAD in their projects from the beginning |
| | 4.2 Disadvantages | 4.2.1 Early architectural design process is mainly about generating design ideas based on the brief.<br>4.2.2 Detailed CAD may hinder the right design idea from emerging. |

# Appendix Two:
# Template Analysis Template No. 2

<table>
<tr><th colspan="3">Initial template for the whole data set</th></tr>
<tr><th>Theme</th><th>Sub-theme</th><th>Data extracts relevant to each sub-theme</th></tr>
<tr><td rowspan="4">1. The Virtual School Test</td><td>1.1 How realistic is the virtual representation?</td><td>1.1.1 All participants recognise the virtual model as replicating the world School<br>1.1.2 Non-professional stakeholders are satisfied with SL architectural design representation.<br>1.1.3 Professional stakeholders are not satisfied with the representation details of SL architectural design</td></tr>
<tr><td>1.2 Evaluate human interaction in SL</td><td>1.2.1 Most participants consider the interaction in the virtual space as real time<br>1.2.2 One third of participants agreed that virtual interactions in SL are “real life”<br>1.2.3 People are equally divided on whether the SL virtual interaction is “truly immersive”</td></tr>
<tr><td>1.3 How MMOG could inform better design?</td><td>1.3.1 Professional stakeholders consider SL to have potential for architectural design<br>1.3.2 It takes time for people to explore the best use of the new IT, such as MMOG and SL<br>1.3.3 The more people use the tools, the more confident they become about their potential and make the best use of SL for architectural applications.</td></tr>
<tr><td>1.4 Compare SL and other forms of visualisation</td><td>1.4.1 The use of the space with an avatar<br>1.4.2 The massively multi-player interaction<br>1.4.3 Better and easier global accessibility<br>1.4.4 SL is not developed for the AEC industry<br>1.4.5 SL involvement can be “time consuming”</td></tr>
<tr><td rowspan="3">2. Real-world architect interviews</td><td>2.1 The way architects manage early-stage design</td><td>2.1.1 Sketches with pencils<br>2.1.2 Physical models<br>2.1.3 Google SketchUp<br>2.1.4 Basic CAD</td></tr>
<tr><td>2.2 The potential SL has over current practice?</td><td>2.1.1Better accessibility<br>2.2.2 Better client/end-user engagement<br>2.2.3 Real-time, multi-user interaction</td></tr>
<tr><td>2.3The reasons real world architects are not using SL</td><td>2.3.1 The AEC industry: issues of innovation<br>2.3.2 Students: lack of SL architectural education<br>2.3.3 Clients: issue of user generated architecture<br>2.3.4 Architects: Interoperability issues</td></tr>
</table>

| | | |
|---|---|---|
| | 2.4. Share ideas with clients | 2.4.1 Difficult for laymen to understand |
| 3. *SL* for real-world architecture | 3.1 Architects' design experience | 3.1.1 Viable real-life architectural design<br>3.1.2 Good quality rendering of design<br>3.1.3 Easy design tool<br>3.1.4 Quick architectural design<br>3.1.5 Design collaboration<br>3.1.6 Cost effective<br>3.1.7 Transcend language barrier<br>3.1.8 Transcend boundary of cultural difference |
| | 3.2Non-professional Stakeholder experience | 3.2.1 Holistic, dynamic, immersive design<br>3.2.2 Understand the architectural proposal<br>3..2.3 User-generated architectural design |
| | 1.3 Issues of using SL for real-world architecture | 3.3.1 IT limitations of *SL*<br>3.3.2 Holistic design concerns from architects<br>3.3.3 Finding the right project and client not easy<br>3.3.4 End-user engagement is a challenge<br>3.3.5Time consuming to explore *SL* architecture |
| 4.Future use MMOG for architecture | 4.1 Originality and imagination in virtual architecture | 4.1.1 Virtual architecture is not limited by real-world physics<br>4.1.2 Virtual architecture is created through virtual methods<br>4.1.3 Virtual architecture is a lab for architectural vision<br>4.1.4 Virtual architecture can be actualised into the real world<br>4.1.5 Virtual architecture and intelligent building<br>4.1.6 3D immersive information hub |
| | 4.2 Virtual architecture Is a new entity in its own right | 4.2.1 More social activities in virtual architecture<br>4.2.2 More jobs for real-world architects<br>4.2.3 Empower experienced architects<br>4.2.4 Marketing tool |
| | 4.3 Virtual architecture is sustainable | 4.3.1 Sustainable virtual architecture<br>4.3.2 Issues of sustainable virtual architecture |
| 5. Validation of the framework | 5.1 Natural interface to access other forms of data | 5.1.1 MMOG is a more natural and intuitive interface to people<br>5.1.2 Other forms of visualisation tools are not intuitive enough for people to use |
| | 5.2 Better collaboration between stakeholders | 5.2.1 Most current visualisation tools are developed for professional stakeholders<br>5.2.2 Few tools are available to effectively engage non-professional stakeholders |
| | 5.3 Useful in projects involving lots of end users | 5.3.1 The usefulness of MMOG is project-based<br>5.3.2 The usefulness of MMOG is stage-based<br>5.3.2 The example of Aloft hotel |

# Appendix Three:
# Template Analysis Template No. 3

| Revised Template for the Whole Data Set | | |
|---|---|---|
| Theme | Sub-theme | Data extracts relevant to each of the sub-theme |
| 1. Real-world architect interviews | 1.1 The way architects manage early-stage design? | 1.1.1 Sketches with pencils<br>1.1.2 Physical models<br>1.1.3 Google SketchUp<br>1.1.4 Basic CAD |
| | 1.2 The potential *SL* has over current practice? | 1.2.1 Better accessibility<br>1.2.2 Better client/end-users engagement<br>1.2.3 Real-time, multi-user interaction |
| | 1.3 The reasons real-world architects are not using *SL* | 1.3.1 The AEC industry: issue of innovation<br>1.3.2 Students: lack of *SL* architectural education<br>1.3.3 Clients: issue of user-generated architecture<br>1.3.4 Architects: interoperability issues |
| | 1.4. Share ideas with clients | 1.4.1 Difficult for laymen to understand |
| 2. *SL* for real-world architecture | 2.1 Architects' design experience | 2.1.1 Viable real-life architectural design<br>2.1.2 Good quality rendering of design<br>2.1.3 Easy design tool<br>2.1.4 Quick architectural design<br>2.1.5 Design collaboration<br>2.1.6 Cost effective<br>2.1.7 Transcend language barrier<br>2.1.8 Transcend boundary of cultural difference |
| | 2.2 Non-professional stakeholder experience | 2.2.1 Holistic, dynamic, immersive design<br>2.2.2 Understand the architectural proposal<br>2.2.3 User-generated architectural design |
| | 2.3 Issues of using *SL* for real-world architecture | 2.3.1 IT limitations of SL<br>2.3.2 Holistic design concerns from architects<br>2.3.3 Finding the right project and client not easy<br>2.3.4 End-user engagement is a challenge<br>2.3.5 Time consuming to explore *SL* architecture |
| 3. The Virtual School Test | 3.1 How realistic is the virtual representation? | 3.1.1 All participants recognise the virtual model as replicating the world School<br>3.1.2 Non-professional stakeholders are satisfied with *SL* architectural design representation.<br>3.1.3 Professional stakeholders are not satisfied with the representation details of *SL* architectural design |

| | | |
|---|---|---|
| | 3.2 Evaluate human interaction in *SL* | 3.2.1 Most participants consider the interaction in the virtual space as real time.<br>3.2.2 One third of participants agreed that virtual interactions in *SL* are "real life"<br>3.2.3 People are equally divided on whether the *SL* virtual interaction as "truly immersive". |
| | 3.3 How MMOG could inform better design? | 3.3.1 Professional stakeholders consider *SL* to have potential for architectural design.<br>3.3.2 It takes time for people to explore the best use for the new IT, such as MMOG & *SL*.<br>3.3.3 The more people using the tools, the more confident they become about its potential and make the best of *SL* for architectural applications. |
| | 1.4 Compare *SL* and other forms of visualisation | 3.4.1 The use of the space with an avatar<br>3.4.2 The massively multi-players interaction<br>3.4.3 Better globally easily accessibility<br>3.4.4 *SL* is not developed for the AEC industry<br>3.4.5 *SL* involvement can be "time consuming" |
| 4.Future use of MMOG for architecture | 4.1 Originality and imagination in virtual architecture | 4.1.1 Virtual architecture is unlimited by real world physics<br>4.1.2 Virtual architecture is created through virtual methods<br>4.1.3 Virtual architecture is a lab for architectural vision<br>4.1.4 Virtual architecture can be actualised into the real world<br>4.1.5 Virtual architecture and intelligent building<br>4.1.6 3D immersive information hub |
| | 4.2 Virtual architecture is a new entity in its own right | 4.2.1 More social activities in virtual architecture<br>4.2.2 More jobs for real-world architects<br>4.2.3 Empower experienced architects<br>4.2.4 Marketing tool |
| | 4.3 Virtual architecture is sustainable | 4.3.1 Sustainable virtual architecture |
| | | 4.3.2 Issues of sustainable virtual architecture |
| 5.Validation of the framework | 5.1 Natural interface to access other forms of data | 5.1.1 MMOG is a more natural and intuitive interface to people<br>5.1.2 Other forms of visualisation tools are not intuitive enough for people to use |
| | 5.2 Better collaboration between stakeholders | 5.2.1 Most current visualisation tools are developed for professional stakeholders<br>5.2.2 Few tools are available to effectively engage non-professional stakeholders |

# Appendix Four:
# Template Analysis Template No. 4

| Revised Template for the Whole Data Set 2 | | |
|---|---|---|
| **Theme** | **Sub-theme** | **Data extracts relevant to each sub-theme** |
| 1.Real-world architect interviews:<br><br>This theme discusses how real-world architects manage early-stage design. What are the tools they used at early-stage design and the limitations of those tools. What potential do MMOG have to augment the early-stage design process in concert with using other tools.<br><br>However, not every architect interviewed was willing to use MMOG at early-stage design. | 1.1 Architects manage early-stage design? | 1.1.1 Sketches with pencils<br>1.1.2 Physical models<br>1.1.3 Google SketchUp<br>1.1.4 Basic CAD |
| | 1.2 The potential *SL* has over current practice? | 1.2.1 Better accessibility<br>1.2.2 Better client/end-users engagement<br>1.2.3 Real-time, multi-user interaction |
| | 1.3 Why real-world architects are not using *SL* | 1.3.1 The AEC industry: issue of innovation<br>1.3.2 Students: lack of *SL* architectural education<br>1.3.3 Clients: issue of user-generated architecture<br>1.3.4 Architects: interoperability issues |
| | 1.4. Share ideas with clients | 1.4.1Difficult for laymen to understood |
| 2.*SL* for real-world architecture:<br><br>This theme discusses how *SL* has been used by real-world architects to augment their real-world early-stage design process. There is a wide range of reasons for doing so. Meanwhile, non-professional stakeholders also find it useful to engage in real-world construction design process. However, various issues have been identified and need to be addressed when using MMOG for real-world architectural design. | 2.1 Architects' design experience | 2.1.1 Viable real-life architectural design<br>2.1.2 Good quality rendering of design<br>2.1.3 Easy design tool<br>2.1.4 Quick architectural design<br>2.1.5 Design collaboration<br>2.1.6 Cost effective<br>2.1.7 Transcends language barrier<br>2.1.8 Transcends boundary of cultural difference |
| | 2.2 Non-professional stakeholder experience | 2.2.1 Holistic, dynamic, immersive design<br>2.2.2 Understand the architectural proposal<br>2.2.3 User-generated architectural design |
| | 2.3 Issues of using *SL* for real-world architecture | 2.3.1 IT limitations of *SL*<br>2.3.2 Holistic design concerns from architects<br>2.3.3 Finding the right project and client not easy<br>2.3.4 End-user engagement is a challenge<br>2.3.5 Time consuming to explore *SL* architecture |

| | | |
|---|---|---|
| 3.The Virtual School Test:<br><br>This theme is based on a detailed example to test out how realistic the virtual representation can be to meet the needs of both professional and non-professional stakeholders in the early-stage design process. How far is the human interaction in the virtual environment considered real time, real life and truly immersive. | 3.1 How realistic is the virtual representation? | 3.1.1 All participants recognise the virtual model as replicating the world School<br>3.1.2 Non-professional stakeholders are satisfied with *SL* architectural design representation.<br>3.1.3 Professional stakeholders are not satisfied with the representation details of *SL* architectural design |
| | 3.2 Evaluate human interaction in *SL* | 3.2.1 Most participants consider the interaction in the virtual space as real time<br>3.2.2 One third of participants agreed that virtual interactions in *SL* are "real life"<br>3.2.3 People are equally divided on whether the *SL* virtual interaction as "truly immersive". |
| | 3.3 How MMOG could inform better design? | 3.3.1 Professional stakeholders consider *SL* to have potential for architectural design.<br>3.3.2 It takes time for people to explore the best use for the new IT, such as MMOG & *SL*.<br>3.3.3 The more people using the tools, the more confident they become about their potential and make the best of *SL* for architectural applications. |
| | 3.4 Compare *SL* and other forms of visualisation | 3.4.1 The use of the space with an avatar<br>3.4.2 The massively multi-player interaction<br>3.4.3 Better easy global accessibility<br>3.4.4 *SL* is not developed for the AEC industry<br>3.4.5 *SL* involvement can be "time consuming" |
| 4. Validation of the framework<br><br>This theme mainly looks at how the proposed framework can be useful to stakeholders of the construction design process. | 4.1 Natural interface to access other forms of data | 4.1.1 MMOG is a more natural and intuitive interface to people<br>4.1.2 Other forms of visualisation tools are not intuitive enough for people to use |
| | 4.2 Better collaboration between stakeholders | 4.2.1 Most current visualisation tools are developed for professional stakeholders<br>4.2.2 Few tools are available to effectively engage non-professional stakeholders |
| | 4.3 Useful in projects involved lots of end-users | 4.3.1 The usefulness of MMOG are project based<br>4.3.2 The usefulness of MMOG are stage based<br>4.3.2 The example of Aloft hotel |

# Appendix Five:
# Interview 30 Practising Architects

1. Personal Details

Full Name: ______Age: ___ Country of origin: ______ MALE☐ FEMALE☐

What is your academic background?

BA:_________________________University:_________________________________

MA:_________________________University:_________________________________

PhD:_________________________University:________________________________

I have worked in the Construction industry for___ years.

My job background is_____________________________________________________

Email:__________________________ Other Contact Details: ____________________

2. Questions

1. What is the design task you need to complete at early-stage design?
2. What tools do you use to augment the early-stage design process?
3. At what early stage of the RIBA Plan of Work do you think those visualisation tools you currently use are useful?
4. What are the limitations and advantages of current tools at early-stage design?
5. What are the overall limitations of those tools to improve early-stage design?
6. Do you have any other comment?

# Appendix Six:
# Interview 20 Architects in MMOG

1. Personal Details

Full Name: ______Age: ___ Country of origin: ______ MALE☐ FEMALE☐

What is your academic background?

BA:_________________________University:_________________________________

MA:_________________________University:_________________________________

PhD:_________________________University:________________________________

I have worked in the Construction industry for___ years.

My job background is_____________________________________________________

Email:__________________________ Other Contact Details: ____________________

2. Questions

1. How long have you been using *Second Life* and other MMOG to augment your real-world architectural design process?
2. At what stage of design will this form of visualisation such as *Second Life* useful?
3. Can *Second Life* augment the early-stage design process? If yes, how? If not, why?
4. Does *Second Life* complement other existing visualisation techniques?
5. Can the social interaction formed in the virtual building have any influence in people's use of the real-world building? If so, in a positive way or in a negative way? If not, why not?
6. What are the limitations and advantages of using *Second Life* to augment the early-stage design process?
7. What do you think are the main barriers for the AEC industry/university/academics to use *Second Life* to enhance architectural practice?
8. What is the maximum time that you are happy to explore new IT such as *Second Life* to enhance your design decision making? Why?
9. Do you have any other comment?

# Appendix Seven:
# Interview 20 *SL* Residents

1. Personal Details

Full Name: ______Age: ___ Country of origin: ______ MALE☐ FEMALE☐

What is your academic background?

BA:_________________________University:_________________________________

MA:_________________________University:_________________________________

PhD:_________________________University:________________________________

I have worked in the Construction industry for___ years.

My job background is_____________________________________________________

Email:__________________________ Other Contact Details: ____________________

2. Questions

1. How long have you been using *Second Life* and other MMOG to design your own virtual architecture? Why are you interested in developing your own virtual house in MMOG?
2. How does the design and development of architecture in the virtual world impact on your involvement in real-world architectural design project?
3. What are the limitations and advantages of using MMOG to engage you in the architectural design process?
4. Do you have any other comment?

# Appendix Eight:

# Interview 48 Participants in the Virtual Hub

## 1. Personal Details

Full Name: ______Age: ___ Country of origin: ______ MALE☐ FEMALE☐

What is your academic background?

BA:_________________________University:_________________________________

MA:_________________________University:_________________________________

PhD:_________________________University:________________________________

I have worked in the Construction industry for___ years.

My job background is_____________________________________________________

Email:__________________________ Other Contact Details: ____________________

## 2. Questions

1. Can you recognise which real-world building this virtual model represents? If so, name it.
2. How realistic is the virtual representation?
3. How are the representation details of this model in comparison with other models generated through other forms of visualisation tools?
4. Have you identified any issues or advantages of using MMOG models to represent real-world architectural design?
5. What is your impression about using an avatar to experience the space in the virtual architecture created in MMOG?
6. How far do you consider *Second Life* human interaction as real-time human interaction?
7. How far do you consider *Second Life* human interaction as real-life human interaction?
8. How far do you consider *Second Life* human interaction as truly immersive human interaction?
9. Can the social interaction formed in the virtual building have any influence on people's use of the real-world building? If so, in a positive way or in a negative way? If not, why not?
10. Do you think *Second Life* provides better human interaction than other visualisation tools that used to be used at early-stage design?
11. Do you think MMOG have the potential to support architectural design?
12. Do you have any other comment?

# Appendix Nine:
# Guidance Validation Interview

1. Personal Details

Full Name: ______Age: ___ Country of origin: ______ MALE☐ FEMALE☐

What is your academic background?

BA:_________________________University:_________________________________

MA:_________________________University:_________________________________

PhD:_________________________University:________________________________

I have worked in the Construction industry for___ years.

My job background is_____________________________________________________

Email:__________________________ Other Contact Details: ____________________

2. Questions

1. At what stage of design will this form of visualisation such as *Second Life* be useful?

2. How far do you agree or disagree with the effectiveness of using the various tools listed in Figure 7.1 to augment early-stage design? Why?

3. Does *Second Life* complement other existing visualisation techniques? If yes, when and how? If not, why not?

4. What are the limitations and advantages of using MMOG to augment the early-stage design process?

5. What can be done to solve the current issues of MMOG to better support early-stage design?

6. Do you think using MMOG to augment early-stage design can be applied to all types of architectural projects? Why?

7. Do you have any other comment?

# Appendix Ten:
# 30 Architects Interviewed in Chapter 4

| Architect | Gender | Age | Years working in the AEC industry | Company Size | Location of company | Company |
|---|---|---|---|---|---|---|
| **A** | M | 34 | 12 | Small | Leicester | John and Chung |
| **B** | M | 60 | 40 | Small | Leicester | John and Chung |
| **C** | M | 34 | 11 | Medium | Leicester | RPG |
| **D** | M | 40 | 17 | Medium | Leicester | RPG |
| **E** | M | 51 | 28 | Medium | Leicester | RPG |
| **F** | M | 55 | 37 | Medium | Leicester | RPG |
| **G** | M | 32 | 7 | Medium | Leicester | RPG |
| **H** | M | 37 | 13 | Medium | Loughborough | B3 Architects |
| **I** | M | 31 | 10 | Large | London | Costain |
| **J** | M | 33 | 8 | Large | Bath | Buro Happold |
| **K** | M | 38 | 15 | Medium | London | David Morley Architects’ |
| **L** | M | 39 | 16 | Medium | London | David Morley Architects’ |
| **M** | M | 37 | 14 | Medium | London | David Morley Architects’ |
| **N** | M | 29 | 5 | Medium | London | David Morley Architects’ |
| **O** | M | 44 | 20 | Medium | London | David Morley Architects’ |
| **P** | F | 35 | 12 | Medium | London | David Morley Architects’ |
| **Q** | M | 43 | 20 | Medium | London | David Morley Architects’ |
| **R** | M | 40 | 18 | Medium | London | YRM UK |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | LTD |
| **S** | M | 31 | 5 | Small | Loughborough | A+G Architects |
| **T** | M | 57 | 31 | Small | Loughborough | A+G Architects |
| **U** | M | 47 | 26 | Small | Loughborough | A+G Architects |
| **V** | M | 38 | 14 | Medium | Birmingham | EC Harris LLP |
| **W** | M | 55 | 27 | Small | Loughborough | Nigel F. Sterry |
| **X** | M | 41 | 18 | Medium | London | Burwell Deakins Architects |
| **Y** | M | 28 | 4 | Medium | London | Burwell Deakins Architects |
| **Z1** | M | 35 | 10 | Medium | London | Burwell Deakins Architects |
| **Z2** | M | 36 | 8 | Small | Leicester | JS+P Architecture |
| **Z3** | M | 45 | 21 | Small | Leicester | JS+P Architecture |
| **Z4** | M | 26 | 2 | Small | Leicester | JS+P Architecture |
| **Z5** | M | 53 | 37 | Small | Leicester | JS+P Architecture |

# Appendix 11:
# 20 Architects Interviewed in Chapter 5

| **Architect** | **Gender** | **Age** | **Years working in the AEC industry** | **Company Size** | **Location of Company** | **Other information** |
|---|---|---|---|---|---|---|
| A | F | 40 | 20 | Small | California, USA | |
| B | M | 38 | 12 | Small | Rome, Italy | |
| C | M | 34 | 11 | Medium | London, UK | |
| D | M | 50 | 32 | Small | California, USA | |
| E | M | 38 | 9 | Medium | London, UK | |
| F | M | 38 | 10 | Small | Manchester, UK | |
| G | M | 32 | 7 | Medium | Leicester | |
| H | M | 53 | 37 | Medium | Cairo, Egypt | Architecture Professor |
| I | M | 31 | 10 | Small | Brazil | |
| J | F | 27 | 2 | Medium | Japan | |
| K | M | 44 | 18 | Medium | California, USA | |
| L | M | 46 | 18 | Large | New York, USA | |
| M | M | 48 | 21 | Large | New York, USA | |
| N | M | 31 | 8 | Small | Melbourne, Australia | |
| O | M | 28 | 4 | Medium | Seoul, South Korea | |
| P | F | 37 | 11 | Medium | Stockholm, Sweden | |
| Q | M | 38 | 20 | Small | Milan, Italy | |
| R | M | 40 | 18 | Medium | Paris, France | |
| S | M | 34 | 10 | Small | Sydney, Australia | |
| T | M | 51 | 21 | Small | Texas, USA | |

# Appendix 12:

# Template Analysis of Data Collection Chapter 4

| Template for the Data in Chapter 4 | | |
|---|---|---|
| **Theme** | **Sub-theme** | **Data extracts to each sub-theme** |
| 1. 2D sketches | 1.1. Trained to use | 1.1.1"Must-have" skill for architects<br>1.1.2 Architecture tradition<br>1.1.3 Effective visualisation tool for architects |
| | 1.2. Creative design idea | 1.2.1 Selective information<br>1.2.2 Sketch most important design data<br>1.2.3 Can be interpreted in multiple ways |
| | 1.3. Share ideas with colleagues | 1.3.1 Should be industry standard to be understood |
| | 1.4. Share ideas with clients | 1.4.1 Difficult for laymen to understood |
| 2. Physical models | 1.4 Share ideas with clients/users | 1.4.1 RIBA stage C to show clients about the landscapes<br>1.4.2 RIBA stage D to give clients a 3D view of the design<br>1.4.3 RIBA stage E to win the tender of a construction project |
| | 1.5 Issues | 1.5.1 Cost: expensive<br>1.5.2 Static model: cannot be re-used<br>1.5.3 Time consuming<br>1.5.4 Google SketchUp: better tools than physical models |
| 3. Google SketchUp | 3.1 Simple and quick to use | 3.2.1 As quick as using a pen<br>3.2.2 Google Warehouse<br>3.2.3 Short training period |
| | 3.2 Good interoperability | 3.3.1 CAD<br>3.3.2 BIM |
| | 3.3 Issues | 3.3.1 Rendering of the model is not realistic<br>3.3.2 Limited 3D models at Google Warehouse<br>3.3.3 Most architects only use it at early stage. |
| 4. Basic CAD | 4.1 Advantages | 4.1.1 Reduce the time to transfer 2D drawings to CAD based detailed design<br>4.1.2 Communicate with engineers who mostly use CAD in projects from the beginning |
| | 4.2 Disadvantages | 4.2.1 Early architectural design process is mainly about generating design ideas based on the brief.<br>4.2.2 Detailed CAD may hinder the right design idea from emerging. |

# Appendix 13:

# 48 Participants Interviewed in Chapter 6

| Particip ants | Types<br>S: PHD students<br>R: Researchers<br>A: Academics<br>P: Professionals | Gender | Age | Years of experience in the AEC industry | Other information |
|---|---|---|---|---|---|
| **A1** | S | F | 24 | 2 | |
| **B1** | S | F | 23 | 1 | |
| **C1** | S | F | 26 | 3 | |
| **D1** | S | F | 22 | 1 | |
| **E1** | S | F | 27 | 6 | |
| **F1** | S | F | 24 | 2 | |
| **G1** | S | F | 32 | 7 | |
| **H1** | S | M | 27 | 7 | |
| **I1** | S | M | 33 | 10 | |
| **J1** | S | M | 27 | 2 | |
| **K1** | S | M | 34 | 8 | |
| **L1** | S | M | 36 | 10 | |
| **M1** | S | M | 40 | 11 | |
| **N1** | S | M | 31 | 8 | |
| **O1** | S | M | 28 | 4 | |
| **P1** | S | F | 27 | 4 | |
| **Q1** | S | M | 21 | 0 | |
| **R1** | S | M | 25 | 2 | |
| **S1** | S | M | 34 | 10 | |
| **T1** | S | M | 31 | 4 | |
| **U1** | S | F | 25 | 1 | |
| **V1** | S | M | 28 | 5 | |
| **W1** | S | M | 34 | 11 | |

| | | | | | |
|---|---|---|---|---|---|
| **X1** | S | M | 26 | 2 | |
| **Y1** | R | F | 32 | 7 | |
| **Z1** | R | F | 28 | 7 | |
| **A2** | R | F | 31 | 10 | |
| **B2** | R | F | 27 | 2 | |
| **C2** | R | F | 29 | 8 | |
| **D2** | R | F | 27 | 6 | |
| **E2** | R | F | 25 | 1 | |
| **F2** | R | M | 31 | 8 | |
| **G2** | R | M | 28 | 4 | |
| **H2** | R | F | 37 | 11 | |
| **I2** | R | M | 38 | 12 | |
| **G2** | R | M | 31 | 9 | |
| **K2** | R | M | 27 | 5 | |
| **L2** | R | M | 28 | 6 | |
| **M2** | R | M | 29 | 8 | |
| **N2** | A | M | 48 | 21 | |
| **O2** | A | M | 31 | 8 | |
| **P2** | A | M | 38 | 14 | |
| **Q2** | P | F | 37 | 11 | |
| **R2** | P | M | 38 | 20 | |
| **S2** | P | M | 40 | 18 | |
| **T2** | P | M | 34 | 10 | |
| **U2** | P | M | 51 | 21 | |
| **V2** | P | M | 49 | 21 | |

# Appendix 14:
# Five Experts Interviewed in Chapter 7

| Architect | Gender | Age | Years working in the AEC industry | Company Size | Location | Other information |
|---|---|---|---|---|---|---|
| A | F | 52 | 20 | Small | USA | Architect |
| B | M | 38 | 12 | Small | Italy | Architect |
| C | M | 34 | 11 | Medium | USA | Architect |
| D | M | 49 | 22 | Small | UK | Construction IT Specialist |
| E | M | 38 | 9 | Medium | UK | Construction IT Specialist |

# Appendix 15:

# Template Analysis: Chapter 6 Original

Template for the Data in Chapter 6

| Theme | Sub-theme | Data extracts to each sub-theme |
|---|---|---|
| 6.The Virtual School Test:<br><br>This theme is based on a detailed example to test out how realistic the virtual representation can be to meet the need of both professional and non-professional stakeholders at early-stage design process. How far the human interaction in the virtual environment are considered real-time, real-life and truly immersive. | 6.1 How realistic is the virtual representation? | 6.1.1 All participants recognise the virtual model as replicating the world School<br>6.1.2 Non-professional stakeholders are satisfied with *SL* architectural design representation.<br>6.1.3 Professional stakeholders are not satisfied with the representation details of *SL* architectural design |
| | 6.2 Evaluate human interaction in *SL* | 6.2.1 Most participants consider the interaction in the virtual space as real time.<br>6.2.2 One third of participants agreed that virtual interactions in *SL* are "real life"<br>6.2.3 People are equally divided on whether the *SL* virtual interaction is "truly immersive". |
| | 6.3 How MMOG could inform better design? | 6.3.1 Professional stakeholders consider *SL* to have potential for architectural design.<br>6.3.2 It takes time for people to explore the best use for the new IT, such as MMOG and *SL*.<br>6.3.3 The more people use the tools, the more confident they become about its potential and make the best of *SL* for architectural applications. |
| | 6.4 Compare *SL* and other forms of visualisation | 6.4.1 The use of the space with an avatar<br>6.4.2 The massively multi-player interaction<br>6.4.2.1 Compare interaction taking place in MMOG and Virtual Reality.<br>6.4.3 Better easy global accessibility<br>6.4.4 *SL* is not developed for the AEC industry<br>6.4.5 *SL* involvement can be "time consuming" |

# Appendix 16:
# Template Analysis: Chapter 6 Revised

| Template for the Data in Chapter 6 | | |
|---|---|---|
| **Theme** | **Sub-theme** | **Data extracts to each sub-theme** |
| 6.The Virtual School Test:<br><br>This theme is based on a detailed example to test out how realistic the virtual representation can be to meet the need of both professional and non-professional stakeholders at early-stage design process. How far the human interaction in the virtual environment is considered real-time, real-life and truly immersive | 6.1 How realistic is the virtual representation? | 6.1.1 All participants recognise the virtual model as replicating the real-world School<br>6.1.2 Non-professional stakeholders are satisfied with *SL* architectural design representation.<br>6.1.3 Professional stakeholders are not satisfied with the representation details of *SL* architectural design<br>6.1.3.1 Participants who had no experience or less experience of using visualisation software, are more likely to be satisfied with the details of representation of the *SL* virtual models.<br>6.1.3.2 The scale of the model does not feel right.<br>6.1.3.3 The details of the interior of the virtual building are far better than the details of the building itself |
| | 6.2 Evaluate Human interaction in *SL* | 6.2.1 Most participants consider the interaction in the virtual space as real time.<br>6.2.2 One third of participants agreed that virtual interactions in *SL* are "real-life"<br>6.2.3 People are equally divided on whether the *SL* virtual interaction is "truly immersive"<br>6.2.3.1 The use of the avatar is immersive<br>6.2.3.2 MMOG only enables its users to experience two senses – the sense of sight and hearing – and thus is not immersive.<br>6.2.3.3 Most immersive IT available remains visual and audio, or feeling, not yet taste and smell.<br>6.2.3.1 Compare interaction take place in MMOG and VR. |
| | 6.3 How MMOG could inform better design? | 6.3.1 Professional stakeholders consider *SL* to have potential for architectural design<br>6.3.2 It takes time for people to explore the best use for the new IT, such as MMOG and *SL*<br>6.3.3 The more people use the tools, the more confident they become about its potential and make the best of *SL* for architectural applications. |
| | 6.4 Compare *SL* and other forms of visualisation | 6.4.1 The use of the space with an avatar<br>6.4.2 The massively multi-player interaction<br>6.4.3 Better easy global accessibility<br>6.4.4 *SL* is not developed for the AEC industry<br>6.4.5 *SL* involvement can be "time consuming" |