A Web-based Design of Mass Semi-customized Housing

By

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in partial fulfillment of
the requirements for the degree of
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A Web-based Design of Customized Housing

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Abstract

The fact that cyberspace, the Internet, and virtual reality are a part of life at present is quite clear. People experience the power that new technologies offer and understand them increasingly. The challenge right now is to make them more accessible and usable. The thesis bases on this thought and focuses on new home purchases, aiming to solve the problems and thus to fulfill the value of new technology. It defines major problems that most homebuyers encounter in current housebuying processes, and proposes corresponding solutions for each stage of home searching, selecting, and buying. The core idea of the thesis is media, and the major problem-solving idea is the standard design, which defines the mass semi-customization and stages a new approach – designing with shape grammars. The web acts as the base to deliver the information and represent the design. It enables homebuyers to easily make evaluations and selections about all options. Meanwhile, the homebuyers can test their choices and take a stroll through virtual houses with walk-throughs enabled by the virtual reality technology. VR attempts to bridge the gap between the homes they desire and the homes they get.

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Chapter 1. Introduction

Information technology is transforming economic and social activities. It opens up new possibilities and offers people more conveniences than ever before. The purpose of this thesis is to appropriate information technology in the mass semi-customized housing. The thesis focuses on the new home buying and clarifies major problems. The goal of the thesis is to create a technological interface to guide and educate homebuyers, provide a semi-customization solution using standard designs and processes, and help homebuyers make informed decisions.

Le Corbusier attempted to address this in 1923 with: "A great epoch has begun. There exists a new spirit. Industry, ...has furnished us with new tools adapted to this new epoch, animated by the new spirit... The problem of the house is a problem of the epoch" (Le Corbusier, 1923). Eighty years later, tools are more powerful than before; however, the problem of the house still exists. Speculative homebuilders still market a handful of "one-size-fits-all" commodities on a "take-it-or-leave-it" basis. Homebuyers are hard to see something on the market that is perfect for them. Rarely have they researched what is involved to achieve their dreams. After the initial "honey, we-could-build-exactly-what-we-want" excitement wears off, important questions begin to surface with no reliable resource for the answers. They realize there are much more to building their dream home than just choosing from the market. Indeed, the homebuyer wants a

house that can accommodate complex family activities and work patterns, and family members seek features following their desires through choice and tailored solutions. However, the custom-home always belonged to the wealthy, and generic mass-produces were hardly satisfied homebuyers' needs. When compared with other industries of the same magnitude, it seems that the house industry is slow to adopt innovations. In the past half-century, auto manufacturing industries have moved from mass production to mass custom-made. The house industry is years behind others in transitioning to the new economy. In North America, "this stands in marked contrast to characteristics that were prevalent during the 1940s and 1950s and that led to the development of numerous housing concepts and to the emergence of an efficient organizational structure that remains intact today" (Friedman, 2002, p. 50).

The impact of digital media on society is being felt in all parts of our economic, culture, and social lives. Every business, including building construction, has been affected by changes in how products are designed and manufactured. It is time to change the rules in the house industry. The Internet, powerful computer tools, and information technologies offer possibilities in creating a new web-based production model for mass semi-customization of housing. With this, the house industry fulfills its transition from personal custom-made to mass production and now to mass semi-customized production. The challenge right now is how to offer homebuyers opportunities to participate in designs and thus to provide affordable custom-home for every homebuyer. The difficulty of

customizing the mass housing is that the subject itself has contradictions, which are between more or less personalized 'customizations' and uniform 'mass' results. The key of the solution is about how to control this balance. The design solution lies at the core of the thesis, and the rest relates to the delivery and presentation of design information.

Buying a home, and seeking the dream-house, should be a memorable and enjoyable experience. However, for current homebuyers, finding the ideal home seems to take the longest amount of time, trawling through property newspapers and up and down sales offices. It is arduous work and is very time-consuming. Meanwhile, the new home purchase is a mix of emotional and rational decisions, from the first step to the closing. Since it is a family's largest investment, decisions are hard to make. The challenge is how to help the homebuyer make informed decisions within a reasonable time-frame.

For the scope of this thesis, the media is the master thread stringing three aspects of design: the web, the semi-customized housing, and the model simulation. The web lies at the base of all solutions and is put in Chapter 2. The design solution included in Chapter 4 is an important part of the thesis. The simulation relates to final decision-making and is included in Chapter 5. The thesis attempts "toward the right solution in the right form for the right person in the right location at the right time and at the right cost" (Boxton, 2001, p. 151).

Chapter 2. Background

The focus in the early stage of this research has been to discover housebuying problems. In doing so, basic market research is undertaken, problems clarified, and the housebuying process analyzed using new media theory. All these background work comprise a solid foundation for follow-up analysis and solutions.

2.1 Market Research

The market research is the starting point of this study, as well as the foothold of the thesis. It consists of web-based and on-site research based on the Ottawa area. All are the valuable sources for later study.

2.1.1 City and Homebuyers

Ottawa stands head and shoulders above other communities in North America as a great place to live. It offers a rare mix of the extraordinary standard of living and beautiful nature, in tandem with cultural and recreational experiences. People enjoy living in this safe, clean and inviting region that always puts families first.

As a national capital, a global technology center and one of the most connected cities in the world, Ottawa has all of the qualities a community needs to succeed in the knowledge-based economy and market, and thus is the suitable

background for this research. The population of the National Capital Region is 1,221,000 and is predicted to grow to 1,390,000 by 2006 (City of Ottawa, May 2001). It will have a hot house market. Nearly 48 % of people were between 25 – 54 years old in 2001 (Canada Census, 2001), and some of them could today be potential homebuyers. 45% of population have university degree or diploma and 7.5% of population are scientists or engineers (City of Ottawa, March 2000).

As a national capital, 83,000 people work for federal government and City of Ottawa. As the “Silicon Valley North”, about 1000 advanced technology companies employ more than 66,500 individuals here (City of Ottawa, 2002). Other major careers relate to education and service realms. Ottawa also has the world's second-largest community net, NCF, based at Carleton University's computing services department. Overall, Ottawa is of a typical knowledge-based city, and the potential homebuyer is of a knowledgeable group. (All data remarked above can be found in Appendix A)

2.1.2 Web-based Research

In order to know the house market, collect first-hand information and evaluate web sites, web-based market research has been done on all new homebuilders in the Ottawa area from January to February 2002. There are total 37 registered new homebuilders in the Ottawa region (not including the Hull area); 33 companies have a web site, and attain 90 percent of all new homebuilders. (See Appendix B - a list of new homebuilders in the Ottawa area)

First, the number of homebuilder's projects was discovered and it was attempted to mark each location onto the map, then projects were tabulated pertaining to different homebuilders and areas. They were later used for analysis, selected site interview and survey.

No.	New homebuilder	Current project quantities
1	Ashcroft Homes Inc.	6
2	Claridge Homes Corporation	10
3	Cardel Homes Limited	3+
4	Domicile Developments Inc.	5
5	Minto Developments Inc.	6
6	Monarch Construction Limited	2; (most in Toronto and US)
7	Phoenix Homes	6
8	Richcraft Homes Limited	9
9	Tamarack Development Corporation	5
10	Urbandale Construction Ltd.	4

Table 2.1 Top ten new homebuilders in the Ottawa area

Table 2.1 lists ten large-scale homebuilders and quantities of current projects in the Ottawa area. Three largest homebuilders include Minto Developments Inc., Claridge Homes Corporation, and Richcraft Homes Limited. Data is collected before February 1, 2002. "3+" means at least 3 projects.

No.	Site locations	Quantities
1	Central area	6
2	East area	7
3	Cumberland & Orleans	12
4	West area	5
5	South area - Hunt club road	4
6	Riverside drive and River road	8
7	Nepean & Southwest - Town central area	7
8	Along Woodroffe Avenue	7
9	Kanata & North area	26+
10	Stittsville	10

Table 2.2 Site locations and quantities

2.1.3 Interview and Survey

The purpose of site interview and survey is to obtain research-relevant information and knowledge. They were done on selected projects by considering site locations and homebuilders. More emphasis was put on Kanata, a Hi-tech area. On-site research began with an interview with the salesperson who knew the homebuyers best.

The first interview was done with a nice saleslady at the “Hunt Club Enclave” sales office. In order to gain experiences and test the questionnaire, the interview proceeded in a free conversation. Valuable advice was received not only on the

house market research, but also on the questionnaire. The format of the interview resulted in six brief questions, “semi-structured” (Lindgaard, 1994), and an open-ended conversation (see Appendix C). The interview had a guide which derived from the ordering of standard “probing” questions, but they were not in a rigid schedule and room was left for gaining additional responses. “Hunt Club Enclave” was revisited for a formal interview. Table 2.3 lists all details of 6 valid interviews that were undertaken from January 2002 to February 2002. The interviews have enriched the knowledge and experience necessary for the proper synthesis of this thesis.

Order	Area	Project	Interviewer	Duration (min)	Homebuilder
1	South, Hunt Club	Enclave	Sales	80+40	Claridge Home Corporation
2	South, Hunt Club	Woodland	Sales	20	Richcraft Home Limited
3	East	OAKPARK	Sales	25	Claridge Homes Corporation
4	West, Kanata	Village green	Sales Consultant	35	Urbandale Construction Ltd
5	West, Kanata	Walden way	Area Sales Manager	50	Cardel Homes Limited
6	West, Kanata	Macassa court	Primary Sales	65	Richcraft Home Limited

Table 2.3 Details of interviews

The survey took out the most important details extracted and summarized from the interview. It was just a so-called pilot survey and its subject was the potential homebuyer. It sought to learn what they exactly wanted and thought. The survey was quite different from the open-ended interview; each question had multiple answers for choosing in order to get quick responses, and all of them were included in one page. Twenty surveys were proceeded by meeting potential housebuyers outside of selected sales offices (in Kanata, South and East areas of Ottawa). An attempt was made to learn why those choice criteria were important, salient, or relevant to them, and try to figure out appropriate solutions in this thesis and thus carry them out in the prototype. (Questionnaires and answer sheets can be found in Appendix D)

2.2 Problem Finding

After finishing all basic market researches, each specific scenario is mapped onto the typical housebuying process. Major problems in every stage are analyzed and defined in this section.

2.2.1 Task Analysis

Buying a new home is enjoyable but hard work; an overwhelming challenge, exciting but arduous. The homebuyer applies all available media for the ideal home search and purchase; the process is quite complicated. If housebuying is regarded as a task, Stammers and Shepherd's theory (1995) can be used to

Figure 2.1 A flowchart of the housebuying process

analyze its process in order to find out specific problems. A flowchart of task analysis briefly shows a conventional housebuying process (Figure 2.1). The actual process is far more complicated than this and may be diverse due to different circumstances; nevertheless, the homebuyer is never away from using various tools of the media. In Figure 2.1, a normal housebuying process follows either a linear or a circulative flow. Various media are used in different stages from mass media, communication media, transportation media and to presentation media. Problems are therefore classified by each of these media. Marshall McLuhan had incisive interpretations on these “mechanical ages” and “electric technology” media. Thus, defining problems is the premise for analyzing the performance of each media.

2.2.2 Problem Statements

Homebuyers usually need to spend a lot of time and energy in the early stage of new home-buying. A few years back when homebuyers were asked how they would find new homes, their answers would very simply involve driving and visiting. Today some answers include using the Internet. Indeed, information technology is becoming a part of ordinary life. However, most homebuyers still drive to search their ideal homes. It may be a habit, a hobby, or even a pasttime. They may like and enjoy the process of seeking dream homes, and these become part of their everyday lives. But once the homebuyer seriously decides to buy a house, endless searching just begins. Conventional communication media is insufficient in providing detail information. The only thing a homebuyer

can do is driving to visit site offices and getting information one by one. Therefore, the method of delivering sufficient information to every homebuyer needs consideration.

The houses on the current market do not meet homebuyers' expectations. There are less house models for choosing and fewer personal choices on their selections. Developers or homebuilders still base their designs on the buy-or-byebye thinking, producing a handful of "one-size-fits-all" commodities, identical and repetitive units, and therefore benefiting from economies of scale. It is to the developer's advantage to limit choices in order to simplify the processes of design and construction. The problem relates to current design concepts for mass housing. Designing houses for the public is totally different than designing a house for an individual. Different people have different uses and various needs for their houses, which relate numerous aspects such as personal taste, habit, religion, culture or even people's emotions. However, the current design for mass housing follows conventional methods and the clients' general needs and is not yet conceived in a wider context. Finding a better solution to solve this conflict and meeting most homebuyers' needs and lifestyles will be the main task of this thesis.

In the current house market, the developers tend to provide a stack of papers and drawings to homebuyers who depend on their peripheral understandings pertaining to a "take-it-or-leave-it" attitude. Too many details need to be

considered including the location, price, layout, upgrading, etc. Uncertain information, invisible results and undefined upgrades confuse homebuyers. Meanwhile, they are often told by sales people: “there is no ideal home existing.” Most disillusioned homebuyers begin to accept this reality, abandon some of their expectations and finally make their decisions to regret later.

The above can be summarized into three problem areas:

Problem 1: too much driving and searching (communication media)

Problem 2: less house models and personal choices (design media)

Problem 3: hard decision-making (presentation media)

According to each related media, details will be discussed and related solutions will be provided in the following chapters.

2.3 Rethinking Media

During the mechanical ages we had extended our bodies in space. Today, after more than a century of electric technology, we have extended our central nervous system itself in a global embrace, abolishing both space and time as far as our planet is concerned. Rapidly, we approach the final phase of the extensions of man - the technological simulation of consciousness, when the creative process of knowing will be collectively and corporately extended to the whole of human society, much as we have already extended our senses and our nerves by the various media.

(McLuhan, 1964, p. 3 & 4)

Marshall McLuhan's media theory can be looked at from two viewpoints: media and their simulation. Media is a carrier and simulation is a means. For this work, media is the foundation and the major topic for running through. Simulation is the aim addressed entirely in the final chapter. It is important to reconsider previous studies in order to find out an appropriate media form for all solutions.

2.3.1 Media Review

Mass media and communication media certainly extend our eyes, hearing and central nervous system (McLuhan, Fiore, & Jerome, 1967). Our thinking and emotion can be incited by newspaper and TV advertisements. So, the developer has to bear reasonably heavy costs for advertising in local mass media. The truth is that the vast majority of the cost of these local media are in the print, physical paper and distribution. However, no one knows whether the information is delivered exactly to the potential homebuyers, or whether homebuyers catch the TV advertising. It is this first stage that is the least efficient for the developer as well as the homebuyers. For the homebuyer, finding an ideal home seems to take a long time. Since mass media only provides brief information, they have to rush between different developers and inquire about details personally.

Indeed, transportation media extends our feet, and some homebuyers enjoy these excited processes in seeking dreams. However, the frequent site visits and extensive driving exhaust their time, energy and even enthusiasm; sometimes they even confuse their memories of houses they have visited. They have to

revisit in order to rearrange their thinking, imagination and feelings since most items homebuyers can get on the current market are promotion brochures and drawings. One purpose of their site visits is to collect information on these houses, because nothing is delivered to their place. Later, they need to envision their unbuilt dream homes referring to model houses, extended by paper media.

Limitations of conventional media cause the homebuyer to spend much time on their early search. What homebuyers want is a simple straightforward way of finding their ideal homes without extra costs or efforts. In this information age, people could combine the advantages of digital media to the activity of housebuying and “approach the final phase of the extensions of man - the technological simulation of consciousness”.

2.3.2 Understanding Media

Conventional media are classified into various categories. Each of them has specific uses and functions. They have accompanied human society through the agricultural age and industrial age. Today the new media brings the humans into the information age, and changes the social consequences (Cutler, 1996). The multimedia enhances the overall quality and quantity of information, converges various realms, and integrates physical and digital media (Bill, Dransch, & Voigt, 1999). Now, people live in a period where three ages overlap. They coexist and compose a new world.

2.3.2.1 The New World

For people living in the era of information society, the unlimited and creative dimensions open up in front of us as flexible and dynamic environments - synthetic worlds, spanning over numerous networks and covering the entire globe (Kunii, 1998). This is cyberspace. Norbert Streitz addressed the concept of a new world when he explored the cooperative buildings in his paper "Roomware for cooperative building: integrated design of architectural spaces and information spaces" in 1998. It portrayed the new world containing both digital information spaces - cyberspace and physical spaces. He illustrated it using three dimensions and mentioned that this "integrated global picture has still to be constructed" (Streitz, GeiBler, & Holmer, 1998, p. 6; Figure 2.2).

Figure 2.2 Three dimensions of worlds, Streitz et al., 1998

Figure 2.3 Chinese Yin-Yang theory

A central aspect includes the “real vs. virtual world” dimension, “local vs. global” context and “individual vs. group” setting. Figure 2.2 is the miniature of this new world, and three dimensions lay out its architecture. Every dimension has two poles (a pole meaning a direction, an element, or a tendency). For example, our day-to-day living and working environment is highly determined by the architectural and physical spaces around people, constituted by buildings. They constitute also rich information spaces due to the inherent affordances as direct information sources. The two poles of every dimension are not absolute but relative. Every pole represents a tendency to change and contain each other. Multiple dimensions permeate and embed each other, forming multi-dimensional space - the new world. The Chinese Yin and Yang can be further used to understand the new world and the two poles of each dimension.

Chinese culture uses the Yin -Yang theory to explain the world (Figure 2.3). Yin (-), the negative principle in nature, represents dark, cold, and shaded space. Yang (+), the positive principle in nature, represents light, warmth, and bright space. Yin -Yang is a dynamic ordering concept explaining the cycles of change. The Yin attains the maximum and gives place to the Yang; the Yang returns cyclically to its beginning. They are mutually opposing and dependent on each other for existence. The two dots symbolize that, as each force reaches its extreme, it contains in itself the seed of the opposite (Ru, & Peng, 1998). The two poles of every dimension have the same meaning.

2.3.2.2 The New Media

Multiplex media coexist in this multi-dimensional world, and the center of it is the new media, which is an irreversible trend in the computer-based system, linking between spaces and between places. Everything has been therefore changed, the way people today live, work, and think.

Type	Paper - based Mass Media	Electron - based Mass Media	Computer-based Multi-Media
Physical Form	Newspaper; Magazine	Fax; Telephone; TV set	Computer; Net; Server
Format	Paper	Paper; Audio; Video	E-document; Live Audio, Video
Characteristic	Analog	Analog	Digital
Composition	Atoms	Electrons	Bits
Communication	Delivery	Delivery; Transmission	Transmission
Time	Distribution & Delivery	Dialing & Waiting	Download
Message Speed	Transportation	Light	Light
Message Quantity	Limited	Limited	Unlimited
Cost	Mid	High	Low

Table 2.4 Media comparison

One can add any new item to this summary (Table 2.4). The multimedia system shows its advantages over others. It “may be characterized as a computer-based system for integrated processing, storage, presentation, communication, creation and manipulation of independent information from multiple time-dependent and time-independent media” (Bill et al., 1999, p.1). Nevertheless, it will not be used to totally supersede any other media since this is the multi-dimensional world with multiplex media. Today, human activities are no longer confined in a single world. The new world represents tendencies of new age defining and offering multiple ways for human activities. The most efficient, convenient way is the use of multimedia system. The World Wide Web is considered as a multimedia delivery system (Morris, 2000). As one form of the new media, it offers a new layer for house searching in the new age.

2.3.3 Web Solution – Prototype Part I

One is maybe familiar with the following television advertising of Canada Post: “cyberspace to your place; from anywhere to anyone”. Today, “everywhere is wired” by networks, and everything is “being digital”. Cyberspace spans over innumerable numbers of computers connecting numerous Internet and web sites. The physical space is comprised by a computer-generated world (Doheny-Farina, 1996; Negroponte, 1995; & Kunii, 1998). People live in both real space and the virtual world. The ubiquitous World Wide Web provides information anytime from anywhere to anyone. It is always there so that conveniences are offered to everybody. People want to view information by just “diving” into the

cyber. The situation changes not only in terms of having a different “place” or “location” for the “same” information but also in terms of new categories and ways of presenting information. There is no boundary between global and local anymore. 40 years ago, the globe was as big as a planet and as small as a post office (McLuhan, 1964); today it is as small as a computer screen.

Since humans live in both real city and cybercity (Boyer, 1996), searching houses through the web assumes a new meaning. The metaphor is that surfing on the information highway is similar to driving in the real world. The cursor moves in cybercity instead of the homebuyer traveling in the real city; it is more efficient, rapid and convenient. It further extends all conventional media. The cybercity also contains the “real world” - virtual reality, a concrete form of cyberspace; and the real city that the computer itself locates is comprised by cyberspace.

For current house developers, the web is becoming a new marketing device. However, the challenge is on how to make it more efficient, useful and powerful. Ottawa currently has 37 new homebuilders who are home to more than 700 web pages. The good and bad are intermingled in different design ideas, skills and methods. Some web sites need a long time to download an insignificant Flash of introduction when the user enters the site; some don't have an explicit layout or flow, leaving users confused. Users usually worry when they enter a website, since they know that there are a large number of pages squeezed vast amounts of information behind the top page. Therefore, the site must give users a clear

layout first, and designer must know what their primary considerations or preferences are. The prototype is designed for various computer-skilled homebuyers. It is based on the thesis interview and survey, attempts to provide them with the most needed information at the beginning phase of the search. Pages are ordered by location (community), category (single or townhouse), model (type and design), custom interior, and custom exterior. Homebuyers can view various types, plans, and virtual reality models, upgrade and test their choices. This prototype design exercise attempts to carry out the concept of the design solution (Chapter 4) and simulation solution (Chapter 5) through web solution.

The web can be a powerful marketing tool; however, how powerful the current webs are depends on how much the technology offers. William J. Mitchell and Malcolm McCullough (1991) classified digital design media in four types: one dimension media such as text; two dimension media such as images, drawings and maps; three dimension media such as architectural rendering; and multi-dimension media such as motion model or animation. Most current web sites lack such powerful multi-dimensional forms that can best interpret architectural spaces. The method utilization of the strong points of multimedia is a challenge addressed in Chapter 5 called Visible Issues.

Chapter 3. Literature and Preceding Works

Industry on the grand scale must occupy itself with building and establish the elements of the house on a mass-production basis. We must create the mass-production spirit. The spirit of constructing mass-production houses. The spirit of living in mass-production houses. The spirit of conceiving mass-production houses. (Le Corbusier, 1923)

Ever since the Industrial Revolution in the late 18th century caused a rural exodus towards cities, the design of mass housing has been an important theme in architecture. Indeed, most of the greatest masters of the 20th century have addressed this issue in their works. Examples can be found in Le Corbusier's the Quartiers Modernes Frugès in Pessac (1924-1929), Walter Gropius and Konrad Wachsmann's the Package House (1941-1952), and Frank Lloyd Wright's Usonian Houses (1946-1954). Many of the best minds of early 20th century architecture were focused on the integration of a new concept, technologies, materials, forms, and aesthetics into innovative approaches to housing. The contemporary mass-produced example can remark the American dream home, Levittown on Long Island (1947-1951). Based on pioneers' practices, later generations put more stress on the variety of design in order to meet people's increasing demands. Such kinds of project include Pritzker Architecture Prize Laureate 1992, Alvaro Siza's Quinta da Malagueira in Evora in Portugal (1977-1998).

Three typical projects are introduced in this chapter. They present architects' different design solutions for mass housing. Le Corbusier considered the variety of design on a grand scale. It was not only on the individual but also on each

combination. Meanwhile, he also painted the different colors on the façades of the villas in order to get an enchanting sight and striking varieties. Walter Gropius and Konrad Wachsmann thought about using the industrial means to fulfill their universal concept and offer people more personal choices. Alvaro Siza also emphasized the variety of designs, but he laid more stress on owner-participation in the design process. Three typical projects represent three kinds of mass housing design - the most conventional design, the end-product design and the custom design. Besides outlining these design practices, two similar theoretical approaches are also introduced: the spatial organization presented by Lionel March and Philip Steadman in their book, and George Stiny in shape grammars. They are used not only for analyzing designs but also for further developing this thesis design exercise. Moreover, an application of shape grammars for Siza's Malagueira project is also remarked.

3.1 The Pessac House Project

Le Corbusier addressed the issue of public housing as remarked above in his book "Vers une Architecture" in 1923 (Ferrand, 1998, p. 6). Henri Frugès, an industrialist, "was completely carried away by the ideas" in a journal entitled 'L'Esprit Nouveau' (Boudon, 1972, p. 7). He asked Le Corbusier to design ten houses at Lège for his family-owned business, and the Pessac (near Bordeaux) project was undertaken as a direct result of it in 1924 (Ferrand, 1998). It aimed to offer the houses to the public at the lowest possible price.

As an instigator and promoter, Frugès wanted to “build new houses in order to give millions of people a roof over their head” and originally intended to build a garden city, comprising of one hundred and fifty to two hundred houses, a public square and garden surrounding each unit (Boudon, 1972, p. 8). Considering the adequate space, the total number of buildings was settled on one hundred in maximum. He asked Le Corbusier “do it in your own way... Ideally, no two villas would have been exactly the same”(Boudon, 1972, p. 8 & 10). He knew that was exaggerated, but he tried to express a desire for the greatest possible variety in the designs.

Le Corbusier resolved this issue ingeniously; his design appeared far freer and simpler. For the 100 houses plans, he adopted the module of 5 m x 5 m, a demi-module of 5 m x 2.5 m and a quarter module of 2.5 m x 2.5 m (Figure 3.1). By playing around with these three elements, by placing them in different alignments, it was possible to obtain considerable diversity without forgoing the advantages of serial production. It contained the whole kernel of Le Corbusier's design concept for Pessac as well as his other projects. All the more detailed and delicate design exclusively worked with these standard components: the same concrete cells, such as the same 1 / 4 cell of kitchen, the same 1 cell of living room and bedroom, the same staircases, dressing rooms, kitchen, washroom and equipments, the same type window and door, and others. The standard plan can clearly show this point (Boudon, 1972; Figure 3.2).

Figure 3.1 Standard module of concrete cell

Ground floor:
living room,
kitchen,
room,
washhouse and
wine cellars

First floor:
large bedroom,
small bedroom,
dressing room
and terraco

Figure 3.2 The standard plan – the scheme

“A standard plan serving as the basis for all the house types in the scheme was sketched in 1924” (Ferrand, 1998, p. 90). There was an opinion that three house types were designed in Pessac (See *‘Oeuvre Complète 1910-1929’*, P78-86). However, most researchers were convinced that in total four house types were finally designed to be built (See Boudon and Ferrand’s books; all house types refer to Figure 4. 2). Apart from one or two exceptions, the dimensions of each house type were identical. Five kinds of color were painted on the façades of the villas in order to achieve variety and enchanting sight (Figure 3.3). Of the 100 houses planned, only 2 houses per week were built. The project was brought to a halt after the completion of the 51st house in 1926 (Boudon, 1972). It met with considerable opposition from the local building firms, administrative departments and bureaucrats. Three years later, the village was occupied.

Le Corbusier said, “we could build wide windows like the windows in the corridors of railway coaches and replace tiled roofs by terraces...”(Boudon, 1972). What he was trying to do in Pessac was have an impact on conventional ideology. By building in a modern style and taking account the economic and social problems, he hoped to produce low-cost houses that would be pleasant to live in. He wanted to provide people with a container in which they could install themselves and live their daily lives. In his dual capacity as architect and town planner, he wanted to create a functional system based on technological criteria, and to this end, he set out to design predetermined, homogeneous and essentially cubist structures, in which open and closed areas would complement one another.

Figure 3.3 House façades painted into different colors

3.2 The Packaged House

Since 1910, Walter Gropius had stressed that linkage between prefabrication and the concept of flexibility in many projects. The factory-made house was his dream. He wrote: "It is by the provision of interchangeable parts that (we) can meet the public's desire for individuality and offer the client the pleasure of personal choice and initiative without jettisoning aesthetic unity" (Larson, 2001). In 1941, Gropius gave "evidence to the Congress of America on the need to develop a factory-produced system of standardized parts which should be interchangeable for use in different types of houses" (Herbert, 1985, p. 248). Gropius and Konrad Wachsman began to develop such a system, later known as the "Packaged House". It aimed to "transfer most of the labor involved in the construction of a building from the site of the building itself to a factory and to make the erection of the building primarily one of assembly." To achieve this, any standard units or section could be interchanged with any other. In this sense, the system was conceived as universal concept (Herbert, 1984, p. 254).

The Packaged House was an advance conception, "Its uniqueness lay in an original synthesis of known and well-established elements. It was appropriate and become the registered trademark of the system as well as its popular appellation" (Herbert, 1984, p. 249). The modified scheme was finished by Wachsman at the end of 1941, which included details of ten standard panels and a sectional perspective (Figures 3.4, 3.5, & 3.6). Based on the experience of prefabrication, Gropius provided "the conceptual framework of his philosophy of

Figure 3.4 Konrad Wachsmann, modified scheme, details of metal connector, 1941

Figure 3.5 Konrad Wachsmann, modified scheme, panels, 1941

Figure 3.6 Konrad Wachsmann, modified scheme, sectional perspective, 1941

Figure 3.7 Gropius and Wachsman, Packaged House, standard house type A, 1942

Figure 3.8 Harvard Graduate School of Design, double-story prefabs using General Panel components, 1943

unity and variety, flexibility and growth, stability and change, standardization and individual choice” (Herbert, 1984, p.259). He developed possible house types with dwelling units of various sizes by using standard components (Figures 3.7 & 3.8).

A demonstration was set up by Gropius after five months of the General Panel Corporation registration in September 1942. It showed the house using General Panel standard components to a large invited group. They were duly impressed when the demonstration house was erected, and then taken down again all in one day, and there was talk of going immediately into production. But no house was actually built for sale during the whole wartime when Wachsman revised and improved the system. Gropius investigated the system’s inherent qualities on flexibility and variability, and many famous architects also joined this research to experiment the system. Until 1947, “a factory was built to produce 10,000 houses per year, but less than 200 had been manufactured by the time the company closed its doors. They soon found that it was impossible to actually offer personal choice with their system” (Larson, 2001). In 1952, the Packaged House saga had come to an end.

It must be emphasized that there is no single reason, no simple formulation for the failure. Herbert said, “industrialized housing is a process; the factory-made house is a product.” To recall the process of the Packaged House, it took more than five years to move from initial design to the final stage of actual industrialized production, held by constant research with high cost of

experimental tests. When the Packaged House, after its long gestation, was eventually ready for production, even favorable conditions no longer held. The corporation missed the wartime market; once again, it lost the direction in the burning market of postwar mass housing. As the end product, the corporation was away from this dream of universality into the more conventional strategy of producing a limited range of standard houses. Actually, when the factory was ready to start production in 1947, thirteen house types, ranging from one- to four-bedroom, were available (Herbert, 1984). But the final production was based on only one house type, which was impossible to “offer the client the pleasure of personal choice and initiative” by such a product. The Packaged House lived on, however, in architectural myth and legend.

3.3 Quinta da Malagueira

Following the revolution in Portugal in 1977, the government of Évora commissioned Alvaro Siza to plan a housing project in the rural outskirts of the city as an extension of Évora. The project was under the Ambulatory Support to Local Residents program of the national housing association, known as SAAL, and was to be one of several that he would do for SAAL (Duarte, 2001). The district “occupies 27 hectares” of undulating terrain, consisting of “1200 houses, infrastructures, and public facilities” (Testa, 1996). The designs began in 1977 and construction started in 1978. Three phases of public housing were completed, and some additional public buildings were also finished in 1998 (Figure 3.9, Duarte, 2001; & Figure 3.10, Frampton, 2000).

Figure 3.9 Layout of Quinta da Malagueira

Figure 3.10 Aerial view of Quinta da Malagueira

Like most housing projects, the aim of the Malagueira project also was to offer low-cost houses to the public. The design represented similarities of Le Corbusier's approaches. It was, nevertheless, influenced by the context in which it evolved and was different from him in some important aspects.

Firstly, the typology of the unit followed the principle of row and variations in profile. Each unit had a single front to the street with 8 meter in width, a unit depth of 12 meter, and a courtyard for every unit. The unit faced either the street and the courtyard was oriented to the rear, or the L-shaped unit surrounded the courtyard that bordered on the street (Fleck, 1995) (Figure 3.11, Rodrigues, 1992; & Figure 3.12, Frampton, 2000). The number of stories was limited to two, varied in accordance with the unit types, and could evolve from one bedroom to five bedrooms. A group of single units combined to a row house (Duarte, 2001, Figures 3.13, 3.14, & 3.15).

Secondly, as one of its desired outcomes, the project had the direct participation of future occupants in the design of their homes. The most particular approach distinguishing the Malagueira project with others is that designers could work with the future occupants to customize their homes. At Malagueira, as in many other SAAL developments, future occupants were cooperative with designers for promoting the development. Siza and his colleagues were arranged to meet with an assembly of co-operants to talk over house details, and then with each individual owner to customize the house (Duarte, 2001).

Figure 3.11 Courtyard

Figure 3.12 View of courtyards from the street

Figure 3.13 Evolvement of house unit from T1 to T5.

Figure 3.14 Combination of single units

Figure 3.15 A row house

To satisfy various requirements of future occupants and simplify the design process, Siza developed a scheme for designing the mass houses. It aimed at increasing owner-participation and allowed for the generation of different houses. He used this scheme to incorporate the users' desire for a unique house into the design process. The scheme was composed of a set of implicit design rules that were used by Siza or his collaborators to design the customized houses. By utilizing this method, Siza laid out five house types - A, B, C, D and E. Some of the types had subtypes, for instance, type A has five subtypes -Aa, Ab, Ac, Ad, and Ae. Each subtype then has variations in terms of the number of bedrooms, which range from one to five - T1, T1, T2, T3, T4, and T5. In total 36 different layouts were designed from one- to five-bedroom family houses (Duarte, 2001), but not all of them were finally built. At Malagueira, Siza attempted and established a unique design approach for customizing mass housing.

3.4 Geometry and Shape Grammars

In recent years, many researchers investigated the possibilities of putting shape grammars into architectural practice. The applications focused almost exclusively on design analysis. Because various principles were applied and different subjects were stressed, the grammars varied accordingly.

Lionel March and Philip Steadman in their 1971 published book "The Geometry of Environment" intended "to help bridge the gap between the new mathematics and the older generation", and expected the book would be of value for youth "as

an introduction to modern ideas of architectural form and spatial organization". The point of the book was that if mathematics was thought of as tool for a "logical pattern construction of entities and relationships" then this might perhaps be seen to be reflected in the physical and spatial arrangement of buildings (March, & Steadman, 1971, p. 6 & 7).

In this book, March and Steadman discuss the relationship between geometry and architecture, and explore the potential value of new mathematics in describing and organizing the geometrical shape of the design. They apply principles of mathematics to analyze architectural designs and organize them into concrete forms via equations and grammars. Their case studies include few well-known designs, such as Le Corbusier's Pessac house project and Frank Lloyd Wright house projects. The principles March employs include mappings, transformations, translations, rotations, reflections, symmetry, matrices, modules, networks, etc.

The first published paper on "shape grammars" by G. Stiny and J. Gips in 1972 illustrates their application of original languages of paintings; the first analytic exercise with "shape grammars" was given by Stiny in his 1977 paper, entitled "Ice-ray: a note on the generation of Chinese lattice designs" (Figure 3.16). Later, a special grammar was developed to explain a corpus of Palladian villas by Stiny and W. J. Mitchell and was tagged as "the Palladian grammar" (Figure 3.17). The

Figure 3.16 Analytic shape grammar, "Ice-ray"

Figure 3.17 "The Palladian grammar"

researchers used a set of existing designs, the corpus, to infer the rules of the grammar. These early studies became the foundation for many researchers that followed. Relying on these and other recent computer technology, shape grammars evolved to become a distinct design approach. It, as a course of study, was integrated in graduate programs at UCLA and MIT Schools of Architecture.

The term “shape grammars” is new, but the idea behind it is not. In 1856, an English architect, Owen Jones, applied this approach in his monumental work “The Grammar of Ornament”. In this application of decorative arts, Jones collected examples of ornaments from many different cultures and ages, and classified them according to their underlying structural similarities (March, & Steadman, 1971). Regardless of where shape grammars derived from, they all focused on the shape of designs and provided a typical approach and framework for current design practices.

3.5 Application of Shape Grammars

Historically, shape grammars were embedded in aesthetic systems for interpreting and evaluating works of art. In 1980, Stiny proposed a specific approach for creating original grammars “from scratch”. In his “Kindergarten grammars” paper, he was concerned with the creation of new and original styles of designs. “Analytical grammars” was developed to “analyze historical styles or languages of designs” by architects no longer alive (Knight, 2000).

Shape grammars emphasize the creation and understanding of designs directly through computations with shapes, rather than indirectly with the use of text or symbols. They perform computations with shapes in two steps: recognition of a particular shape and its possible replacement. Rules specify the particular shapes to be replaced and the manner in which they are replaced. Terry Knight (2000) defines the shape grammar as follows:

A shape grammar is a set of shape rules that apply in a step-by-step way to generate a set, or language, of designs. Shape grammars are both descriptive and generative. The rules of a shape grammar generate or compute designs, and the rules themselves are descriptions of the forms of the generated designs.

She employs the illustrations (Figures 3.18 & 3.19) clearly, showing that shape rules generate designs using the shape operations of addition and subtraction, and spatial transformations familiar to designers such as shifting, mirroring, and rotating. Entities can be freely decomposed and recomposed at the discretion of the designer. “The starting shape for computations, called the initial shape, consists of two L-shapes.” In Figure 3.18, from the second step on, the rules can apply to either emergent L-shapes or emergent squares. Either the addition rule or the subtraction rule can be applied to a design. The user of the grammar, whether human or machine, must decide the rule to apply and the shape of a design. In Figure 3.19, another computation using the different grammar is shown. After three steps of adding L-shape, subtracting square and disjointing small L-shape, the computation diverges and follows a different path to produce a different design. Many other computations are possible with the grammar (Knight, 2000).

Figure 3.18 The principle of addition and subtraction

Figure 3.19 Shape is generated under a different grammar

This approach is simple enough to be grasped and rich enough to serve as the starting point for complex, sophisticated designs. Nowadays, shape grammars have become an established paradigm in design theory, computer-aided design, and related fields. It has been explored through applications addressing a variety of design problems.

3.6 Development of Shape Grammars

José P. Duarte recently developed a shape grammar for Siza's Malagueira mass housing project. Duarte analyzed Siza's design and identified limitations of his design system. He systematized and organized Siza's design rules "in an explicit way", and wished to convey them to other designers. He also developed a

computer implementation of the grammar to overcome difficulties of Siza's system in representing the universal solutions using traditional design media. "A computer program encoding the grammar would allow one to use Siza's system" to do custom design (Duarte, 2001). When coupled with new prototyping and virtual reality techniques, users would visualize various design proposals.

In this application, the initial shape was a rectangle with a label "L" representing the lot. The house unit was based on rules for manipulating rectangles representing rooms. These rules included dissecting (Rule A), connecting (Rule F), and extending (Rule G) rectangles, as well as rules for assigning (Rule H) and permuting (Rule I), and the functions associated with them. By applying these rules, Duarte translated most of the house types that Siza designed at Malagueira (Figure 3.20). He developed the shape grammar and enriched the new design approach. His research spanned between analytical and original grammars.

Recent research on shape grammars mostly focus on the analysis of known or existing design works. There is no doubt that design analyzing is absolutely requisite. However, the method of developing shape grammars in research and utilizing them for new designs will be their ultimate manifestation. These are concerns that are addressed in this thesis pertaining to conceptual design.

Figure 3.20 Siza's house design at Malagueira, developed by Jose Duarte, 2001

Chapter 4. Design Solution

This chapter comprises three sections. Three projects remarked in last chapter are organized and analyzed at the beginning. They provide the theoretical foundation for the thesis design solution. Following every common point summarized here, frameworks are set up and solutions proposed, and conceptual designs are presented in the last section.

4.1 Theoretical Analysis

In attempting to verify the mass housing designs, three design practices are introduced in last chapter. There are some common specifics among these projects. Le Corbusier, Gropius, and Siza all desired to devise schemes that could be used to generate affordable mass housing; they simplified design processes, and used industrialization as a means to reduce costs and offer people personal choices. Design aims were very clear, and all works were around them. Although their design solutions and methods were varied, their general design thinking and approaches were quite similar. However, all their efforts had suffered from inherent system drawbacks, insufficient solutions and limited owner-participation, and constrained by the traditional design media. In this section, their common aspects and special features are organized and analyzed, and their limitations discussed.

4.1.1 Design Concepts

For mass housing, Gropius, Le Corbusier, and Siza employed similar design approaches, using the scheme or standard components to design mass houses. Different design concepts led to various design solutions. As a result, the system potentials were also diverse.

The factory-made house was Gropius and Wachsman's dream. The unlimited solution was their original idea. Conceptually, the theory of the Packaged House "envisaged a universal set of components out of which an almost unlimited number of alternative designs could be generated" (Herbert, 1984, p. 293). The design system had an infinite potential for numerous combinations. Under this concept, Gropius and Wachsman did a lot of work searching for the ideal design solution and exploring the system's inherent potential. New design system also interested many modern architects to test this exciting theory postulate. Thirteen house types in total were designed by using general panel components (Figure 4.1). But, could all of these demonstrate the unlimited design concept? Gropius intended to generate a very wide range of design options from a single design source - connectors and panels - and generate from them limited set of integrated components. This was the inherent drawback of the design system. Moreover, it spent too much time on design research and improvements. There were evidently difficulties in developing the design source and in representing the universal solutions by using traditional design tools. These were common problems, which also appeared on two other cases.

Figure 4.1 Gidoni, Bromberg, Gropius, Neutra's designs for houses using General Panel components, 1947

The standard plan for Pessac was generated by combining several modules. Actually, it first appeared in preliminary sketches drawn in 1917 and served for three of Le Corbusier's projects. In Pessac, it was more detailed and became the standard plan serving as the basis for all the house types in the scheme (Ferrand, & Feugas, 1998). This standard plan represented a logical development of Le Corbusier's previous designs, and could be regarded as a portion of Le Corbusier's series works. In addition, each house type could be used as the design source to develop the various combinations according to site situations. The varieties of design were not only combinations of modules but also combinations of each individual, therefore the system had a large design potential. Whereas only four types served for one hundred planned houses, it seemed to have difficulties in developing the varieties of design by using traditional design tools. The same problem also happened in Siza's design.

Siza employed initial designs to develop the house types, and then the subtypes. At Malagueira, total 10 subtypes were generated. They were Ab, Ac, Ad, Ae, Bb, Ca, Cb, Da, Db and E (using itself as the subtype). Each of them had five possible variations from T1, a one-bedroom house to T5, a five-bedroom house. Figure 3.20 only showed a part of Siza's design, which was developed by José Duarte in his research in 2001. Siza set up a design system for this large-scale project. But what about his design concept and performance of his design system?

Actually, Siza's design concept was more "closed" in comparison with Gropius and Le Corbusier's unlimited or open concept. On the one hand, in order to satisfy future occupants' customizing demands, the only way Siza would do so was to develop a new house type or subtype. By using traditional design tools, each of these processes was separate and resembled an individual design. Each design was self-enclosed and isolated from others although there were some linkages among them. Unlike Gropius or Le Corbusier who utilized universal parts to overcome drawbacks of traditional design tools, Siza's system lacked standard components to simplify design processes. As a result, design tasks were repeated and strenuous. This point can be understood by comparing his design with Le Corbusier's in Figure 4.2. On the other hand, Siza's design method was very passive. He relied only on the addition of new types to satisfy clients' needs. It made his design system very big, but its potential could never be fully utilized under his design concept. The next section will further detail how to overcome these drawbacks in the conceptual design.

4.1.2 Grammars of Designs

No matter the kind of design, it is always generated by following some rules, which architects have set up depending on general principles and specific conditions. Even if rules are implied, they can be interpreted in an explicit way - such as the grammars. As for Le Corbusier and Siza's designs, it is worth doing this work because their designs are valuable in directing design practice.

For the Pessac project, Le Corbusier used standard components and a standard plan serving as the basis for all the house types. The generations of house types and combination followed the same approach but in various means. By applying March's spatial organization theory, these types can be organized by grammars and rules, which are clearly shown in Figures 4.2a, b, c, d and e. In one house type, Le Corbusier "reflected the plan about the party wall to form two semi-detached dwellings" (Figure 4.2a, March, 1971, p. 21). Le Corbusier used a standard plan by mapping two kinds of combinations. One design was a fine-turning of the combination of dwellings arranged in a "z" formation (Figure 4.2b, Ferrand, & Feugas, 1998). In another design, Le Corbusier created a terrace by reflecting. "The plan about its midpoint and gliding it one bay so that houses alternately 'front' and 'back' onto the road" (Figure 4.2c, March, 1971, p. 21 & 22). By translated house plans, "the house is simply repeated along a line to form a combination with the terrace" (Figure 4.2d, March, 1971, p. 21). Three house types are shown in above cases, and the fourth house type is shown in Figure 4.2e (Boudon, 1972). The designs presented Le Corbusier's "five points of a new architecture" (Moos, 1979).

Figure 4.2a Reflected house plan

Figure 4.2b The combination of standard plan in “Z” formation

Figure 4.2c House plans showing reflection and translation

Figure 4.2d Translated house plan

Figure 4.2e Le Corbusier's two-storeyed house type

In the Malagueira project, Siza used some implied rules for himself and his collaborators to control the customized designs. These rules were applied in each design process in order to systematically develop variations from each subtype. Siza never laid out such rules clearly, but they were distinctly embedded in his designs and could easily be found. A series of variations in Figures 4.3 shows one of these rules (Figure 4.3a, Testa, 1996; Figure 4.3b, Duarte, 2001). Four variations of subtype Bb were developed under one rule. They were the same on the first floors, but the designs of second floor showed a sequence of regular changes following the quantity of bedrooms. By adding one bedroom on each floor plan, Siza gradually developed sequential floor plans. In this manner, variations were customized from a two-bedroom to a five-bedroom family house. Future occupants could easily choose the designs that satisfy their needs.

Figure 4.3 Siza's grammar: (a) Siza's designs; (b) 3D models, developed by J. Duarte

This rule is simple but useful. It can be explained by shape grammars. José Duarte (2001) organized this kind of Siza's rules as a named "addition rule" in his application. This rule controlled floor shapes and ordered all variations. By adding one unit to an initial shape, a variation was developed, which could be used as the new initial shape to generate the next variation and so on. Duarte set up all Siza's design rules "in an explicit way" and thus developed Siza's grammars. Duarte's computer program just encoded Siza's grammars to interpret all Siza's designs.

Figure 4.3 shows a typical evolvement of variations. Some subtypes, such as Ca, had five variations generated under the same rule. This subtype can express this addition rule better (Figure 3.13). Unlike subtype Bb, some variations were also different on the first floor, but such changing was small and also followed the design rule. The different variation only appeared on a one-bedroom house, such as subtype Ca, or one- and two-bedroom houses, such as subtype Ac.

4.1.3 Standard Components

The merits of "serial production and "standardization" were being argued by all leading architects in the early 20th century. Actually, the Pessac project and the Packaged House were the products of this international movement. Le Corbusier applied the standardization concept to the mass housing design in Pessac. He used three type modules of concrete cells to generate the standard plan, and then to develop all types. For design purposes, the module appeared in each

house unit, and therefore simplified design processes. For manufacture and construction, the module was a perfect means of unification in the mass production of manufactured articles. It offered the possibility of the followed application of prefabricated components and harmonious integration of standardization products. In Pessac, industrial standard products were used everywhere. The same type of window, door and washroom equipments appeared in all house types. The Pessac project was conceived at a time when modern architecture had entered a particularly fruitful phase and when Le Corbusier himself had reached the peak of his first creative period. The standardization ideas introduced by le Corbusier in Pessac were not entirely his own, which were also explored by Gropius and Wachsman.

The Packaged House was an ambitious project during the wartime. Its system was designed and conceived as universal, with an infinite potential for combination of a set of standard panels related to each other by standard connectors in three directions. Standard units or sections, each fundamentally consisted of a duplicate of the other so that any panel could be interchanged with any other. "It was hoped originally to market these standard components, this kit of parts, rather than completed houses". The perspective of the company not only planned to distribute the house products to the entire United States, but also to export to Canada and other North American countries (Herbert, 1984). Both design concept and company strategy offered the Packaged House a universal meaning of standardization.

The use of both standard parts and modules was an ingenious method to simplify the design process and thus overcome drawbacks of inefficient design tools. However, the ideas of universal solution, of standard components and their standardized, anti-regional, international architecture compete with the traditional, localized, vernacular architecture on cost, but obviously neglected individuality. As for today's mass housing, it is "neither old nor new but simple true - not through a spirit of compromise at all costs, but through logic and the realistic evaluation of material and need" (Piacentini, 1975, p. 27). A standard idea is a reasonable solution and can be adopted, but its impersonality needs to be discarded. On the one hand, "houses must not become uniform" everywhere. On the other hand, people think of each house today as a personal dream. Individuality should be added into the house, and people should have the chance to be involved in the design process of the house in which they live everyday.

4.1.4 Owner-participant

People want houses in accordance with their wishes. Architects are capable of satisfying their clients' deep habitational needs. But in fact, "the mere definition of these needs, which are still obscure, would presuppose that they were capable of existing independently of any living context, which is hardly likely". It seems that, far from isolating illusory general truths, a study in depth, carried out within a clearly defined and limited context, can clarify the relationship between the architect's original conception and the residents' reactions (Boudon, 1972). For mass housing, clients' demands are ever changing. What architects attempt to

do is to satisfy general requirements of mass clients without jettisoning essential functions of houses. This is the normal way that most architects have adopted.

Le Corbusier isolated each pair of houses in functional terms and achieved a high degree of isolation in both physical and psychological aspects. But he neglected the future occupants' feelings and tastes, especially their acceptability for new styles. His modern living containers presented as an ideology and not as a technical innovation (Boudon, 1972). People did not have any chance to customize their dream homes. Gropius and Wachsman considered this point and were willing to give people "pleasure on personal choice and initiative." As an end product, the Packaged House was designed as a highly customizable home. But the final product was divergent from this original idea. With increasing demands of living standards, both architects and clients have given more consideration to the personalization of houses. Siza's design especially stressed this point. He incorporated the clients' desires for customized houses into the design process. Since the beginning, all suggestions were accepted and were then applied into the customized house design. All changes were mainly dictated by costs, personal taste and local culture habits, and were transferred to designs by Siza and his colleagues. But later, assemblies and individual meetings became less frequent because they were time-consuming. This became a common phenomenon, also occurring in many other custom designs. Moreover, there were obvious difficulties in representing the universal solutions using traditional design tools and there were difficulties in transforming every occupant

demands to the designs and then conveying these to occupants. Inefficient design tools constrained not only Siza's project, but most custom design for mass housing.

Another common phenomenon occurred frequently on customization projects such as those in Malagueira. Different kinds of clients had different demands and conceptions for their dream homes. Different occupants' organizations led to different kind of uses and appearances, which changed the original designs. At the beginning of project, all transformations occurred just inside of the buildings, never influencing the urban form. But later, "a lot of transformations had been undertaken by the owners. Uses of the compartments of the dwellings, had changed from those proposed by Siza. All these changed the townscape, entrance doors, windows and colour lines have been changed or added...."(Pinto, 1999). A local architect Fernando Pinto in Évora addressed this phenomenon, by stating "no one is master of the taste of a whole population, even though if the name involved is the one of Alvaro Siza Vieira or any other well known architect. This is the path of a bit of a living city, and people are an important part of it". He thought that it was not Siza's fault and all the occupants' behaviors were legitimate. Normally, the role of the architect finishes with the end of the construction work. Siza continued his intervention for some more years by controlling all external interventions. At least this instance gives us a reminder that customization needs design control in order to keep all customized houses harmonizing on a big scale.

4.1.5 Industrialized Means

The prime consequences of the industrial evolution in “building” appeared at this fundamental stage were the replacing of natural materials by artificial ones, of heterogeneous and doubtful materials by homogeneous and artificial ones tested in the laboratory and by products of fixed composition (Le Corbusier, 1923). As pioneers of modern architecture, Le Corbusier and Gropius put stress on architectural innovation by influencing both theories and practices. The Pessac project was like an experiment, and all ideas followed Le Corbusier’s perspectives on mass housing few years ago (as cited in Boudon, 1972, p. 33):

By slow degrees the building sites will become industrialized, and the incorporation of machines into the building industry will lead to the introduction of standard components; house designs will change, a new economy will be established; the standard components will ensure unity of detail and unity of detail is an indispensable condition of architectural beauty...Thanks to the machine, thanks to standard components, thanks to selectivity, a new style will assert itself.... (Le Corbusier, 1923)

Pessac could be regarded as a laboratory, and Le Corbusier put his theories into practice and carried them to extreme conclusions. He established suitable forms of standardization, built walls, floors and roofs with high standards of strength and durability and introduced a full system of tailorization by the use of machines. As a result, Le Corbusier used the industrial means to create the modern form and reduce costs. He built a new style of containers for people that are easy and pleasant to live in. It mirrored what he stated later: “The house is a machine for living.... As to beauty, this is always present when you have proportion...” (Le Corbusier, 1923).

Like Le Corbusier's idea, the Packaged House also used the way of industrial mass-production to reduce costs. It was developed as an industrialized product and aimed to transfer most of the labor from the site to the assembly factory. Gropius and Wachsman hoped to produce a factory-built product that was competitive in quality with the traditionally built houses of the tract developer, at a significantly lower price. This was the goal of the Packaged House. However, since only one type of house was produced, their dream ended. The Packaged House "was entirely self-contained and comprised a kit of parts whose every component element was purpose-made". As a result, it hardly incorporated with the products mass-manufactured by others and all parts had to be produced in one comprehensive factory. It was a rational system in that number of components was severely limited (Herbert, 1984). Besides its wrong strategy and inherent drawbacks, it was also limited by external reasons. In its industrialized housing process "there are of necessity other subsystem, relating production to distribution, financing, legislation, transport, and land. As a product to be manufactured, it was not yet conceived in term of this wider context (Herbert, 1984, p.256)." This instance mirrored another American mass housing project – Levittown in Long Island. It was developed in the same approach and in the same age of the Packaged House.

Levittown was a comprehensive and very successful mass-produced housing project developed by William and Alfred Levitt from 1945 to 1954 (Kelly, 1993). It was a homogenous mass of mass-produced housing, which was preplanned and

standardized. The Levitt house was produced by using the assembly-line production system. The majority of components were prefabricated en masse and assembled by carpenters on site who specialized in a particular installation. The institution of power tools and labor specialization at the construction site was attributed to the Levitts. The housing construction was divided into 26 steps, with extensive use of prefabricated components. The resulting implication of this carefully controlled production methodology consisted of an 800-square-foot house being completed every 15 minutes (Friedman, 2002; Clark, 1986). Due to these industrialized means, the houses were sold at a very low price, for example a basic 1949 Ranch was only \$7,990, which caused people to stand in line to buy houses. Moreover, buyers could select from several options of facades for the same layout which provided some choices and alternatives to suit their preferences. The Levitt house had two types, Cape Cod and Ranch. Figure 4.4 only shows the Ranch models of architect's renditions for 1949 and 1951 (Kelly, 1993; Hayden, 1984; Hales, n.d).

The Levitt house and the Packaged House were both the standardized products prefabricated in the manufactory and assembled on site. From design to construction, they had the same concept and used the same industrialized means. The success of Levittown was not merely due to the fact that it had more house models to choose from than the Packaged House. The main reason was that the Levitt house was not as an end product to be developed; therefore, it kept away from the wide context, which the Packaged House was dealt with. The

industrialized house as an end product needed a long-term process to develop and is not mature even today. Present house development in North America still follows the approach, which Levittown adopted.

Figure 4.4 a-e for the Levitt Ranches 1949-50; f-h for the Levitt Ranches 1951.

4.2 Solution Frameworks

Nowadays, We have new web-based communication systems, computer aided design tools, and an advanced manufacturing industry, which make it possible to finally "offer the client the pleasure of personal choice and initiative" in an industry that, except for the very few offers, essentially offers no choice to homebuyers. Indeed, today sees favorable conditions that the masters could never have imagined. However, the challenge to offer the current homebuyer "the pleasure" requires architects to study intensively and think deeply. Undoubtedly, Le Corbusier, Gropius, and Siza's design concepts are deliberate and solid. They certainly provide theoretical foundation for this research. By discussing their design works, one attempts to learn from their thinking. By arguing their design limitations, one intends to seek better solutions. These are the main purposes for the theoretical analysis in last sections. Following every point remarked previously, the frameworks are set up and solutions are outlined in this section.

4.2.1 Introduction

Homebuyers have dream homes in minds, and each one has specific needs and different uses for their houses. Although there are lots of new houses for sale, optional targets are always limited. Fewer selections of house models cannot make homebuyers content, and insufficient personal choices cannot satisfy their specific needs. Such problems are caused by the current design concept for

mass housing. Ever since the architect began to design the house for the public, design modes have not been altered significantly. Today's design of mass housing is based on satisfying most people's general needs and is less responsive to their specific requirements and uses. Although architects and developers currently provide more and more design options and personal choices than ever before, such efforts never make any remarkable effect. Whereas today's house design is no longer just for the few adventurous wealthy, the public should also have the chance to customize their houses according to their wishes. The homebuyer on current house market is a loose group of individuals. The architect don't have definite client anymore. Therefore, a corresponding design solution needs to be explored in order to meet these future homebuyers' expectations.

To recall preceding design works, ideas can be sought from them. Le Corbusier did not offer any personal choices to the client; nevertheless he satisfied their general needs by relying on his intensive study and exquisite design. Siza made an attempt at customizing the mass housing. He offered a lot of time and options to his clients, but his design method - cooperative meeting, still stayed on the traditional mode that was used for customizing personal houses. Gropius and Wachsman's system could conceptually generate almost unlimited numbers of alternative designs, in such a manner, they could "meet the public's desire" and offer client "personal choice and initiative." This solution is reasonable and is

more suitable for current client situations. The following solution for mass customization is enlightened by this unlimited concept.

4.2.2 Matrix Concept

In the previous section, more stress was put on the masters' design concepts and system potential. Based on these studies and combined with other researches, the matrix design concept is defined in this section. Under this concept, an appropriate design approach and a design system are developed.

The design aim is to offer homebuyers a wide range of personal choices and interactive selections of initiative. In order to achieve this, the system must have the potential to generate a large number of design options. Under this concept, every design is different with others, with the hope that it will always have the design option that meets every homebuyer's desire. As to the term 'custom design', it does not appear in the architectural design process but on the final house generation process. This customized process, the initiative, is left to homebuyers. By freely selecting various design options by themselves, they can customize their houses following their needs. However, meeting all homebuyers' needs is not easy, and people should know that the actual homes they will buy and the ideal homes they imagined are always not the same. The proposed solution aims to reduce such discrepancies, giving homebuyers more pleasure and decreasing their regrets.

4.2.2.1 Theory

In their book, March and Steadman (1971) explored the possibilities of mass-produced housing. Le Corbusier's housing scheme at Pessac was used as the example, and the type of window was selected as the start point to analyze varieties of each type of window in each type of house. March and Steadman systemized three types of window Le Corbusier used at Pessac: a quadruple square window, a double square and a single square one. They used what architects call a "window schedule", a listing of the quantities of each type of window in each building to make a matrix. They mapped "an array onto an abstract mathematical structure, a system of mathematical pigeon-holes" (p. 87; Figure 4.5). It was array of numbers, "most neatly done in the form of a table". On the top was the type of house and the left side was the type of window. They explained it as followed: the position of the numbers might not be changed arbitrarily because the array of numbers had a characteristic. The order of house types and window types was fixed. So, the place of each number in the array also was fixed. As the result, they got this 3 x 4 matrix, which had three rows and

four columns like this:
$$\begin{bmatrix} 0 & 0 & 3 & 2 \\ 4 & 6 & 3 & 2 \\ 2 & 1 & 2 & 1 \end{bmatrix}$$
. The row was a representation of the number of windows of type 1 (first row), type 2 (second row), type 3 (third row) in each house: house type 1 (first column), type 2 (second column) and so on. If someone only wanted to know how many windows of type 1 there were in each house type, a row of numbers could be expressed like this: $[0 \ 0 \ 3 \ 2]$, which was a 1 x 4 matrix, or "row vector" (March, & Steadman, 1971).

House type:		1	2	3	4
	second floor
	first floor
	ground floor
Window type:					
1		0	0	3	2
2		4	6	3	2
3		2	1	2	1

Figure 4.5 The 'window schedule' of Le Corbusier's Pessac project.

This analysis is quite concrete and easy to understand. It is unique in applying a mathematic principle to an architectural research field. The computation principle of shape grammars is also established in similar approach. March and Steadman's method is simple but general which makes sense. Actually, the matrix concept derives from this case study and shows its logical development. In order to clearly clarify this point, Siza's design is used as the example to describe the application of the matrix method, and the method to use the matrix concept to set up the design system.

4.2.2.2 Application

A review of Siza's house design and subsequent analysis of his design potential using the matrix methods is enclosed in this section. At Malagueira, some subtypes are never built and are not included here (such as Aa, the preliminary design). In total 10 subtypes, including 36 house layouts, were designed by Siza and by his collaborators under Siza's supervision (regarded type E as a subtype). Table 4.1 lists all the subtypes and quantities of variation(s), which follows the category that Duarte organized in his research in 2001 (Figure 3.20). It only collected 26 house designs / variations; however, all possible variations were not merely 26 or even 36. The reasons were that some of one- and five-bedroom houses were less needed and never built, and three customized subtypes for individuals only on one variation. According to Siza's design method, each subtype could reach its five maximum variations - from T1 to T5. If every individual subtype is kept on one variation, all possible variations should still be 38 ($7 \times 5 + 3$), which is close to the number of Siza's designs. Furthermore, if three individual subtypes are considered to be used for the public, all possible variations should reach to 50, which is the maximum number of variations in Siza's system.

<i>Subtype</i>	<i>Ab</i>	<i>Ac</i>	<i>Ad</i>	<i>Ae</i>	<i>Bb</i>	<i>Ca</i>	<i>Cb</i>	<i>Da</i>	<i>Db</i>	<i>E</i>
<i>Variation</i>	4	4	1	1	4	5	1	4	1	1

Table 4.1 Quantities of variations

The matrix method can be applied to analyze Siza's design potential. Before deriving a map of all possible variations to the matrix, a more detailed expression is needed. In all subtypes, variations of each subtype are different on the second floor. They are all generated under the same rule and should have five designs when variations reach their maximum. Such a rule is also applied to the variations on the first floor but not to all subtypes. In some subtypes, such as Bb, variations are the same on the first floors. In other subtypes, such as Ac or Ca, most variations are also the same on the first floors, and the differences occur on one- or two-bedroom variation or both of them. If a calculation of the quantity of possible variations still follows Siza's design method, such different designs can be covered by identical designs in the same subtype. In summary, possible variations of each subtype have one design on the first floor and five designs on the second floor, which are all listed in Table 4.2. Here, March's quantities of window types are replaced by Siza's quantities of variations. It shows separate designs of variations on two floors. This is more distinct and can be used to calculate possible designs.

<i>Subtype</i>	<i>Ab</i>	<i>Ac</i>	<i>Ad</i>	<i>Ae</i>	<i>Bb</i>	<i>Ca</i>	<i>Cb</i>	<i>Da</i>	<i>Db</i>	<i>E</i>
<i>1st floor</i>	1	1	1	1	1	1	1	1	1	1
<i>2nd floor</i>	5	5	5	5	5	5	5	5	5	5

Table 4.2 Quantities of variations on each floor

If one wants to know how many designs there are in each subtype, a column of numbers can be expressed like this: $\begin{bmatrix} 1 \\ 5 \end{bmatrix}$, which is a “column vector” in a 2 x 1 matrix. Following the array and combination principle, there are 1 x 5 designs generated. They can be regarded as five-times the combinations of one design of the first floor with five designs of the second floor. Similarly, variations of all subtypes shown on Table 4.2 can be mapped as an array into this 2 x 10 matrix:

$\begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 5 & 5 & 5 & 5 & 5 & 5 & 5 & 5 & 5 & 5 \end{bmatrix}$. The number of the final combinations is: 10 x 1 x 5 = 50. The result is same as before, but the meaning has totally changed.

First of all, a clarification of two terms is needed in order to distinguish these definitions from previous descriptions for others. For the term “combination”, it is almost the same as the meaning of Siza’s “variation”, but it generates from a different way. It is redefined in this section and given “combination” name in order to distinguish it from Siza’s “variation”. In here, the term “combination” is more appropriate to express its form of generation. Moreover, the meaning of “variation” must be clarified. The “variation” of the floor plan used later is different with Siza’s floor plan of the variation. Although they are almost same, they derive from different design approaches.

Second, in this application Siza’s design is simply interpreted into a matrix, and a calculation of the possible combinations still follows his design concept, so the result is sustained at 50. From the matrix viewpoint, in each subtype, Siza used

every design of the second floor only one time to combine the design of the first floor composing of five combinations. Even if variations on the first floor had differences, the maximum variations would be still five. That is why subtype Ac (or Ca) uses the identical design on the first floor omitting the less discrepancy.

Finally, the above arithmetical calculation shows that the amount of house designs is determined not only by how many types / subtypes exist, but also by the number of designs on either floor or both. To increase the design potential, the better way is to increase all of them. Only adding the new type cannot generate a very remarkable result, which is the reason of why Siza's design system was so big, but its potential was not fully used.

4.2.2.3 Postulates

Following the above result, some postulates must be proposed to shift Siza's solution and try to develop his design step by step by following three conceptual postulates. However, an attempt is made to find a solution for the general mass housing, not only for Siza's design. Three postulates are merely based on his design and aim to organize it onto a general expression for this design use.

First, in each subtype, if a new design of first floor is added, variations on the first floor will increase to two designs and its matrix also changes to: $\begin{bmatrix} 2 \\ 5 \end{bmatrix}$. But the premise is that the new design must be compatible with the designs of the second floor. The matrix principle can be followed to calculate. The following five

designs of the second floor combine twice with each design of the first floor, and the combinations are 2×5 , thus total combinations increase to $10 \times 2 \times 5 = 100$. As a result, the system doubles its design quantity. Certainly, to reach the above result, in total, ten more first floor plans are needed to be designed. But these are not ten more subtypes. The difference is very clear by comparing $(10+10) \times 1 \times 5$ with $10 \times (1+1) \times 5$. Although they are the same in the result, their meanings and design loads are different, which can also be demonstrated by next point.

Second, Siza's design can be further expressed by the following statement. In order to equally compare the postulate with Siza's concept, the number of combinations is set up at 50. In the last section, Siza's design is mapped to this

original 2×10 matrix: $\begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 5 & 5 & 5 & 5 & 5 & 5 & 5 & 5 & 5 & 5 \end{bmatrix}$. This design interpretation is a long matrix with 10 columns, with each column representing a subtype.

Actually, we can simplify it by joining the same kinds of subtypes to five original types - A, B, C, D and E. The first four columns are four subtypes of type A and

can be combined like this: $\begin{bmatrix} 1 \\ 5 \end{bmatrix} + \begin{bmatrix} 1 \\ 5 \end{bmatrix} + \begin{bmatrix} 1 \\ 5 \end{bmatrix} + \begin{bmatrix} 1 \\ 5 \end{bmatrix} \Rightarrow \begin{bmatrix} 4 \\ 5 \end{bmatrix}$. These gather all the four

designs of second floors and unite designs of first floors to five identical ones.

After the same method is applied to types C and D, and is the same for types B

and D, the original matrix can be simplified to this: $\begin{bmatrix} 4 & 1 & 2 & 2 & 1 \\ 5 & 5 & 5 & 5 & 5 \end{bmatrix}$. The amount

of combinations of each type is: type A, 4×5 ; type B, 1×5 ; type C, 2×5 ; type D, 2×5 ; and type E, 1×5 ; and total combinations remain 50. In the new matrix,

designs of each floor remain representative of Siza's forms. It still keeps ten varieties of the second floor and reorganizes them in five types. It discards repeated designs of the first floor, because within the same kinds of subtypes, variations on the same number of bedrooms are almost the same and can combine or replace each other. By using this postulate, the design system can be reduced. It saves half the workloads of the first floor and while achieves the same design quantities. This postulate can be regarded as the juncture between the other two postulates, which still has the capacity for further development.

Finally, in an attempt to improve the applicability of last postulate, a more general expression is developed on previous considerations. Although Siza's design is summed up to ten subtypes, house units are all in 8 x 12 m standard lots. They can be classified into two families of houses, depending on whether the yard is at the front - bordered on the street surrounded by an L-shaped unit, or at the back - oriented to the rear. The front yard family houses include four types: A, C, D, and E whereas the backyard family houses only include type B. Based on the last postulates, the matrix of Siza's design can be further simplified and

expressed like this: $m \begin{bmatrix} F_f \\ S_f \end{bmatrix} + n \begin{bmatrix} F_b \\ S_b \end{bmatrix}$, which includes two house categories. F_f and S_f represent designs of the first floor and the second floor with the front courtyard; similarly, F_b and S_b represent designs of two floors with the back yard. The numbers of S_f and S_b range between one and five: $S_f \leq 5$, $S_b \leq 5$, representing designs of one- to five-bedroom. m and n determine how many subtypes of combinations there are in each category. Siza's design is therefore

organized into this general expression, whereas the matrix of either the front courtyard or the backyard can be used as the framework to develop design grammars for this thesis.

(a) To restore Siza's design, the values for m and n can be set up as $m = 9$ and $n = 1$, which represent Siza's nine subtype with the front courtyard and one

subtype with the backyard, Thus, the matrix changes to this: $9 \begin{bmatrix} Fr \\ Sr \end{bmatrix} + \begin{bmatrix} Fb \\ Sb \end{bmatrix}$. If

designs of every floor of each subtype are put into every row of Fr , Fb , Sr and Sb , this matrix will go back to the original 2×10 matrix, which is Siza's design. (b) To simplify Siza's design, m and n can be set as $m = 1$, $n = 1$; Fr and Fb can be set as $Fr = 9$, $Fb = 1$; Sr and Sb can equal to five. Therefore, the sum of the combinations is: $1 \times 9 \times 5 + 1 \times 1 \times 5 = 50$. As a result, the system reduces to only two house types with different yards, and the design load only equals to ten normal house designs. Although there are some repeated works in Siza's design, the workload should not save too much due to the use of traditional design tools, and his design load is far more than ten. This postulate avoids repeated design works and enables the workload to become more reasonable. These are very important for the mass housing design.

The above statements are just conceptual postulates. They are the ideal solutions but need some requirements to make them work. Certainly, some of the combinations will not be exactly the same as Siza's original variations; however, the attempt is to explore a new design approach, which is merely based on his

design structure, not on his specific design. The final postulate is the outcome of the previous works. It is based on Siza's design analysis, organizes this specific design work, and then summarizes it onto a general expression - a grammar. Once this is established, it can be further developed and used for the following conceptual design. To make this postulate possible, every design of each floor must be interchangeable, and all of them must be compatible each other.

4.2.3 Grammar and Rule

This section aims to develop the above outcome for a type of grammar, which can be used for the conceptual custom design for mass housing. Meanwhile, the rules and system potential are described.

4.2.3.1 Matrix Grammar

According to the design conditions, Siza classified various designs into different house types and followed specific rules to generate variations depending on the number of bedrooms. In comparison, here the number of bedrooms is used to sort the house types and then designs of the floors are employed to compose the combinations. The single house will be used as the model to develop a typical form of expression, which is fit for all house types of the conceptual design.

Generally, a typical Canadian single house has one basement and two stories above the ground. Its function and topology are very clear and fixed. For developing its typical expression, it is supposed that a single house has three

floors, and each floor is set up like this: letter **B**, **G** and **S** represent the designs of the basement, ground floor and second floor. Based on the final postulate, the

grammar of combinations can be expressed by this three-row matrix: $\begin{bmatrix} B \\ G \\ S \end{bmatrix}$, which can be described by following description. On each row, designs of floor should consist of one initial plan with its variations, several different plans, or several initial plans with variations. Each of these is individual and is interchangeable. Moreover, every design on each floor can be compatible with all designs on the other two floors and one can freely compose the combinations. The designs of each floor can be set up like this: **B**, **G** and **S**, respectively has a set of **a**, **b**, and **c** number of similarity transformations, which is represented by letter **T**, and **Cn** represents **n** number of final combinations – house designs. The grammar formalism can be summarized in this equation:

$$Cn = T(Ba) + T(Gb) + T(Sc). (a, b, c \text{ and } n \geq 1)$$

According to the matrix principle, the final results are a series of arrays and combinations of floor designs. The number of design combinations can be calculated by this equation:

$$\sum Cn = a \times b \times c$$

These equations and the above matrix are the typical form of expression, which can be used for every type of the conceptual design, ranging from two- to five-bedroom houses. When **a** = **b** = **c**, each floor has the same number of designs, and the number of combinations will be **a**³, which is the special case of the typical expression. Due to less design variety for the basement, this case should

only happen at the beginning of the design process. In the following discussion, two examples will be used to explain the two aspects of typical expression: design rules and system potential.

4.2.3.2 Matrix Rule

This example indicates how the system works under the design rules. To do so, the designs of each floor - **B**, **G** and **S**, are supposed having two transformations - **a**, **b**, and **c** = 2. They could be either two different designs or two related variations of design. The combinations can be expressed by a column of

numbers like this: $\begin{bmatrix} 2 \\ 2 \\ 2 \end{bmatrix}$, and combinations of the system is: $2 \times 2 \times 2$ (or 2^3) = 8.

The design load of all floors equals to two normal house designs, and a total of eight different house designs is achieved by using the matrix concept. In order to clearly show its rule, the numbers can be replaced by more concrete forms, supposing two designs for each floor like the following: **B1** and **B2** for basement, **G1** and **G2** for ground floor and **S1** and **S2** for second floor. All of them can be

mapped onto this 3 x 2 matrix: $\begin{bmatrix} B1 & B2 \\ G1 & G2 \\ S1 & S2 \end{bmatrix}$, and eight design combinations which can be listed as follows: **B1G1S1**, **B1G1S2**, **B1G2S1**, **B1G2S2**, **B2G2S2**, **B2G2S1**, **B2G1S2** and **B2G1S1**. This example concretely demonstrates how the system works under the matrix rules, which follows the matrix principle of the array and combination of every element onto each row and column.

4.2.3.3 System Potential

In order to provide adequate designs to the massive homebuyers, the system with high design potential is the first consideration. The matrix concept is developed on this basic point. It provides a solid theoretical support for the design solution. By applying matrix grammar, the system can generate a large number and a wide range of design options to meet people's desires. Homebuyers can interactively select the designs and freely combine them to develop final house designs that follow their wishes.

For actual cases, design quantities on each floor are surely not always equal. For example, for the basement, it normally does not have many designs, but it has at least two designs, whether finished or unfinished. Besides satisfying functionality, it is not difficult to get three designs on the first floor. By shifting the position, shape, size of bedrooms or washrooms, four designs on the second floor also easy to achieve. All designs of floors are almost equal to three normal house designs. After combining every three designs of each floor, finally $2 \times 3 \times 4 = 24$ different combinations can be developed. The design quantities on each floor are used to show the system potential, and in actuality, more quantities can be achieved. This instance only shows one house type of one house model. By changing the number of bedrooms, at least four types of family houses ranging from two- to five-bedrooms can be developed, thus one house model will have 24×4 combinations. The total design sum is equal to 12 normal house designs. If the house layout keeps changing, various house models in different styles can be

designed. Therefore the system has the conceptual potential to generate unlimited combinations.

4.2.3.4 Summary

The matrix concept combines all previous studies. It derives from March and Steadman's matrix case study, Siza's design case, Gropius's unlimited design solution, and Gropius and Le Corbusier's standard components and combination approaches. The proposed solution attempts to absorb the design kernels of these designers and eliminate design limitations they encountered. All this can be explained by following statement.

Design variations or possible designs are always constrained by adequate functionality, reasonable limits, aesthetic acceptability, prevailing taste and many other aspects. Every design, such as the Packaged House, is limited by this wide context. It is possible to say that the unlimited design solution is not realistic. In this proposed solution, house models and designs of each floor are also limited by such context. However, the matrix concept is unique in its generation approach. Its design rules determine that the generation process does not occur in a single, linear and stage-by-stage way but by numerous ways of array and combination. Every possible design is not only used one time. It obviously increases efficiency by utilizing every possible design and thus remarkably lowering conventional design limitations. The system can conceptually generate unlimited designs of combinations; however, considering the above design

context, the matrix concept is not defined by this but a solution with a large number and wide range of designs.

The combination approach integrates Le Corbusier's design generation concepts and matrix regulation. All final outcomes are combinations of floor-designs, which are similar with Le Corbusier's combinations of structural components, but are different on design expectability. Under the matrix grammar, all combinations are generated following the rules and can be expected on their processes, quantities and results. However, to achieve this, every design must meet the requirements of combination.

4.2.4 Standard Designs

Under matrix concept every design of floors can be regarded as the source and used to generate the final combinations in multiple ways. However, in order to get the proper combinations following the matrix rules, all designs of each floor must be interchangeable, and must be compatible with designs of other floors. Therefore to do so, all designs must be standard, which is the premise of the matrix grammar. This standard concept and combination approach receive the theoretical support from Gropius and Wachsman's Packaged House and Le Corbusier's Pessac house project. The standard design defines a new usage of standard component.

4.2.4.1 Concept and Development

The basic concept of standard design derives from two modernist precedents. Gropius with Wachsman used standard connectors and general panels to generate a floor unit in two design steps: firstly, panels combined to a set of integrated components, and secondly, several set of integrated components combined to a floor. Le Corbusier employed modules of concrete cell to combine each floor. The masters used standard components to design the mass housing, but there existed an essential discrepancy between the manufacturing of components. The module used by Le Corbusier included only standard structures, not standard parts, connectors and panels. As a result, he saved one design step in comparison with Gropius's design process. In the conceptual design, each floor utilizes standard components, which are design sources for generating combinations. It is the logical development of the masters' design concepts and the basic requirement for matrix grammar. This enables the house design to be more efficient.

4.2.4.2 Defining Standard

The idea of approaching the standard from the mass customization of industrial products will be attempted. With build-to-order computer systems, Dell meets various, specific customers needs; Toyota operates the same processes worldwide, while expectations for a residence vary widely according to place and culture. Computer mainboards and automobile chassis can be standardized. Similarly, a house 'chassis' also can be 'standardized' depending on the number

of bedrooms. Once the adequate function of first floor is 'fixed', the design can be proceeded and various needs can therefore be added. But, the 'standardized' or 'fixed' doesn't mean that house will become the 'international face' like industrial products. The standard designs or house 'chassises' are diverse due to the various numbers of bedrooms and different house models. The 'standardized' concept has the meaning of a series of designs in one house model or type. It merely gets the "standardized" specification from industrial products but no longer possesses an international signification.

The matrix grammar is a generation approach of the combination, with the standard design being the basic source. The standardized concept defines the starting point of conceptual design and thus the design can be proceeded following the shape grammars due to the characteristics of mass housing, similarity and diversity.

4.2.4.3 General and Specific Fits

The custom design for mass housing is obviously different from the private house design. The architect does not have specific clients, and the design is not definite for anyone. The client is now represented by a large number of future homebuyers whose exact needs are unknown. It is known as "design without client information". Normally, usages of functional spaces constitute the basic considerations. They are fixed and defined by the designer. Researchers call these as the "general fit". Homebuyers have shared needs, and these are tagged

as general. They lead to the general design strategy. It is not difficult to satisfy common needs through the general design method based on studying habitual use patterns.

The “specific fit” is flexible and mostly determined by the homebuyer. A large number of standard variations can be generated using shape grammars in an attempt to meet homebuyers’ specific needs. Two usages of shape grammars are defined and applied in the design process, and all designs are standard floor transformations pertaining to each house type for various needs.

4.2.4.4 Shaping and Reshaping

In the matrix grammar, if each floor - **B**, **G** and **S**, has one design only - **a**, **b**, and **c** = 1, the combination is also one and can be expressed like this: $1 \times 1 \times 1$ (or 1^3) = 1. It comes back to the normal design, since it is the only one special case under the combination grammar. But in the design process, it is actually the first house design done in the normal way, and standard designs are developed from this basic source. This house design can be regarded as the initial design containing three individual designs of the floors. Each of them can be used as the initial design of the floor to generate standard variations in the same floor and the same house type. To do so, the shape grammars is applied to get the following design results.

First, get variations from the initial design of the floor by changing the shape, size, and usage of room. Second, through the same rules, use either the initial design of the floor or any variation as new sources to generate other variations. Third, redesign the house layout of potential standard designs to get the same house type in different house models by using the rules, such as reshaping, resizing and reassigning the usage of the rooms. Fourth, get different house types in the same house model by using the rules of addition or subtraction. The above four methods are basic usages of the shape grammars that are organized and used for generating standard variations from the initial design. In the actual design application, they may not be applied following the above sequence. For example, a different house model can be achieved by designing a new house layout, or there may be more than one house design generated at the very beginning, and thus the above methods will be combined.

The first three methods develop variations in a horizontal method following the same house type either in the same or in the different house model, whereas the last method develops variations in vertical way following the different house types in the same house model. All variations are systematically generated and follow these two ways of methods. However, due to differences, the last method is given another term name – upgrading grammars in order to organize variations between different types. In this conceptual design, the first and last methods are mainly used in two typical ways of shape grammars.

4.2.4.5 Upgrading Approach

Currently, the first consideration of most homebuyers is the adequate bedroom with bathroom, and secondly, it is the house layout with an appropriate lot. Meanwhile, they compare different houses following the number of the bedrooms or house styles, balance their discrepancies and then select the most satisfactory house with a good layout and price. The number of bedrooms is the preference of the homebuyer and thus becomes the first consideration of the conceptual design. The different house types are organized by the number of bedrooms in one house model, and the different house models are arranged by the different house layouts. Such classification mainly considers the homebuyers' purchase habit and psychology. The upgrading grammars is developed just for this purpose. It is an extension of shape grammars, used not only for design generation but also enhancing design presentation.

The idea for the upgrading grammars can be traced to Siza's addition rule while taking theoretical support from Frank Lloyd Wright's practices of house design. Wright was concerned with adjusting the design to the households in line with his "concept of houses being as different as their owners". He expressed "their individuality and way of life" in the design of 47 different Usonian Houses (Sergeant, 1978, p.12). Every house was different, yet each one used what Wright called the same "grammar", which formed the framework of his "organic" architecture. The relationships of the house mass to the carport and terrace, of the living areas to the central kitchen and bedroom wing remained remarkably

constant. Therefore the house could easily be expanded following his “grammar” (Sergeant, 1978). March and Steadman (1971, p.28) used their spatial organization theory to interpret “organic” houses with a graph, which showed space and room linkages in figure 4.6a. “The controlling geometric unit ordered the plan and pervaded the details.” In three Wright’s houses, “the unit is a four-foot square in one house, a circle in another, and an equilateral triangle in the third (Figures 4.6b, c, d). Each building has extremely marked individuality, so much so that each looks completely different from the other“. The dotted lines in figure 4.6a referred to the additional bedroom B’. Wright’s “grammar” provided an approach for extending the house.

The upgrading grammars is based on above concepts and consists of their reasonable development. Following the orders of house types, standard designs can be easily expanded by adding bedrooms as well as other rooms and functions. They are generated and kept in order; therefore, they can be shown to homebuyers following a sequence. The upgrading grammars is in both ways of addition and subtraction, which enable the homebuyer either to upsize or to downsize the house. But, in most cases homebuyers prefer the additional way. They normally like to upgrade their basic selections in house type, layout, material, appliances, finishings, etc. Whatever homebuyers choose, they will clearly know what they will pay and what they will get so that they can find a balance satisfying all choices and arrangements. This is a way of getting homebuyers involved in the design process.

Figure 4.6a Wright's house space and room linkages

Figure 4.6b *Life* 'House for a family of \$5000-\$6000 income', Wright, 1938

Figure 4.6c Ralph Jester house, Wright, 1938

Figure 4.6d Vigo Sundt house, Wright, 1941

Note: B, bedroom; B', Additional bedroom; C, carport; D, dining-room; E, entrance; F, family room; J, bathroom; K, kitchen; L, living-room; O, office; P, pool; T, terrace; Y, yard.

4.2.5 Custom Design

The issue of the mass customization of the housing certainly relates to enabling a large number of future homebuyers to participate in their design. Alternative computer interaction is a way of establishing the dialogue between the designer and the homebuyer, and the computer is the right media that provides the adequate information in a convenient way with high efficiency. Meanwhile, an appropriate interface needed to drive this powerful tool.

4.2.5.1 Virtual Collaborator

The mass customization approach can be traced to the industrial household products. The Electrolux Group, the world's largest producer of powered appliances in Sweden, offers the refrigerator with hundreds of choices for finishes, handles, shelves, etc. The customer can place a personalized order going directly to the factory floor for assembly. The resulting specification is also used to customize furniture and furnishing of the house. Ikea and Home Depot now offer customized kitchen design services to create unique combinations of standardized cabinetry components with a large selection of colours, textures, door types, and hardware. The mass housing has also begun to move in this direction; however, a face-to-face conventional approach no longer works to customize this kind of mass product.

Whereas face-to-face conversation is the primary modality of communication between humans, discussion with the client has been the conventional and

implicit means for the custom design. However, face-to-face meeting time between the designer and the client is always limited. It is enough for customizing the industrial products but insufficient for far more complex and specific houses, and, in fact, is the impossible for the architect to personally meet every prospective homebuyer. Similarly, Dell adopts build-to-order systems, where the perspective customer can select features for the computer – mainboard, processor, hard drive, memory, various PCI cards, case, etc. – following his/her needs with simple web-based software. Today we can see that even a small computer shop also can do this. The customer can freely select every item, assess the discrepancy in every stage and think carefully about the combinations. The computational system achieves communication between the customer and the supplier. It has infinite time and is always patient, unlike many human counterparts.

The computer can be seen as a tool enhancing the design. It enables the necessary communication, through the metaphor that the computer can act as a virtual design collaborator. Moreover, sometimes an architect's idea or client's desire is hard to be expressed even by speech, intonation, gesture and other nonverbal modalities. Working with computer graphics and 3D models seamlessly in an integrated environment, the information is more easily and directly understood than just expression and imagination; from the client's point of view, the result is more visible than face-to-face conversation. However, why this interface is possible to achieve the goal of the homebuyer?

4.2.5.2 Rigid and Flexible

While a browser opens up in front of the client, information presented on the screen is rigid and immutable. No matter what format it is, standard questions in text, queries in games, or designs in graphics and models, all are fixed. However, a dialog can be circulated through switching or interacting with interfaces, and a “communication” is established between the human and hypermedia. Therefore, flexible custom outputs can be attained from standard inputs and processes. This custom solution is interpreted by Professor Callahan and his research partner, Mackenzie, using a business model in Figure 4.7 (Firestone, 2002).

Figure 4.7 A business model of custom solution

The interface takes people systematically through a series of scheduled steps. Selections or answers are standard but people choices are ever changing and flexible results occur in final outcomes. There are no ambiguous meaning and nonsense. Through iterative process and helpful advice, people approach to their desired results gradually. Dell establishes a successful model of e-commerce. It provides custom solutions using standard processes. Someday a new Ford car customized through the web and delivered to the door will be possible. However, what will be the right interface solution to achieve this?

4.2.5.3 Cases and Problems

Similar to Dell's idea, Kent Larson proposed a customized solution in his article - "The Home of the Future" (2000). He presented a scenario where, in 2015, a couple used web-based, automated design tools linked to mass-customization fabrication to take control of the process of creating a sophisticated, responsive home. How realistic is this scenario? It seems farfetched; nevertheless current solutions for the mass housing have been being forward to this direction. In the early 90's, Barros & Barros, a Portuguese cabinetry company, developed customized solutions where the software asked users about their needs. The software controlled the rules of good cabinet design to generate a drawing that could be used for fabrication. Similar approaches for the mass customization of housing were developed by *house_n* researchers in MIT. Larson (2001) organized them in three necessary elements: a Preference Engine, a Design Engine, and a Production System to fabricate the components for assembly on

the site. But, what is the performance of such kind of system and what constitutes its interface?

The Preference Engine collects and refines responses, needs, preferences, and values that users are willing to make. The system would, ideally, approximate the dialog that an architect may have with a client during the design process. However, there could be an ever-expanding set of questions, and perhaps 1000 questions deal with the most important issues (Larson, 2001). Responding to such a large amount of queries that this would quickly become tedious. Moreover, the Design Engine is a computational system that makes use of a set of rules encoded into a grammar that defines the architectural strategy of the designer. Whereas the system utilizes client profiles based on a form, it is not entirely clear how to best elicit useful, accurate information, and this obviously presents some problems regarding psychology and system outcomes. Therefore, how to control the mass customization through an appropriate strategy and usable interface needs consideration.

4.2.5.4 Design Control

There is no doubt that the advantages of such a kind of Design Engine greatly supersedes face-to-face customization. However, it places more stress on the individual and gives less consideration to the control of the mass. Current mass customization of housing is not merely a stack of individual customizations but is a whole entirety relating to land, city plan, cost, and a wider context. Any

personal customization is possible and can be done promptly; but the presently localized and fragmented industry can hardly provide a large number of personalized houses at a low cost. The difficulty results from the contradiction between personalized “customization” and impersonalized “mass” products. Therefore, the thesis mass semi-customization of housing could be the compromise between people needs and some available possibilities. The custom solution is using standard design attempts to control this balance in order to meet general restrictions and provide affordable housing for homebuyers. Seemingly, standard design has the impact on the customized result. But, like Dell’s way, it represents a custom strategy. The standard design of mass semi-customized housing is a tradeoff that the buyer is willing to make and the builder can provide.

A solution to the control of mass semi-customization from previous instances of industrial customized products can be found. They use standard parts to balance the contradiction and utilize one common process of electing and then combining industrialized, standard parts to produce a personalized, entire product. Current houses serve only as an entirety for selecting, and lack the above process. The result of the standard strategy enables every design of floors to be selected as virtual house components, and therefore fulfills the personalized combination process. Automated design tools now make it possible to “industrialize” such design processes and to “produce” mass, digital house components, which are inherently standard designs.

Like the industrial part, the standard strategy not only provides the opportunity of customization for the homebuyer, but also controls the result of custom designs. Unlike the adaptable or plug-in concept, the standard design does not relate to future development. Custom result is easier to be controlled. All designs can be presented through the computer interface for either web-based home researching or computer-based site talking. The client is not passively controlled by the query interface and Design Engine, but through the interaction that controls the customization.

4.2.5.5 Interface Control

The human-computer interaction is certainly a good way to supersede face-to-face conversation and thus to contribute to a breakthrough at the choke point of customizing the mass housing. Indeed, the Preference Engine establishes a dialogue fulfilling this goal; however, it must not repeat and imitate conventional conversation, since such usage is not the strong piece of current human-computer interaction. As we know, face-to-face conversation for the customization consists not only of lingual modalities, such as the definite dialogue, but also of nonverbal modalities, such as indefinite client's emotion or architect's sketches. Moreover, it is hard to foresee the system generations that only are based on client responses but created by encoded grammars, and thus has the problem of controlling the result to exactly match client expectations. Complex functionality is necessary but no longer sufficient to guarantee helpfulness. The reasonable interface should be usable and accessible.

The challenge is finding a suitable solution to accomplish the intended purposes. Based on whole concept for mass semi-customization, the prototype adopts the essential form of the interface – Menu Selection, “an intuitively simple solution to the problem of user control (Norman, 1991, p3).” It is easy to implement and easy to use. Since such kind of interface is the ground of cognitive process, it suits clients at all level of computer knowledge. They can easy gain a high-level understanding of how things work and therefore perform tasks more quickly and effectively. The menu structures of the prototype follow the sequences of standard designs that are organized by the grammars between different designs in one house type and between different types in one house model. Since the task is clear, the flow can therefore be controlled. The hyper media offers the clients the convenience to choose the targets at any stage. They can directly select and browse any designs through listed menus that suit their needs and expectations. Normally, a communication between the client and the computer takes place via a finite, well-defined set of words, drawings, and 3D models, rather than through open-ended command language. Meanwhile, designs in graphical and dynamic forms are more visible and concrete than indirect query, and the final result can be controlled through the interfaces by the clients not by the encoded program. It will be easier to reach clients’ goals since only the clients know what they exactly want. By selecting different design, colors, textures and materials, the client can control and preview virtual results. With high fidelity visualization tool, they can walk-through the virtual house to test their ideas and choices.

One process of custom control is not obvious. An advanced design system encodes the economic program, the economic engine, to control the cost. After getting all needed responses, the system would carefully filter and refine information about each topic at hand. It would analyze and tailor all information in order to minimize and control the cost. The tradeoffs would be appropriate information which could best elicit the most economic output from the system. It can provide a feedback loop through the iterative process, enabling the client to get a satisfying result in a reasonable cost. In the prototype, such process is conducted by clients. The economic control is attained by selecting each design and upgrading each choice through the interface. Clients have infinite chances and sufficient time to select their favorite designs, compare discrepancies in prices and layouts, make judgments and evaluations, and finally balance all choices. Everything is visible and each action is active. The process would be iterative. It enables the client to get the best combination in choices and costs.

4.2.6 Availability of The Industry

In comparison with other types of manufacturing, the housing industry is years behind. Most major manufactories outside of housing compete internationally, with innovation on one side of the globe instantly rippling across to the other. New materials, technologies, and processes are adopted quickly. Industrial behemoths have become lean, agile, integrated, and digital; they tap information in real time. In the housing industry, processes are labor-intensive, competition is primarily local, and innovations take a very long time to find their way into homes

(Larson, 2000). As impressive as early industrial forays are in mass customization, they do not approach the complexities of creating a workable approach to the mass customization of housing; nevertheless, they more or less induce the housing industry to move in this direction.

Primarily, automobiles can be fully assembled in the factory and shipped completely to the customer, while this is rarely possible for a product the size of a house. Due to the present situation, the housing industry will probably be proceeding in the usual way, but will aim to distribute complete house components with high technology content, good quality, before and after-sale services, and less labor consumption on site. The product is more like the advanced “Packaged House”, and such perspective was presented in Larson’s article “The Home of the Future” (2000): “in 2015... the shrink-wrapped, digitally tagged house components arrive on their site four weeks after ordering, and three installers connect the pieces together using conductive, industrial Velcro fasteners. They move in two weeks later.” Indeed, the current housing industry has begun to move in this direction; windows, doors, trusses, and many other architectural components can be fabricated with automated Computerized Numerically Controlled (CNC) equipment. Large assembly lines of mass production systems can create thousands of identical products, and CNC equipment offers the possibility of efficiently producing unique products for various needs.

Second, the automobile industry is made up of a few, large, well-capitalized corporations who compete internationally with the central control of decision making, while the housing industry is fragmented, local, and made up of thousands of small, less sophisticated companies. Local materials are more readily available, as previously mentioned, and houses must not become uniform all over the world for the reason of standard. Nevertheless, local housing industry is on the way of transforming to the information economy and going bigger. Large building material companies, such as Owens Corning and International Paper in the US, are committed to moving from commodities to integrated systems and services - with complete building systems becoming a logical consequence of this trend.

Finally, as remarked above, the auto manufacturing industry embraces innovations, while the housing industry cannot be viewed as a homogeneous group. Innovative builders welcome new technology and others avoid change due to current conditions; nevertheless, the industry tries to catch up this trend. Digital technologies now make it possible to replace both inefficient labour-intensive site production as well as inflexible mass-production with agile mass-customization. Automated design tools may also permit architects to finally play a significant role in the house design. The mass housing industry will be based on new industry-wide standards for both physical building components and digital technologies. The evolution may be slow but is nevertheless in process.

4.3 Conceptual Design Descriptions

The conceptual design of the prototype focuses on the single family house and selects one house model for generating the initial design. General house specifications are reviewed and design strategies are sketched, based on new home requirements, from which initial house design is developed. Standard designs are systematically generated and organized following design principles and shape grammars. Meanwhile, the design rules are applied in the transforming process. The designs convey the ideas presented in previous sections.

4.3.1 Design Source

The house model used as source for conceptual design is selected from the current house market. At the beginning, single house designs of each homebuilder are previewed through the web. The focus is on several “best sales” house models. The model evaluation is based on whether the design has the potential to best represent thesis design intention and adequate for further development. At the end, a Phoenix Homes’ 3-bedroom single house is selected as the final conceptual design model (Figure 4.8). Basic design strategies are clarified and the initial design of a standard 3-bedroom house is developed from this selected source model. The initial house design is used as a universal model to generate other house types.

Figure 4.8 Basic source of the initial design, Phoenix Homes

4.3.2 Strategies

The house must have adequate functions and reasonable layout, and each floor needs to accommodate all of the basic demands and appropriate arrangement. Some design strategies need to be outlined before the design starts. They are the footholds of this conceptual design.

4.3.2.1 House Layout

The use of a square or rectangular floor plan with as few interior subdivisions as possible can efficiently utilize space and keep housing prices low. Economy can be achieved through such a kind of floor plan, since it can minimize the land use and the amount of materials required for the foundation walls and insulation by comparing with irregular layouts. It is also substantially cheaper to service, due to

lower heating costs resulting from more efficient surface areas exposure especially in cold areas. Square or rectangular floor plans present another advantage to the developing house combination. When the lots are narrow, the single house can be used as a basic unit composing of either semidetached homes or town houses. Moreover, for the interior, a rectangular room would be desirable since it presents less limitation for furniture arrangements.

4.3.2.2 Functional Zones

The first step is to decide the size of the house according to the number of bedrooms. The interior design begins with establishing zones, and the house is divided into public, semipublic, and private areas. The two-story single home permits the division of functions into two distinct zones on each level. The ground floor is primarily for public use, and second floor is mostly a private area. The uses of the basement will depend on the finished result; it normally accommodates utility functions and additional usages. Once the location and area of zones are decided upon, their proportions need to be balanced, and then the concepts and strategies are applied to these zones to divide these spaces. The process begins with locating the rooms according to their unique function and interior layout.

The house has undergone a transformation as the result of new lifestyles and technology. New design concepts obscure the limits between functional zones, since lifestyle trends transform some spaces to the crossing areas. Multi-purpose

rooms and large open spaces such as the home office and studio are a result of such changing of interior layout. Moreover, new room uses are led by innovations in information and appliance technology. When the home is wired by telecommunication hardware, it offers something to everyone, anytime in any room. People can watch TV in their bedrooms or even pay the bills in the living room through the Internet. Whereas these facilities are fast becoming common, auxiliary activities in many rooms of new home, appropriate care therefore has to be taken in this design of these spaces in order to meet these particular needs. Meanwhile, since auxiliary activities need extra hardware to support, the principal activities still represent the main function of the place. The design presents these new changes not only to the rooms themselves but also to their relationships.

4.3.2.3 Locating Services

The placement of the staircases will influence the layout in general and movements in particular on all levels throughout the home's life cycle. Locating the staircases is very important since they are the links of all floors. A strategy is to place them along the longitudinal wall rather than in the middle of the room. At the moment, another primary consideration is the bathrooms. Since the new house has more than one bathroom and all of them have different locations, they have different functions, uses, and equipments arrangements. Once all of these are confirmed, the size and layout of each bathroom can be planned. While staircases and bathrooms are located, other functional rooms can follow on and thus the skeleton of circulation and house layout can be created.

A substantial portion of house area is devoted to circulation. The single function of hall and corridors is to link one function to another and this can also be regarded as lost usable areas. "Given the fact that circulation space can account for up to 30 percent of a floor space (Friedman, 2002, p137)." In an attempt to reduce these areas, some ideas are applied such as combining corridors with public areas to make them usable, shortening corridor length, and assembling all the entrances in the same area.

The placement of utilities also needs to be considered, since the location of the wet function will influence the exchange of areas between zones. Current technology provides the freedom to place wet functions wherever people want; however, for easy construction and economic reasons, the laundry room, bathroom, and kitchen should be placed near one another on the same floor. Normally, the kitchen is placed in the rear of the house; bathrooms are located centrally and are better to be located in the same position on each floor.

4.3.2.4 Door and Window

The placement of doors should aim to leave the space uninterrupted by circulation. Doors can be placed along any of the four perimeter walls in a single house, whereas the placement is reduced to three walls in a semi-detached home and two walls in a town house. Mainly considering people's habit and the above reason, this design focuses on initial access - a main access at the front and a rear door to backyard. Other doors will be placed according to specific

situations of house type. The garage of the current single house is mostly on the ground level and thus the garage door is in the front with the main entrance. The placement of the door from the garage to the ground floor will be based on easy-to-access entry, either to the hall or to the kitchen.

The placement of the windows is based on the ideas of economy and beauty, and meets the design requirements for natural lighting. Windows, doors, and wall panels are standardized products, aiming to efficiently lower costs, simplify the construction process, and keep house façades in harmony.

4.3.2.5 Structure and Assembly

Construction of the basement level is facilitated by the existing need to build a foundation below the frost line. This type is more common in regions of cold climate. The designs of the upper two levels are based on the platform frame of wood structure. In general, the floor and the envelope are an integrated system; the floor is built first and then the rest of structure and subcomponents are constructed and assembled on top of it. Whereas the basement is the cast-in-place concrete structure, its bearing wall is usually 6 to 8 inches thick. The upper levels of the house are the wood-frame structure, where the walls act as infill components. Its thickness is considered to be 6 inches for interior wall and 8 inches for exterior wall. All dimensions are solely for this design. Actual case will be varied due to diverse site circumstances and different surface finishings.

Whereas the concept of standard design regards each floor as a standard house component, it can be designed either as a partial of a house or as an individual floor, and thus the whole floor can be considered as an integrative house component to be produced and then assembled. Current manufacturing provides a plentiful supply of standard parts. Windows, doors, washroom equipments and kitchen appliances as standard subcomponents are used in this design. Moreover, since building stairs in a wood frame structure on site is still considered labour-intensive and complicated, the length of straight runs and the height between floors are both fixed in the design. Therefore, the stair structure is viewed as a set of prefabricated subcomponents, and can be built in the factory and then assembled on site.

4.3.3 Initial Design and Principle

Based on above strategies, the initial design of a standard 3-bedroom house is generated from the selected source model. The basement is finished following the structural layout. A small change occurs in the laundry room on the ground floor. New ideas are added on the second floor by considering further development (Figures 4.11, 12c, & 20). This initial design is used as a universal model to develop other house types.

The resulting house classifications carry out all of the design concepts. The houses are sorted in different models depending on various styles and layouts. In this house model, the houses are classified into five types according to the

number of bedrooms. These include 2-bedroom, small 3-bedroom, standard 3-bedroom, 4-bedroom and 5-bedroom family houses. Since the standard 3-bedroom family house is more popular and consists of the middle ground of all types, it becomes the preferred, typical type, and this universal model is used to develop other four house types in the one house model. This arrangement consists of easy-to-control transformation processes while keeping all variations in order.

Design principles can be clarified by reviewing Siza's design in Figure 3.13. Siza left a large space on the second floor of one-bedroom for further development of other variations. By adding one bedroom on the second floor one at a time, five house variations were achieved. The conceptual design applies similar principle. On the second floor, one bedroom with correlative bathroom is used as a unit space. By subtracting or adding one unit on the second floor plan of the universal model, a variation for the small 3-bedroom or 4-bedroom house can be generated, and then these are used as new sources to develop variations for the 2-bedroom and 5-bedroom in the same way. On the ground floor, Siza's variations do not have big difference since every design is fixed in an 8 x 12 unit. As for this conceptual design, ground floors are varied due to different lots and house specifications, but the design transformation can apply the same principles that are used on the second floor. The ground floor of the universal model is also used for the 4-bedroom and 5-bedroom houses. For other two types, the design uses a family room or a breakfast as a unit space. By subtracting one unit of the

family room, a variation for the small 3-bedroom house is generated from the universal model. Similarly, by subtracting both one unit of the family room and breakfast, a variation for 2-bedroom house is achieved. Same principles are also applied to the basement design. By subtracting one unit space of the family room or two unit spaces of family room and breakfast, the variation for the small 3-bedroom or 2-bedroom house is achieved. The basements of the 4-bedroom and 5-bedroom types use the same plan of the universal model. In transforming to the 2-bedroom and small 3-bedroom houses, the unit space on each floor always keeps the same (a unit of a family room for transforming to the small 3-bedroom; a unit of a family room with breakfast for transforming to the 2-bedroom)

Above principles can be summarized to upgrading grammars. Each resulting variation is finally used as the initial design of each house type. Each of them is regarded as a combination of three individual floor plans. Shape grammars are used as an idea design generator. By playing with specific rules in each design-transforming process, standard variations are achieved.

4.3.4 Description of Rules

The addition and subtraction rules change the house layout between the types in a longitudinal way and present spatial sequences and relations. In order to distinguish them from other rules that are used for horizontally generating variations in one type, the upgrading grammars is defined in last section. Although two rules represent different ways of transformation, they both appear

in one upgrading process. Its naming mainly reflects the notion that homebuyers like to continuously upgrade from basic selections and then downgrade a little to balance all choices.

“Shape grammars treat shapes as nonatomic entities - they can be freely decomposed and recomposed at the discretion of the designer” (Knight, 2000). In each house type, variations are taken from the initial designs of floors by changing the interior layout, room shapes and sizes, and the usages of rooms. The major rules that are used in design processes are dissection, extending, connecting, and assigning a new function. They are general design principles which are defined in explicit purposes. All regular transformations occur inside of the houses, and all variations are still in the same house type. When the transformations change the house layout, the variation is achieved in the same type but in a different house model. This transformation occurs in horizontal way, which is different with the use of upgrading grammars.

The use of design grammars allows many choices of rules, and many ways to apply them, in each step of the transformation. Shapes and spatial relations are continually modified and redefined until the designs generated satisfy the general goals. Under this situation, the behaviors and outcomes of rules must be predictable with foreknowledge. Choices of shapes, relations, and rules are thus influenced by specific circumstances.

4.3.5 Designing with Rules – Prototype Part II

It is likely that interior design trends will continue to be introduced along with new technologies and emerging lifestyles. It is necessary to bear in mind that each room has both principal and auxiliary activities (Friedman, 2002). The principal use remains the same, while the auxiliary activities vary. New uses and functions make more varieties of house layout. Design grammars provide possibilities of more design transformations generated under various design rules, which offer people more options and choices.

4.3.5.1 Basement

In most cases, the basement of current new house is unfinished and normally has some service functions. The mechanical equipments are located here, such as the heating system, hot water tank, and frequently, main electrical panel. Some people like to keep the basement unfinished and just use it as a storeroom or workshop. Their usages and purposes differ in a thousand ways. Their needs will decide whether to finish it for specific uses in future. Other people simply like choosing the finished basement to have more rooms or more house value. Design cases are mainly classified into these two kinds.

One of the advantages of the two-story design is its versatility as to the use of the basement. When its windows are placed well above ground, sufficient natural light will be let in; the basement can be designed as an independent floor, and thus a two-story house can easily become a three-story one. The designs use

the dissection rule, which occur by placing interior walls to partition the spaces and form rooms. Normally, the place of mechanical service room or equipment is fixed, and the bathroom is located near the wet function of the upper level. Other rooms are arranged around them and are shaped and reshaped to form different layouts. All ideas are conveyed into the following design cases. The typical plans of unfinished and finished basement designs are for a 2-bedroom house with single and double garage above (Figure 4.9); others are designs for a small 3-bedroom house (Figure 4.10) and a standard 3-bedroom house and larger houses (Figure 4.11). The basement is finished with the home office, optional room, hall, and game room along with different house sizes, showing an upgrading sequence.

The finished basement has become the multipurpose floor with ancillary functions. With the conveniences that advanced communication offers, full-time work from home has become common for many. According to the survey of Canadian Statistics in 2002, 6.3% population, or 900,000 Canadian, work from home in 2001(not including farmers). This trend has lasted 10 years since it reached the peak of 6.4% population in 1991. Leaving out this specific usage, the home office can also be used for part-time activities that complement a person's regular day job, or for simple household chores such as paying bills. The optional room can be used as the additional bedroom mainly for guests. It intends to separate such uses from the private sleeping area. It can also be arranged to service new family member or can even be used as an independent room for rent.

Figure 4.9 Basement designs for 2-bedroom house

Figure 4.10 Basement designs for small 3-bedroom house

Figure 4.11 Basement designs for standard 3-bedroom and larger houses

Hall and game rooms provide a good place for informal use and additional functions. They also can be used for entertainment purpose.

All design cases show typical room uses and layouts. With shape grammar and auto design tools, layouts can be easily shaped and reshaped, and homebuyers can choose their favorite designs and arrange the usages of the rooms following their specific needs.

4.3.5.2 Ground Floor

A ground floor normally has a foyer, a powder room, a laundry, a living/dining room, a kitchen, and a single garage to provide adequate functions. The additional functions include a separate breakfast and family room. Rules of sharp grammars affect the family room, kitchen, breakfast, and garage to make differences following the changes in house types. Figure 4.12 shows a series typical ground floor plans for all types.

The living area encompasses several rooms or functions. The kitchen is integrated into this multifunctional zone and is one of the main rooms that concern homebuyers. In form, it is transformed into a pragmatic single or double L-shaped workspace equipped with practical appliances and gadgets. Two typical layouts preset different concepts and house specifications. They are also the consequences of the upgrading grammars.

(a) for 2-bedroom houses

(b) for small 3-bedroom houses

(c) for standard 3-bedroom and larger houses

Figures 4.12 Typical ground floor plans

Certainly, a full open kitchen is a tendency, and the current kitchen is normally designed on this concept; however, its drawback is the disruption of formal activities in the living area. The solution considered on thesis surveys and interviews include the concept that some old Canadians, Europeans such as the English, and most Asians such as the Chinese like to have the kitchen more closed. The kitchen of a standard 3-bedroom house is designed on a semi-open concept, surrounded by partition walls and double L-shaped counters but connects other rooms with big openings. As a result, the breakfast also has an individual function. This design is used as the typical solution for a standard 3-bedroom house and larger houses. However, the typical solution does not mean the preferred plan for every homebuyer. As the universal model, a standard 3-bedroom house presents full functions and specifications. Individual kitchens and breakfasts will be easy to please homebuyers who require high demands and clear functions for each room, because the design attempts to provide more options to meet various needs. The typical design of the kitchen is a compromise between the traditional and open concept, and it is easy to adapt to other transformations. The homebuyers' needs will decide to only take the partition walls off (Figure 4.13a) or establish a further connection with the living room (Figure 4.13b). In the open concept, a low counter is the only division between the kitchen and other rooms, transforming the kitchen from its traditional service purpose into a practical and efficient utility space that not only accommodates culinary services but enables clear supervision of children playing and facilitates the serving of meals by being adjacent to the dining area. The above design

cases apply the connecting rule by removing the partition walls to complete the transformation of spatial combination. This approach is also used on the variations for the kitchens of a 2-bedroom and a small 3-bedroom houses. Due to the smaller size, the breakfast integrates into the kitchen, and L-shaped workspace is along two sides of walls. The corridor is also integrated into this area in order to make large open space connecting the living room. This design is more suitable for the small family, saving space without losing any functions. Moreover, food storage, preparation and a related variety of tasks and devices will be the principle chore. Considering the normal process and flow of food preparing, the design locates the positions of electrical appliances, sink cabinets and counters. For individuals from shopping, in some designs, a door is placed in the kitchen connecting the garage through the laundry room.

Figure 4.13 (a) kitchen options in half open and (b) full open concepts

The living room requires a greater amount of natural light, and whole households spend most of their time here. The design maintains its principal functions for family-seating and considers it an all-purpose space. It acquires the diverse uses as study, dining room, parlor, playroom, and for festive occasions. Since dining activity is part of the kitchen, the design leaves a big opening connecting the living room with the kitchen. Meanwhile, large plate-glass and partial walls dissolve the confining impression of conventional walls and instead extend the perceived limits of the room (Figure 4.14).

The family room extends and replicates the living room in a less formal arrangement. It could be a media room, or the play area of toddlers under the watchful eye of a parent working in the kitchen. It is designed with an open concept; in standard 3-bedroom houses, its upper space is surrounded by ambulatory of second floor (Figure 4.15). Standard 3-bedroom houses and larger ones contain both living and family rooms, while 2-bedroom and small 3-bedroom houses only have a living room with a mixture of both rooms' functions. Different specifications of houses follow the changing types, which is achieved by adding or subtracting the unit space of the breakfast or family room.

The garage only has two choices, which include single size and double size. Homebuyers can attach either one to the house depending on their needs. When people need more rooms on the second floor, expansion from the top of the garage can take place. The garage therefore has a structurally sound flat roof

aligned with the second level's floor. Such an idea is used for some standard 3-bedroom houses and all 4-bedroom and 5-bedroom houses.

Figure 4.14 Large plate-glass and partial walls in the living room (VR screen shot)

Figure 4.15 Open space in the family room (3D rendering)

4.3.5.3 Second Floor

The greatest number of changes in a house take place on the second floor, mainly including the number, size, arrangement of bedrooms and bathrooms. When more than two bedrooms are needed on the second floor, the two-story house is a suitable prototype, permitting a variety of bedroom configurations. Considering various households and their needs, specifications of houses start from two bedrooms, offering homebuyers choices up to five bedrooms. Another major preference that homebuyers are concerned with is the number of bathrooms, which is normally determined by the house size.

The design of the second floor also applies the dissection rule. Since the position of the staircase is already fixed and the bathroom will be located in the middle of the floor, other rooms will be easily formed by placing the walls to partition the space. A room with a closet is recognized as a normal bedroom. A master bedroom frequently comes with a walk-in closet and an attached bathroom – master suite, and a large place will likely facilitate all these functions. Other functional spaces or rooms are varied along with house specifications. Meanwhile, open spaces present new home features and life styles.

Two-bedroom houses normally only have one bathroom on the second floor, which is adequate for a small household. People accept the master room without a suite but require a walk-in closet. They prefer a more useful function than an otiose usage for this compact type. The optional space provides multiple choices

by applying rules of assigning new function and dissection. There should be an open space vertically connecting with the living room, a wooden deck extending the room function to the outside, a separated space for different uses, a study room or even an additional bedroom with ancillary functions (Figure 4.16). For example, a bedroom is obviously not a good place to put the computer, and one option can fulfill such a need. Options in design cases only transform in one place, and more possible variations can achieve through the same approach.

One design case of a small 3-bedroom house applies the addition rule. The master bedroom is extended, tracing on one unit of the additional breakfast on the ground floor. New room functions are added in, and the house is therefore upgraded (Figure 4.17). When the first floor is further upgraded by adding another unit - the family room, the second floor of a standard 3-bedroom extends its spaces (Figure 4.18). Both cases show typical configurations of a 3-bedroom house with two bathrooms. When the master bedroom is relocated on the top of garage, the second floor now has more space for upgrading. New uses of spaces further added in, the house presents additional features and multi-purpose functions. An open studio is achieved through assigning a new usage and adjusting some partition walls (Figure 4.19). It provides a large semi-public space, where is more quiet and private than the family room. When the upper space of the family room is opened, spatial communication between two floors can be attained (Figure 4.20). "It can be argue that a single person might need a minimal number of walls in the private zone since acoustic separation and

privacy are less of a concern” (Friedman, 2002, p.127). The design also attempts to use the open concept in many other places such as the stair half, the second floor above the living room of a 2-bedroom house, or even in the master bedroom.

By applying similar rules and approaches, more bedrooms and bathrooms can be added in, and thus 4-bedroom (Figure 4.21) and 5-bedroom houses (Figure 4.22) can be achieved. One top case shows a 5-bedroom house with an open studio and two and half bathrooms.

All design cases shown here are just typical variations for one house model, merely aiming to present the design ideas for the mass customization. More design principles can be used for shaping the house spaces, such as some basic methods Devido (1996) introduced in his book. More design grammars and rules can be explored and defined, and therefore a large number of design options can be provided to meet various needs and desires of homebuyers.

Figure 4.16 Second floor plans for 2-bedroom house

Figure 4.17 Small 3-bedroom

Figure 4.18 Standard 3-bedroom

Figure 4.19 Standard 3-bedroom with studio

Figure 4.20 Universal model

Figure 4.21 Second floor plans for 4-bedroom house

Figure 4.22 Second floor plans for 5-bedroom house

Chapter 5. Visible Issues

Conventional marketing tools play significant roles even today. Tangible presentation media and physical site visiting will still be necessary. Now, computer technology is moving into this field. Digital presentation media will make up for the shortcomings of conventional tools. It will become a new marketing device enabling information to be visible, meeting high demands of homebuyers, and helping them to make final decisions.

5.1 Introduction

New houses are built only when they are sold. Homebuyers cannot see, touch, perceive, or inspect their purchases before they buy them. The only thing they can do is envisioning their future homes by relying on drawings and similar model houses. They usually need to spend time making final decisions since the risks of the investment are not only financial but also concerns the satisfaction of their needs. Every imagination is indistinct and everything is indefinite. At most, they must rely on their personal judgment.

As part of the routine purchasing process, homebuyers are allowed to change the interior layout by combining spaces and adding features according to their needs and budgets. They are given the option of selecting from variations of the same design or from different models. After homebuyers purchase the houses,

they are offered an array of interior finishings to choose from. Among these options are paint color, types of floor coverings, styles of cabinets, light fixtures, and accessories throughout the home. Although they can see and touch everything, they still need to imagine the final results, and subcontractors or suppliers are not able to help in this area.

All these undefined and unclear factors require to make hard decisions at every stage, and this is the reason why homebuyers like to buy model house. Although it is “used” and more expensive, everything is clear including the space, lighting, material, color, texture, furniture, price, etc. How to make all the information visible and certain in order to help homebuyers make decisions is the goal of this chapter.

5.2 Decision-making

The process of human decision-making is quite complex and still unclear today. Related researchers map people’s specific thoughts onto every stage to find specific problems. In buying a new house, the homebuyer will make a series of decisions according to personal circumstances. The key decisions are all in final buying stage and can thus be narrowed down. These decisions are difficult to make among all alternative choices.

5.2.1 Decisional Conflicts

It is important to recognize that all decisions involve choices among alternative behaviours or courses of action. A decision always involves the selection of one possible behaviour or action from a set of at least two alternative behaviours (Olson & Reynolds, 2001). Usually, it is the decisional conflicts on alternative choices that retards the course of decision-making. Dr. O'Connor at the University of Ottawa has developed a research program to understand and support the decision-making of practitioners and consumers facing a variety of choices. She organized four factors that affect the course of people's decision-making including certainty, informed, clear values and supported (O'Connor).

First of all, the homebuyers must know what they want and what they want to choose. They need all certain information to confirm this notion. Meanwhile, they need to know all available options in order to get informed knowledge, and therefore learn, compare and balance all choices. Furthermore, they must clearly know their values - what feature is the most important or is the most needed. Finally, they need to have enough support to make a choice, such as financial situation, helpful advice, good price, etc. The problem-solving focuses on these points, aims to give the homebuyers decision aids.

5.2.2 Interface and Perception

The tangible media group at MIT designed the "ambient information displays" to explore the use of kinetic physical objects to present information at the periphery

of human perception. They installed 40 large-scale computer-controlled spinning pinwheel units in a museum, presenting information within an architectural space through subtle changes in movement and sound (Figure 5.1). The pinwheels spin in a "wind of bits" at different speeds based upon their input information source (Figure 5.2). They mapped information that represents people's activities onto spinning pinwheels - movement in a physical space such as traffic, and activity in cyberspace such as e-mail exchanges. For example, an e-mail message with a large attachment will generate a blast of wind that spins several pinwheels on each rod (Ishii, Ren, & Frei, 2001).

This research explored a new form of digital information visualization through moving the interface off the screen and into the physical environment. The movement caused by invisible information flow can be perceived by people, and thus they would have further realization on digital information. As interfaces between human and information, a drawing in hand or on the screen, both can be observed and recorded by human perception. This behavioral approach refers to human inherent "introspection, a form of mental experience". It "could range from reporting immediate sensory impressions to the onset of a stimulus" (Scott, 1991, p1). However, it does not mean that one media or interface can supersede another because human perception and feeling have discrepancies on the same object appearing in different media formats and environments. On this point, Hiroshi Ishii had an exact interpretation in his paper <<Last Farewell>> - traces of physical presence (1998).

Figure 5.1 Overview of the gallery with 40 Pinwheels in the NTT-ICC museum in Tokyo from June 22nd to July 9th, 2000

Figure 5.2 Setup of Pinwheels system

Figure 5.3 Perception as an active process

Through the human cognitive approach, the mind can actively process the information it receives, and can transform it into new forms and categories. In Figure 5.3, if the dot in the center is stared at, the fluctuating nature of perception can be witnessed. The brain performs numerous transformations, seeking the different patterns inherent in the cubes (Scott, 1991). Since the mind sometimes misleads cognition, people may deviate from the norm. In order to get exact perception and feeling, “physical presence” of site visit is still necessary. However, the model house is not available for every layout or each project. Virtual “presence” overcomes the limitation of people’s experience. Digital simulation is a good solution enabling people to present a “live” future home.

5.2.3 Simulation and Consciousness

One of the earliest architectural simulations can mention Mies Van der Rohe’s house project for Mrs. Kroller, the owner of the famous Kroller-Muller Museum. She purchased a large piece of country dune land in an affluent suburb of The Hague, and “preferred to build the house on the edge of the dune” to have a “backdrop of the woods behind and great space in front, with a large, spreading meadow” (Schulze, 1985). Mies’ design was completed in 1921, including drawings and a scale model. However, Mrs. Kroller did not adopt it right away. As fully explaining her intentions was not easy and envisioning the completed result was hard, she translated Mies’ design to a full-scale mock-up to simulate the completed landscape, test the design idea and check it whether against the woods background. The full-scale mock-up was constructed by wood and

sailcloth on the actual site, painted to match the intended final house color (Figure 5.4). It showed an exact landscape as built (Schulze, 1985; & Johnson, 1978).

Figure 5.4 Mies Van der Rohe, full-scale mock-up, The Hague, 1912

The instance conveys the basic ideas of simulation. The values of it lay in translating an architectural design into a drawing, a scale model, even a full-scale mock-up in an understandable context, so that information can be presented clearly before projects are built. This information is of value to architects as well as clients. “The power of simulation as a communication media follows from the importance of people's perceptions or mental images of a project in shaping their decisions about it” (Sheppard, 1989, p. 6). Simulation is a highly useful tool and a potential approach for current house marketing, because it “allows for more informed decisions”. It can be used as the catalyzer to accelerate the course of homebuyers’ decision-making. The reason it works is that simulation can willingly cheat human consciousness. Simulated objects are not real. However, the more lifelike it is the more consciousness can be tricked.

"There are some criteria for saying of some organism or state that it is conscious. Consciousness involves experience or awareness. Human mental life has a phenomenal side - a subjective side, and conscious mental states are heterogeneous in phenomenal kind." (The Oxford Companion to Philosophy, 1995) Sensations, moods, emotions, feelings, thoughts, self-awareness all occur consciously. A continuous blending of these composes our consciousness. For Descartes, "all thinking is conscious; conscious thought is the essence of mind. Humans have privileged and incorrigible access to their own conscious states." But the modern naturalistic consensus is that only some mental processes are conscious and that all mental events and processes are physical. That is, all mental states have neural "realizations" in "Homo sapiens". The term of "realizations" is the relation of levels; the representation of a form at one level of abstraction that can be "realized" by lower or less abstract level. Real objects can therefore be realized by partial simulation, through conscious mental states to form subjective consciousness. All means of simulation follow the same method, including architectural simulations for house marketing.

5.3 Simulation Means

Simulations are among the major forms of communications in use in both the architectural field and the house business. It is the powerful presentation tool for design as well as for marketing. One of the first things the homebuyer would probably want to know is "What will the completed house look like?" Simulation

drawings and model houses play the most important roles as conventional ways of design exploration and marketing expression; however, how well are these conventional presentation media performing?

5.3.1 Drawings and Images

The most basic drawings that current homebuilders provide are plans and elevations, which contain valuable information relating to houses. They are used not only for presentation purposes but also as legal documentation in the future. However, homebuyers' decisions are not only based on these drawings. In most cases, they want to understand spatial relationships of rooms and preview finished results. Two major forms of the simulation drawing used in the current house market are perspective sketches and renderings.

The sketch is the essential simulation drawing containing the architect's thoughts and deliberations. Sketching by hand is the direct formulation, which is fast and economical. The sketch can create an ideal future vision, which encompasses the entirety of a project (Figure 5.5). Perspective renderings effectively combine with sketches and floor plans to supplement the two-dimensional views. The advantage of the perspective rendering over the photo of the model is in the technique of delineating colors and materials with different amounts of detail and texture (Figure 5.6). In comparison, the close-up view of a model photo looks flat; the foreground detail is rough, and the background lacks other adjacent buildings to support. However, no matter how life-like simulation drawings are, they are

never able to rid their artificial traces. Some developers have recently begun to explore a new simulation method – the photomontage.

Figure 5.5 Similarities between the sketch and the actual site as built (Sheppard, 1989)

Figure 5.6 A rendering of a single house

Homebuyers are always anxious to see the realistic result of the completed landscape. With the help of present photography and computer techniques, this

requirement can be satisfied. Photos of drawings, models, or computer renderings are valuable resources and can be used in the composite process. They can be set into the image of the actual environment and provide a truly realistic image of the way the project will look when completed (Figures 5.7a, b, & c). However, making an excellent photomontage is not easy or cheap. The angle, lighting and scale of the photograph of the model must correspond with the angle, lighting and scale of the photograph of the existing site. Shading and colour are reconstructed by computer collage and retouching (Busch, 1991, & Burden, 1985). This is accomplished through many processes and techniques, and is very time-consuming.

Figure 5.7 Three composites of (a) photo of 3D rendering (Burden, 1985); (b) photo of model (Busch, 1991), and (c) image of computer rendering (Sanders, 1996)

The uniqueness of drawing or image simulation is that they place objects into a clear relationship with other objects and with the surrounding context or setting (Sheppard, 1989). This overall scene and context constitute a visual environment. However, they contain low efficiency hand works, and are usually

done from a fixed position because of the elaborate methods necessary to plot and draw one viewpoint. Drawings and images obviously have difficulties in providing adequate spatial information to homebuyers.

5.3.2 Models and Model Houses

The model has an unlimited choice of viewpoints and variations of distances. It can represent accurate spaces and can clearly interpret architectural drawings at a simple and overall view. Figure 5.8 can clearly describe this point. In a different view, an example is a door shown open in plan and closed in elevation (Sanders, 1996). The model provides a way of looking at things in order to understand them. As presentation media, it is the efficient way to transfer ideas, spatial information, especially a kind of close sense to the homebuyer. However, creating a house model is not cheap, and its biggest weakness is that one cannot present inside spaces to homebuyers. Most builders now turn to build the model house, and its purposes are not merely about presentation.

Figure 5.8 Relationship between the drawing and the model

When the homebuyer's identity and preferences are unknown, the model home holds a great deal of importance as a marketing device. It is the merchant builder's "store" that is visited by many potential homebuyers (Friedman, 2002). With minimal variations in the plans produced and few options available to cater to user needs, the model home is design to entice potential homebuyers and provide them with an image of what their home may resemble.

Model homes involve a precisely calculated manipulation of lighting effects, and dramatic attention – grabbing appliance and furniture. Developers build and merchandise their model homes to appeal or even lure their targets, which represent the majority of their home sales. After visiting the model home, many homebuyers may wish to purchase the homes in their standard formats or even buy model homes. Others will have ideas for modifying the interior layout or exterior appearance.

Taken to the highest level, efforts invested in model home presentation can become very expensive. The building cost is financed by a construction loan, but borrowing money for landscaping, furnishings or displays is difficult. "Merchant builders spend on average about four percent of the sale price for selling, model home presentation, and advertising" (as cited in Friedman, 2002, p. 54). The numbers of model house is always limited. Also, the automobile factory has now begun to use a new simulation technology, called virtual reality.

5.3.3 Virtual Reality

The homebuilder cannot provide model houses for all house types of every model, and homebuyers are no longer content with static drawings, models or photos to envision their dream homes but want to experience them. Computer simulations are a new way to predict how a planned building may look and “how it can be experienced in space and time” (Schmitt, 1999). With the newly available virtual reality technology, it is nowadays possible to offer every homebuyer an opportunity to experience and evaluate his or her choices and thus get obvious and overall information to support his or her decisions. This should add a new layer of simulation to the house marketing.

Most people get to know virtual reality from games or exhibits, and equate virtual reality with sensors and head-mounted displays. Actually, this is only one of the many possible configurations of its system, which is not always present. Low-end virtual reality systems display a perspective view of the simulated world and provide a movement through the environment. In most instances, the only display device is the computer screen and interactive devices such as the mouse and keyboard (Bertol, & Foell, 1997). It therefore provides the premise for applying virtual reality to the broader field and the larger public.

The unprecedented growth of the Internet - the World Wide Web (WWW) has led to a desire and a demand for three-dimensional content experienced through graphic interfaces. Virtual Reality Model Language (VRML) brings architectural

"space and place" to the web. "It is currently one of the greatest areas of interest for the WWW with major attention focused on its technological developments and business potentials" (Bertol, & Foell, 1997, p. 88). It offers a new simulation means through the computers or Internet for the house business in addition to helping homebuyers. It will overcome the drawbacks of conventional tools and bridge the gap between virtual selection and real buildings.

5.4 Testing Your Choices – Prototype Part III

The major keywords, "full scale", "human sense", "real-time", and "participant" depict the two most crucial aspects of virtual reality, "immersion" and "interaction", which are at the heart of virtual reality and are the most useful functions for the homebuyer to test their choices.

5.4.1 Immersing in Future Home

The physical model limits a homebuyer's ability to experience the quality of the space since it cannot be perceived from its inside. Effective simulations can be achieved by using the digital model of virtual reality. Its unique advantage is the three-dimensional, full-scale mapping of the ideated design, which can be viewed from any viewpoint, from its outside as well as its "inside". A feeling of being "inside" is called "immersion" (Bertol, & Foell, 1997). The architect renders a physical immersive environment by its natural characteristics; similarly, virtual reality creates a full-scale complete world as the substitute of the actual world in

human perceptions, and provides the same possibility in the virtual world. So, it also can give participants, the potential homebuyers, a perception of "presence" an entity - a feeling of immersion. They can go inside of their selected homes to experience the interior form, space, and structure of their virtual houses. Any elements or spatial situations can be directly described and observed, so that homebuyers can clearly understand their selections and decide to keep them or change them.

The most effective means of realistic looking results is the use of "near photo-realistic" texture mapping, which is used to simulate material surfaces such as the wood, brick, metal, glass, stone and so on. Meanwhile, more than one hundred 3D-simulated objects are placed in the interior and exterior of the 3-bedroom typical house model. They are appliances and cabinets in the kitchen, standard equipment in bathrooms, and furniture, lights, pictures, and electrics in different rooms. The exterior are placed fences, decks, lights, plants, BBQ, spa, etc. All 3D objects and their realistic textures can give participants a visual and immersive perception.

5.4.2 Interacting with Interfaces

The real-time responsiveness of the computer to the participant's action distinguishes virtual reality from other types of computer-generated simulation. In contrast to other 3D animations where the user is passive viewer, the user in a virtual reality world is an active participant, controlling every interaction. Actions

of dynamic observing can be achieved by navigating through the virtual house and changing the viewpoint at every occasion desired.

Navigation is the most basic interaction used in house simulation. In simple navigation, the only interaction available is movement, which allows homebuyers to walk-through the virtual house as they do in real model homes. They can stroll in each room by simply moving the mouse to control the movement, the place and the duration of each shot. The sense of proportions of different architectural elements is discerned only by dynamic navigation. It enables the homebuyer to acquire the spatial feeling of a room, a perception of closeness because only the totality of views can provide a fair perception of an architectural space. In a walk-through, the virtual house is easily implemented. The majority of objects are static and only the participant's viewpoint is dynamic. "A navigation can bring to the surface many design problems, which would not be detected from static representations" (Bertol, & Foell, 1997, p. 121).

The participated homebuyer is able to interactively change the perspective to view the model of a standard design by simply moving the mouse or shifting the viewpoint of each virtual camera. Interaction occurs after an appropriate viewpoint is selected, and the homebuyer can be directly brought to the selected place. Moreover, the homebuyers can interact with objects that are encountered, such as opening a door, turning on a TV, lighting, a PC... They are also given chances to select the colour, texture and type of materials for walls, steps, floors

and so on. By navigation, they can test various ideas and selections and preview different results. Virtual reality provides a visual simulation and acquires a higher degree of realism that anyother media has ever reached.

Charter 6. Conclusion

The thesis explores three stages of the entire housebuying process - searching, selecting, and buying. According to the problems in each stage of the process, the thesis discusses three possible solutions – web tool, custom design, and VR simulation - and utilizes the media as the thread. The web is the base for all solutions. It not only serves as a transmission of information, but also as an appropriate multimedia to best present designs. The custom design is the theme of this thesis. The simulation offers a powerful way to test designs. However, like homebuyers rarely seeking their “dream” home, it is hard to assure every means is the perfect solution. Each of them has limitations, and future developments will improve and enhance their functions.

6.1 The Web

Computers are becoming the vehicle for today's housebuying. Acquisition of news, mail and even social interactions become more and more computer-based, which have expanded the technical knowledge and skills of average homebuyers. They can search and “read” house information through the web and are thus becoming more informed and knowledgeable before they drive out or enter a sales office. It avoids pointless driving and reduces searching time. However, after web-based house searches, the best way will still be a personal tour of a model home and the community within which it exists. As for buying a new home through the web, hopefully, it will be available to the public.

Housebuying through the web will depend on the development of the house industry. In the past, a dramatically expanding population placed tremendous pressure on builders to improve their speed and efficiency, leading to valuable technological breakthroughs to satisfy the astounding demand for housing. One of these breakthroughs was the notion of prefabricating units as whole products. The Packaged House explored the way of selling through the conventional media. Similar attempts are explored today. The current "Packaged House" and its web buying process are prospected by Kent Larson. Presently, new technologies for the housing industry are only waiting for applications and market demand. Information and communication technologies are integrated into the house industry. Embedded, low-cost sensors can continuously measure the state of the house, connect to Internet home services, and provide feedback to users through large displays. Environment-responsive infrastructure can monitor occupants' health, exercise and nutrition to identify potential problems. Environment-aware systems can recognize most objects entering and leaving the home by embedded sensors (Larson, 2000). The more technologies are integrated into the house, the more possibilities exist for houses bought through the web. Since people will put more consideration in new functions and less on style or layout, standard and technological house functions are easily judged through the web. Someday in the future, buying a home through the web will just be like buying a computer in this manner today. People will pay more attention to its functions, like computer speed, and less consideration will be given to its face, like the computer case. In this stage, the house will reach Le Corbusier's idea of

“houses as machines for living in”, a pure container, which is like many objects are seen in science fiction movies.

If we eliminate from our hearts and minds all dead concepts in regard to the houses and look at the question from a critical and objective point of view, we shall arrive at the ‘House-Machine,’ the mass-production house, healthy (and morally so too) and beautiful in the same way that the working tools and instruments which accompany our existence are beautiful. (Le Corbusier, 1923)

6.2 Housing Design and Industry

The standard designs lie at the heart of the design solution by becoming the basic sources not only for customizing the houses but also for running the matrix grammar. Every homebuyer fulfills the customized process by selecting the standard design of each floor, and the matrix grammars ensure to provide as many design combinations as possible for all homebuyers. Homebuyers themselves have more opportunities to participate in the modification of their homes to their own changing needs. Either architect or salesperson can provide a physical environment to physically give some guidance and finally confirm all selections to the homebuyer. The uniqueness of standard design is also based on the production of the house; each design not only can be selected as a digital floor plan, but also can be produced as an integrated house component. Current communication technologies and the house industry offer conveniences and possibilities to reach this aim. Finally, the house design and make will fulfill its transition from mass production to mass semi-customization. The house industry will thus catch up to other manufacturing industries, and sophisticated homebuilder will sell services, experiences, and lifestyles, not just commodities.

Most North American homes are built conventionally, including those that are produced currently in Ontario. Framers assemble pre-cut wood segments on site. Almost 90 percent of all building components sent to the building site are prefabricated, which in itself constitutes an initial level of flexibility in assembly (Friedman, 2002). This provides the promise to fulfill mass semi-customization. Today, the integrated design and construction methods are currently taking place in Japan, and choices made by the homebuyers using computers can be sent electronically from the sales office to production plants where they are constructed and delivered to the site for quick assembly (Friedman, 2002).

Because of the diversity and comparability of the mass housing designs, the design following shape grammars is emphasized, in a manner to keep all designs generated in a proper order – between initial designs and variations and between designs of house types. The shape grammars provide a design approach based on the general design principles. It makes the design process simpler and easier, and enables designs to become diverse and standard. Currently, before houses are sold, an alternative approach is to leave the interior unfinished. This strategy allows greater choice at no additional cost and the fitting of the units' interiors to the homebuyers' needs. The upgrading grammars extend the meaning of upgrade to the customized stage. Homebuyers can upgrade any design from any level among different types and models. Through the digital interface, homebuyers clearly know all information, including what they will pay and what they can get. This approach refers to the experience at Ikea.

Although all standard designs are generated by automatic tools, they still derive from designers' subjective design concepts and strategies and thus are confined by their skills, abilities and experiences. To resolve the suspicious limitations, future design generations can depend on the Design Engines. Currently, many developing design engines provide automatic generations not through the query but on graphics. In the US, "Art Star" architects may license design engines for mass marketing, like many now do with furniture and furnishing design. Large, well-capitalized corporations from outside of the housing industry may develop "branded" product Design Engines that focus as much on lifestyle and image as on function and price (Larson, 2000)

6.3 The Simulation

The simulation overcomes people's limitations of experience. It can help the homebuyer to get better understanding of the design and is thus the accelerator that expedites homebuyers' decision-making. As a media, virtual reality simulation extends people's consciousness. However, VRML is a kind of application of virtual reality in the low-end system. It prevails on the web and is oriented to a large public without peripheral devices. Some pure characteristics of virtual reality should be missing and effects should be weakened since personal computing interfaces squeeze graphics onto the screen. Fortunately, cheap peripheral devices now appear on the market. A 3D glass is sold for only 10 Canadian dollars. Other devices can be also acquired at inexpensive prices for family use. Recently, a large-size stereo projection becomes more attractive

since this allows the simultaneous access to virtual reality for many people. For the house business, the developer may easily provide a place to offer VR services in the sales office. The manufacturing pioneer, Ford, plans mass customization for the car. It envisions show rooms where the consumer would "design" the car with the desired features, test-drive it using VR, finalize details, arrange financing and then transmit the order to the factory.

However, current Information is presented as pixels on screens that must be in the foreground of a user's focus of attention to be processed. Some researches are trying to move the interface off the screen. Well-known holographic technology is moving into this advanced vision of simulation. Current researches at MIT are exploring natural and invisible interfaces (Harris, Ishii, Chung, Dodsworth, & Buxton, 1999). Displayers will disappear, and interfaces might consist of natural media, such as air, ground and water. This will bring the computer simulation into a new stage of development. A perspective can be taken from English architect Martin Pawley's book "Terminal Architecture". He portrayed a scenario of visiting 'Ideal Home 2098' (1998, p13 &14); he wrote:

We don't say house any more. We say terminals... Jim's terminal was connected to his car... it looked as though he might be able to stretch out full length in it, just. 'How can you live in here, there's no space.' Jim picked up an umbilical keypad and punched a button. Suddenly the vast Dolby hush of a great cathedral descended over the interior of his tiny capsule. The terminal's envelope had become a screen and a panorama of open desert stretched away in all directions. It was astounding. It might have been a hundred miles from wall to wall. If we had shouted, we would have heard echoes. 'Plenty of space,' said Jim phlegmatically, and eclipsed the image with his finger.

In this situation, people will reach the final phase of “the extensions of man - the technological simulation of consciousness”. This is in the future but is not dreamy.

“Tomorrow will bring new methods of communication, new competitive challenges, and new demands... Get ready for tomorrow because it’ll be here this afternoon (Sterne, 1995).” The web, the design and the simulation are all included in Lao Tzu’s word:

“Thirty spokes converge upon a single hub;
It is on the hole in the center that the purpose of the axle depends.

We make a vessel from a lump of clay;
It is empty space within the vessel that makes it useful.

We make doors and windows for a room;
But it is these empty spaces that make the room habitable.

Thus while the tangible has advantages;
It is the intangible that makes it useful.”

Lao Tzu (c. 550 B. C.)

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Appendix A

Ottawa Facts and Homebuyer Group

From: <http://www.ottawaregion.com/facts/index.asp>

Ottawa

FACTS

Population

Area	1996	2001	2006
City of Ottawa *	721,135	800,000	910,000
Ontario municipalities adjacent to Ottawa	116,957	128,000	150,000
Quebec municipalities:			
Outaouais Urban Community	217,615	252,000	280,000
MRC Collines de l'Outaouais	32,982	41,000	50,000
Outaouais Subtotal	250,597	293,000	330,000
Ottawa Region, Total	1,088,690	1,221,000	1,390,000

Source: City of Ottawa, Population, Employment, Household & Dwelling Projections 1996 to 2031, May 2001 (using Scenario "B")

Area: Ottawa region

* as of 1 Jan. 2001, all municipalities in the former Region of Ottawa-Carleton were amalgamated into the new City of Ottawa

June 2001

Population by Age Group

Age	Total	Male	Female
0-14	205,315	104,810	100,500
15-19	69,190	35,395	33,790
20-24	71,975	35,865	36,110
25-44	347,705	170,560	177,150
45-54	159,695	78,120	81,575
55-64	94,750	46,235	48,515
65-74	63,810	29,355	34,455
75-84	36,620	15,210	24,410
85+	11,600	3,175	8,430
Total	1,060,660	518,725	544,935

Source: 2001 Census, Ottawa-Hull CMA

Levels of Higher Education in Selected OECD Countries

Note: Country data is for 2000; Ottawa data is for 2001

Source: Country data - OECD (Organization for Economic Co-operation and Development), Education at a Glance 2002; Ottawa data - 2001 Census

Ottawa FACTS

Educational Attainment

Source: 1996 Census

Area: Ottawa-Hull Census Metropolitan Area

Data reports level of highest educational attainment, population 25 and over

March 2000

Ottawa FACTS

Major Employers Public and Private Sectors

Employees	Employer	Business Type
75,000 +	Government of Canada	Federal government
9,000	Nortel Networks	Advanced technology
8,000	City of Ottawa	Municipal government
4,001 to 5,000	Canada Post Corporation University of Ottawa Ottawa-Carleton District School Board Ottawa Hospital Carleton University	Postal service University School board Health services University
2,501 to 4,000	Bell Canada JDS Uniphase Alcatel Canada Loblaws Ottawa-Carleton R.C. School Board	Telecommunications services Advanced technology Advanced technology Food retail School board
1,501 to 2,500	OC Transpo Bank of Canada Callian Technology Canadian Corps of Commissioners Conseil des écoles française Government of Ontario Ottawa Police Service Sisters of Charity Ottawa Health Service McDonald's Restaurants	Public transit Central bank Advanced technology Security services School board Provincial government Police Health services Food services
1,001 to 1,500	Algonquin College Mitel Networks EDS Canada Children's Hospital of Eastern Ontario Royal Ottawa Health Care Group	Community college Advanced technology Advanced technology Health services Health services

Continued

Source: Ottawa Economic Development and City of Ottawa surveys

Area: City of Ottawa

August 2001

Private Sector Advanced Technology Employment Ottawa-Hull

Advanced Technology Jobs

Year	Advanced Technology Jobs
1976	8,200
1981	16,000
1986	21,900
1990	27,534
1991	31,158
1992	30,965
1993	30,225
1995	35,329
1996	41,000
1997	48,312
1998	52,700
1999	63,000
2000	79,000
2001	69,500
2002	66,500

Source: Ottawa-Carleton Employment Surveys and OCRI High Technology Industry Surveys
Note: Data for 1986 and prior years include public sector and advanced technology jobs

Households with at least One Regular User of Computer Communications

CMA	All Locations (%) (home/work/school)	All Locations (%) (home/work/school)
	2001	2002
Calgary	65.2	70.9
Edmonton	59.5	68.3
Halifax	64.1	68.6
Hamilton	54.9	57.8
Kitchener-Waterloo	52.7	59.7
London	59.2	71.4
Montreal	46.6	60.1
Oshawa	Not Available	65.6
Ottawa*	65.2	77.6
Quebec	50.3	55.0
Regina (SK)	Not Available	69.2
Saint John (NB)	Not Available	63.0
Saskatoon (SK)	Not Available	61.5
St. Catharines-Niagara	46.0	59.2
St. John's (Nfld. Lab)	Not Available	64.4
Toronto	57.9	67.0
Vancouver	60.0	69.1
Victoria	59.1	68.0
Windsor	47.5	54.9
Winnipeg	53.9	61.8
Canada	51.3	60.2

Source: Statistics Canada 2001 Census

*Ottawa refers to the Ontario side of the Ottawa-Hull Census Metropolitan Area

Appendix B

The OCHBA Members - New homebuilders in Ottawa area:

1. <u>Ashcroft Homes Inc.</u> 18 Antares Drive, Nepean, Ontario K2E 1A9	226-7266
2. <u>Brigil Homes</u> Suite 200, 500 Boul. Gréber, Gatineau, Quebec J8T 7W3	243-7392
3. <u>A & B Bulat Homes Limited</u> Suite 202, 11 Gifford Street, Nepean, Ontario K2E 7S3	723-1008
4. <u>Campanale Homes</u> 200-1187 Bank Street, Ottawa, Ontario K1S 3X7	730-2000
5. <u>Cardel Homes Limited</u> 3368 Carling Avenue, Ottawa, Ontario K2H 5A8	820-1959
6. <u>Cedarstone Homes Limited</u> 384 Richmond Road, RR #3, Ashton, Ontario K0A 1B0	838-4663
7. <u>Claridge Homes Corporation</u> 2001-210 Gladstone, Ottawa, Ontario K2P 0Y6	233-6030
8. <u>Denmoor Development Corporation</u> 47 Paxton Lane, Gloucester, Ontario K1B 1B7	746-6981
9. <u>Domicile Developments Inc.</u> 1 - 371A Richmond Road, Ottawa, Ontario K2A 0E7	728-0388
10. <u>El Pine Homes Corporation</u> 180 Waller Street, Ottawa, Ontario K1N 9B9	238-5000
11. <u>Guildcrest Building Corporation</u> 20 Mill Street, Box 10, Morewood, Ontario K0A 2R0	448-1190
12. <u>Holitzner Homes (1995) Ltd.</u> 1300 Main Street, P.O. Box 149, Stittsville, Ontario K2S 1A2	831-3484

13. <u>Land Ark Homes</u> P.O. Box 324, Stittsville, Ontario K2S 1A4	836-7565
14. <u>Lapointe Developemnts Ltd.</u> 1199 Notre-Dame, Embrun Ontario K0A 1W0	443-5263
15. <u>Larco Management Inc.</u> 200-104 CentrepoinTE Dr, Nepean, Ontario K2G 6B1	225-0040
16. G. Lemay Construction (1998) Inc. Unit 8, 5330 Canotek Road, Gloucester, Ontario K1J 9C2	746-6430
17. <u>Longwood Corporation</u> 5-1010 Polytek Street, Gloucester, Ontario K1J 9H8	746-1300
18. <u>Maple Mountain Homes Ltd.</u> 3551 McBean Street, P.O. Box 730, Richmond, Ontario K0A 2Z0	838-1201
19. <u>Minto Developments Inc.</u> 300-427 Laurier Ave W, Ottawa, Ontario K1R 7Y2	230-7051
20. <u>Monarch Construction Limited</u> 3584 Jockvale Road, Nepean, Ontario K2G 3H2	692-8672
21. <u>Carolyn Munro Design</u> 18 Catherwood Court, Kanata, Ontario K2K 2K1	839-7333
22. <u>Muirfield Homes Inc.</u> 601 - 1420 Blair Place, Gloucester, Ontario K1J 9B8	748-5060
23. <u>Olympia Homes</u> 1914 Merivale Road, Nepean, Ontario K2G 1E8	226-6573
24. <u>Pinkney & Gardiner Construction Inc.</u> P.O. Box 220, Cumberland, Ontario K4C 1E6	833-0027
25. Pierre Garand Enterprises 49 Loch Isle Road, Nepean, Ontario K2H 8G6	733-0060
26. <u>Phoenix Homes</u> 18 Bentley Ave., Nepean, Ontario K2E 6T8	723-9227

27. <u>Richcraft Homes Limited</u> 201-2280 St. Laurent Blvd, Ottawa, Ontario K1G 4K1	739-7111
28. <u>SAVVY CUSTOM BUILDER LIMITED</u> P.O. Box 73010, 555 Leggett Drive, Kanata, Ontario K2K 3C5	860-9895
29. <u>Sienna Properties Inc. / Sienna Homes</u> 60 Robertson Road, Nepean, Ontario K2H 5Y8	721-4110
30. Talos Homes Limited P.O. Box 13328, Kanata, Ontario K2K 1X5	834-7455
31. <u>Tamarack Development Corporation</u> 3187 Albion Road South, Ottawa, Ontario K1V 8Y3	739-2919
32. <u>Tartan Development Corporation</u> 200-331 Cooper Street, Ottawa, Ontario K2P 0G5	238-2040
33. Tomar Homes Ltd. 11 Lanigan Street, Stittsville, Ontario K2S 1G9	836-1179
34. <u>Uniform Urban Developments Ltd.</u> 300 - 117 CentrepoinTE Dr., Nepean, Ontario K2G 5X3	225-0770
35. <u>Urbandale Construction Ltd</u> 2193 Arch Street, Ottawa, Ontario K1G 2H5	731-6331
36. <u>Valecraft Homes Limited</u> 216-1455 Youville Drive, Orleans, Ontario K1C 6Z7	837-1104
37. <u>Woodfield Homes Inc</u> 1451 Youville Drive, Orleans, Ontario K1C 4R1	834-1118

Last retrieved March 1, 2002, from <http://www.ochba.com/members/builders.htm>

Appendix C

Site Interview

Six interviews with salespersons were conducted.

Details:

South area: Enclave; Mrs. Barbara (Claridge)

Woodland; saleslady (Richcraft)

Kanata: Walden Way; area sales manager, Mrs. Christine (Cardel)

Macassa Court; primary sales, Mrs. Doreen (Richcraft)

Village Green; sales consultant: Mrs. Diane (Urbandale)

East area: OAKPARK, saleslady (Claridge)

Questionnaires:

1. What are most homebuyers' occupations?
2. What is the first consideration of homebuyer?
3. What are the frequently asked questions of homebuyers?
4. What are specific needs of homebuyers?
5. What are problems (of design or client) you found in sales process?
6. What is the most important factor in final decision-making? Is the model home necessary?

Answer Sheets:

1. What are most homebuyers' occupations?

- Hi-tech
- Government
- Doctor
- Services
- Teacher

2. What is the first consideration of homebuyer?

- Location
- Price
- Homebuilder
- Size
- Quality

3. What are the frequently asked questions of homebuyers?

- Can I get lower price? Can I make a deal? What is free?
- Can I change the design?
- What is the standard, and what include and exclude?
- What's the specific feature of the house?
- What upgrading is available, and cost?
- Can I choice the color, pattern...?
- Can I buy this model home?

4. What are specific needs of homebuyers?

- Need a separate place for work
- Need a guest room in the basement
- Need the different external finishes from the next door
- Need a big ventilation fan in kitchen

- A open space on second floor for living and entertainment
 - Some people don't want the full open concept of kitchen
 - Hope to own a bathroom
5. What are problems (of design or client) you found in sales process?
- A lot's of people want to change the design, such as the place of the staircases, windows, wall, etc., but don't want to pay for that
 - Can't get clear understanding on the design
 - The house can't meet buyers' expectations when they take position.
 - Houses in same style, color, layout over and over
 - People return to visit the model house many times, suggest a new way for searching, such as internet, saving time, driving, and energy
 - Several sites use one model house
 - Laundry room in the basement
 - Change the model frequently
 - People don't want to buy the houses near the City Living area (subsidy house), high voltage line and heave traffic road
6. What is the most important factor of final decision-making? Is model house necessary?
- Good understanding on design, can't assume
 - Homebuyers' emotion and feeling
 - The design meet homebuyers' needs
 - Sales' presentation
 - People must know what they exactly want, and scale all desires
 - Attractive price
 - Bus station, primary or high school, or park nearby
 - Model house is absolutely needed

Appendix D

Client Survey

20 surveys with potential homebuyers were conducted.

Original Copy of Questionnaire:**Client Survey****What is the highest level of education you have completed?**

High school Technical school College University Higher

Are you a:

First-time buyer Move-up buyer
Relocating buyer Down-sizing buyer

You hear about the advice from (check all that apply):

Friend Family member Person who just bought a new home
Salesperson Consultant

When you are selecting your new home, what is the most important factor?

Price Location Builder Design Size
Special features Others (specify): _____

What kind of search media you would like to use (check all that apply)?

Newspaper Magazine TV commercial Internet
Others (specify): _____

How skilled are you at using computers?

Novice Intermediate Advanced

How often do you access the Internet?

Everyday Once a week Few times a week
Few times a month Never

What is your feeling when you search your new home (check all that apply)?

Enjoyable Exciting Tired Headache Dislike

Do you need a home office?

Yes No

What kind of information format can help you understanding the design better (check all that apply)?

Drawing Scale model Sample of photo Model home
Similar house Others (specify): _____

Have you even visited the new homeowner and his house?

Yes No

You would like to: Select house from the market Custom made
And why?

Answer Sheets:**What is the highest level of education you have completed?**

<u>4</u> High school	<u>3</u> Technical school
<u>5</u> College	<u>6</u> University
<u>2</u> Higher	

Are you a:

<u>7</u> First-time buyer	<u>6</u> Move-up buyer
<u>5</u> Relocating buyer	<u>2</u> Down-sizing buyer

You hear about the advice from (check all that apply):

<u>8</u> Friend	<u>17</u> Family member
<u>12</u> Person who just bought a new home	
<u>14</u> Salesperson	<u>2</u> Consultant

When you are selecting your new home, what is the most important factor?

<u>5</u> Price	<u>7</u> Location
<u>2</u> Builder	<u>3</u> Design
<u>2</u> Size	<u>1</u> Special features
<u>0</u> Others (specify)	

What kind of search media you would like to use (check all that apply)?

4 Newspaper

10 Magazine

2 TV commercial

13 Internet

0 Others (specify)

How skilled are you at using computers?

3 Novice

12 Intermediate

5 Advanced

How often do you access the Internet?

11 Everyday

0 Once a week

7 Few times a week

0 Few times a month

2 Never

What is your feeling when you search your new home (check all that apply)?

12 Enjoyable

15 Exciting

11 Tired

17 Headache

0 Dislike

Do you need a home office?

12 Yes

8 No

**What kind of information format can help you understanding the design
(check all that apply)?**

<u>7</u> Drawing	<u>4</u> Scale model
<u>5</u> Sample of photo	<u>17</u> Model home
<u>8</u> Similar house	<u>0</u> Others (specify)

Have you even visited the new homeowner and his house?

<u>14</u> Yes	<u>6</u> No

You would like to:

- 18 Select a house from the market
- 2 Custom made

And why?

- Expensive
- No time
- Select a house from the market is easy
- Too much headache
- Take too long time
- Don't like that way
- Not sure for the result