A CHOICE MODEL FOR MASS CUSTOMISATION OF LOWER-COST AND HIGHER-PERFORMANCE HOUSING IN SUSTAINABLE DEVELOPMENT

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ABSTRACT

Market demand for housing changes over time, in response to the wants and needs of both individuals and society. Changes in socio-demographics highlight the emergence of non-traditional households in Canada and influence the configuration of a house (or *product*) which meets buyers' individual requirements. In turn, this affects the design approach (or *process*). At the same time, society today requires *sustainability* in housing development, since building a house consumes large amounts of energy during construction and after occupancy.

Technology that improves the *cost* and *performance* of housing has advanced over time. Although some innovative design and construction systems (or *approaches*) that attempt to meet societal and individual demands for housing are available in today's market, homebuilders tend not to apply *unfamiliar* approaches to their housing developments, since their business operation is often based on *convention*. Another reason, which inhibits a builder's adoption of new housing technology, is the extra *cost* required for seeking and analysing information. Thus, the homebuilders' decision-making processes for the adoption of 'familiar' and 'unfamiliar' design and construction systems (or *housing systems*) which affect the configuration of housing need to be well *programmed*.

Accordingly, this study, composed of four parts, focuses initially on identifying housing market trends and issues in Quebec, as well as introducing the new concept of *mass customisation* that encourages homebuilders to *standardise* parts of a house—i.e. the creation of *mass custom homes*. Then, in consideration of this new concept, as well as a value analysis approach that helps facilitate homebuilders' buying decisions, it proposes a *choice model* for the design and construction approaches to the delivery of 'lower-cost and higher-performance' housing. Thirdly, to assess its practicality, the proposed decision-making model is *demonstrated* in collaboration with a selected homebuilder in Quebec. Finally, the results of this study are discussed in depth in order to identify

future research opportunities.

In view of the demonstration project conducted in this study, the author concluded that the proposed 'choice model' could function effectively as a *practical* decision-making support tool (or *system*) that helps open the door for homebuilders to generate and select alternatives that aid them to produce lower-cost and higher-performance housing. As a consequence of programming the homebuilders' buying decision-making process, the *goal identification uncertainty* and *goal/purchase matching uncertainty*, which often hinder their adoption of unfamiliar, innovative housing systems, could be reduced, or eliminated.

RÉSUMÉ

La demande de logements change au cours du temps et ce, en réponse aux souhaits et besoins tant des individus que de la société. Les changements sociodémographiques soulignent l'apparition de foyers non traditionnels au Canada et influencent la conception d'une maison (produit) afin de satisfaire les exigences individuelles des acheteurs. À son tour, ceci affecte l'approche (procédure) de design employée. En même temps, la société d'aujourd'hui exige des développements résidentiels qui requièrent la soutenabilité puisque de grandes quantités d'énergie sont utilisées durant la construction et suite à l'occupation des maisons.

La technologie permettant d'améliorer le coût et la performance dans l'industrie de l'habitation a progressé au cours du temps. Malgré la disponibilité de systèmes (approches) novateurs de design et de construction qui tentent de satisfaire les exigences sociales et individuelles en matière d'habitation, les constructeurs n'ont pas tendance à appliquer des approches inconnues à leur processus de développement résidentiel, puisque la gestion de leurs opérations d'affaires étant souvent fondée sur le conventionnel. Une autre raison, qui entrave l'adoption des nouvelles technologies, est le coût supplémentaire associé à la recherche et à l'analyse d'information. C'est pourquoi les processus décisionnels des constructeurs de maisons pour l'adoption de systèmes de design et de construction (systèmes d'habitation), familiers et moins familiers, ayant un effet sur la conception de logements doivent être bien programmés.

Dans ce cadre, cette étude, comprenant quatre volets, porte dans un premier temps sur l'identification des tendances du marché de l'habitation au Québec et des questions découlant de ce dernier, ainsi que sur l'introduction du nouveau concept de *mass customisation* qui encourage les constructeurs de maisons à standardiser des éléments d'une maison, c'est-à-dire, à la création de logements personnalisés en masse. Dans un deuxième temps, en tenant compte de ce nouveau

concept, ainsi qu'une approche d'analyse de valeur qui facilite la prise de décisions des constructeurs lors de leurs décisions d'achat, cette étude propose un modèle de choix pour des approches de design et de construction à la livraison de maisons de coût réduit et d'une performance élevée. Troisièmement, dans le but d'évaluer sa praticabilité, une démonstration de l'application du modèle de prise de décision proposé est présentée en collaboration avec un constructeur choisi au Québec. Finalement, une discussion approfondie des résultats de cette étude suit afin d'identifier des opportunités ultérieures de recherche.

Tenant compte du projet de démonstration effectué dans cette étude, l'auteur conclue que le «modèle de choix » proposé pourrait fonctionner de façon efficace comme outil (système) pratique d'appui au processus de prise de décisions offrant aux constructeurs de maisons la possibilité de générer et de sélectionner des alternatives qui leur permettent de construire des logements de performance élevée à un coût réduit. Une conséquence de la programmation du processus décisionnel d'achat des constructeurs de maisons consiste en la réduction, voir l'annulation, des incertitudes quant à l'identification du but et à l'adéquation entre ce dernier et l'achat, lesquelles empêchent souvent l'adoption de systèmes d'habitation novateurs inconnus.

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PART I:

INTRODUCTION

1.1. INTRODUCTION

The fundamental aim of this study is to show how one might improve the delivery process of Canadian wood-frame houses, especially in Quebec. Such improvements may be realised by introducing a new value management approach to housing development; an approach capable of coping with economic and cultural realities resulting from inflation, energy shortages, changing world development patterns, and new societal standards. Thus, ***sustainability in housing development*** should be considered a normative question to which this study seeks a solution.

In this chapter, the term *sustainability* will be defined by reference to a number of features of the environmental movement introduced in the 1980s and 1990s. The meaning of *sustainability* in this study will be identified, following the overview of today's homebuilding activities that reflect the industry's cyclical nature, as well as some potential, state-of-the-art construction technologies toward sustainable development that to some degree affect those activities, which are carefully defined as *routines*. According to a market survey of fifty-two housing manufacturers in Quebec, conducted by the author, it was found that today's *homebuilders*[1] rarely apply industrialised building systems to their housing developments, despite the relatively high in-factory completeness of their housing components. The selection of research problems, as well as the objectives of the research will be also set forth in this chapter, presupposing that homebuilders are unlikely to considerably change their cyclical mode of operation (or *routines*) by adopting industrialised systems.

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[1] In North America, there is no clear-cut distinction between *developers* and *builders*—the former essentially means *land developer* that purchases land and carries out the necessary administrative procedures, while the latter is responsible for obtaining the necessary building permits, planning the building work, and supervising the construction (Friedman 1986:36). Therefore, for the purpose of this study, the terms such as *developer* and *builder* are used synonymously and are replaced with the term *homebuilder* that acquires land with the intention of building a housing project.

1.2. "SUSTAINABILITY" – DEFINITION AND ITS MEANING IN THIS STUDY

According to the Oxford English Dictionary, *sustainability* is defined as "capable of being borne or endured", "capable of being upheld or defended" and/or "capable of being maintained at a certain rate or level." The responses of individuals and companies, based on market considerations, to environmental *sustainability* in housing development have been widely studied. However, the term *sustainability* is sometimes narrowly defined, understood with regards to only environmental problems, such as 'global warning' and 'acid rain', caused by high-energy consumption, especially in developed countries (Lee 1996:14). Thus, the notion of *sustainable development* should be broadened to the point that it encompasses a wide range of social, economic and environmental problems that require immediate, practical solution (D'Amour 1991:13).

In April 1987, the World Commission on Environment and Development (WCED), commonly known as the Brundtland Commission after its chairwoman, published a report entitled *Our Common Future,* and presented it to a special Plenary Session of the General Assembly of the United Nations. The WCDE report, produced after 900 days of deliberation by an international group of politicians, civil servants and experts on environment and development, made several key statements on *sustainable development*. In the report, the WCDE (1987:43) defined it as:

> "...development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

The commission also explained that sustainable development contains two concepts:

1. The "concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given..."
2. The "idea of limitations imposed by the state of technology and social organisation on the environment's ability to meet present and future needs."

From which, the WCED (1987:46) argued that:

> "Sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations."

In 1992, the notion of sustainable development was given additional impetus at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro. Most recently, the conceptual focus of sustainable development has tended to link the collective aspirations of the world's people for peace, freedom, improved living conditions and a healthy environment, with the need to reconcile conflicting perspectives on the economy and environment, and on the present and future. Diverse groups and institutions have taken ownership of the concept, projecting onto it their own hopes and goals. Based on the extensive reviews of the diverse concepts and definitions concerning sustainable development, National Research Council (1999:23) developed a general framework that links these groups' "common concerns" to their "differing emphases" on:

1. What is to be sustained;
2. What is to be developed;
3. What types of links that should hold between the entities to be sustained and the entities to be developed; and
4. The extent of the future envisioned.

Since publication of the WCED report, there has been much discussion regarding the meaning of the term *sustainable development*, which can be considered as an oxymoron—*sustainability* and *development* (D'Amour 1992:13). The explicit use of the term *development,* rather than *economic growth,* might lead to an assumption that sustainable development embraces the quality-of-life concerns not necessarily reflected by annual estimates of production and consumption, or Gross

Domestic Product (GDP)—an indicator of the well-being and development status of nations. Economic growth is commonly understood to mean an on going expansion in scale of the physical dimensions of the economic system; however, such activities cannot be maintained, let alone increased without adverse affects, on or from, the surrounding environment (D'Amour 1992:14). The concept of sustainable development is vague and open to individual interpretation; thus, there has been a general failure, or reluctance, to develop and establish the concept on any specific sound theoretical foundation (Lawn 2001:17&20). In other words, the concept put forward in the WCED report is devoid of operational value; thus, specific parameters and guidance that would allow for rational choices to be made, relative to goals, are lacking. These need to be developed.

For purpose of this study, *sustainable development* will be redefined by reference to the following quotations written by three selected proponents:

I. "...the reconciliation of society's developmental goals with its environmental limits over the long term"[2] (National Research Council 1999:22)
II. "...an implicit recognition of desirable ends and limited means" (Lawn 2001:21)
III. "...a relative concept which should be measured against the next best, or worst, alternative course of action" (D'Amour 1992:14).

Not surprisingly given what was stated above, while sharing common concerns, these proponents advocate different means to achieve sustainability at different levels. The National Research Council's approach to sustainable development focuses on recognising the interdependence of environmental, social and economic issues, reflecting the spirit of the Brundtland Commission, which

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[2] This idea originally emerged in the early 1980s from scientific perspectives on the interdependence of society and environment. It has evolved since significant advances in our understanding of this interdependence were recognised (National Research Council 1999:2).

garnered increased political attention by putting forth a normative, rather than scientific question. On the other hand, Lawn believes the *ends-means* spectrum provides the appropriate theoretical light in which to view the concept of sustainable development, given that ecological macroeconomics explicate the interdependent relationship between *sustainability* and *development*. D'Amour's approach to sustainable development seems to be most realistic, emphasising the importance of developing some means of balancing our interests in the emphases on the entities that should be sustained, and the entities that should be developed, by measuring the alternatives and narrowing them to create a reasonable 'choice set'.

This study focuses on improving the quality of domestic architecture, i.e. housing, relative to significant and diverse social issues. Housing can essentially be seen "as a function of individual and as a function of society" (Code 1992:42). Sustainable development is a matter of global concern, posing social, economic and environmental problems, which the housing industry also needs to address. In order to identify the industry's role in tackling these problems, the meaning of sustainability in housing development will be analytically reviewed on a macroeconomic scale, relative to our redefinition of sustainable development in the last section.

The ancient Greeks referred to the household as the *oikos* (or *ekos*), from which English derives two terms for household management: economics and ecology. This study reaffirms the importance of that ancient insight: the economy and environment are intimately intertwined. In order to answer specific questions, as to how that is so, an environmental-macroeconomic spectrum will be reviewed as an aid in understanding the position of the housing industry with regards to sustainable development. Some issues of interest will be identified with reference to the impact of today's homebuilding activities on our environment, and in response to those issues, general characteristics of industrialised building systems and the significance of a value management approach will be briefly introduced. Finally, the nature of the homebuilding industry will be clarified based on some literature reviews, and the market survey of housing manufacturers conducted by the author, will be revealed.

1.3. AN ANALYTICAL REVIEW OF THE HOUSING INDUSTRY TOWARDS SUSTAINABILITY

Development recognises a society's desire to attain a set of desirable goals and objectives, while *sustainability* acknowledges that, in striving to attain such goals, society is constrained by the existence of limited means that compel humankind to make 'choices' which, in turn, demand human valuation. Thus, the questions may extend simply to what **valuation** should be placed on limited means, what **criteria** should be employed to rank and prioritise ends, and what **choices** should be made in allocating scarce means. Specific *parameters and guidance* help determine the extent to which humankind progresses or develops toward sustainable development (Lawn 2001:21).

1.3.1. AN ENVIRONMENTAL MACROECONOMIC SPECTRUM

The concept of the "ends-means spectrum" may help us understand the position and role of the housing industry in view of *environmental macroeconomics*[3] (Fig. 1.1). Originally, the ends-means spectrum was envisioned by Herman E. Daly, based on his concept of the "steady-state economy", which was defined as "…an economy with constant stocks of people and artefacts, maintained at some desired, sufficient levels by low rates of maintenance "*throughput*"…" (Daly 1991:17). The ends-means spectrum is composed of four basic categories: Ultimate Means, Intermediate Means, Intermediate Ends and Ultimate End. Each intermediate category in the spectrum is an end with respect to lower categories, and a means with respect to higher categories. According to the first law of thermodynamics, matter-energy is neither created nor destroyed—"The rest of the world is a

[3] "Environmental economics" is considered as a new domain of economics, whose theoretical focus is on prices. However, the key issue is how to internalise external environmental costs to arrive at prices that reflect full social marginal opportunity costs (Daly 1996:45).

source for its input of matter-energy and a sink for its output" (Daly 1991:15). However, the flow-through, or throughput, of matter-energy is "entropy" in nature; thus, there is no substitute for matter-energy itself (Lawn 2001:21). It is apparent that the fund of physical and human capital has some important relations with the rest of the world (Daly 1991:15). Thus, matter-energy (natural capital) is the fundamental stuff of the universe, without which humanity cannot produce and maintain the human-made capital (intermediate means), including houses, cars, televisions, food, clothes, and so forth—the things required to satisfy human needs and wants (intermediate ends). Moreover, the ultimate end is seen as "that which is intrinsically good in and of itself and does not derive its value from being instrumental in achieving some other end" (Daly 1991:19).

A generalised vision of modern economics, especially macroeconomics, may be realised using a circular flow diagram of production and consumption (Fig. 1.2). The macro-economy, so conceived, is considered as an "isolated system," in which exchange values circulate between firms and households responsible for the majority of production and consumption decisions, in a closed loop allowing for no exchanges of matter or energy with the environment (Daly 1996:47). Daly indicates that according to this model, aggregate production in the standard macro-economy can be "...written as Y = f (K, L), i.e., output is a function of capital and labour stocks. Resource flows (R) do not even enter! Nor is any waste output flow noted." However, if the micro-economy is seen as an "open system" rather than an "isolated system," the issue of its relationship to the environment will be taken into consideration (Fig. 1.3).

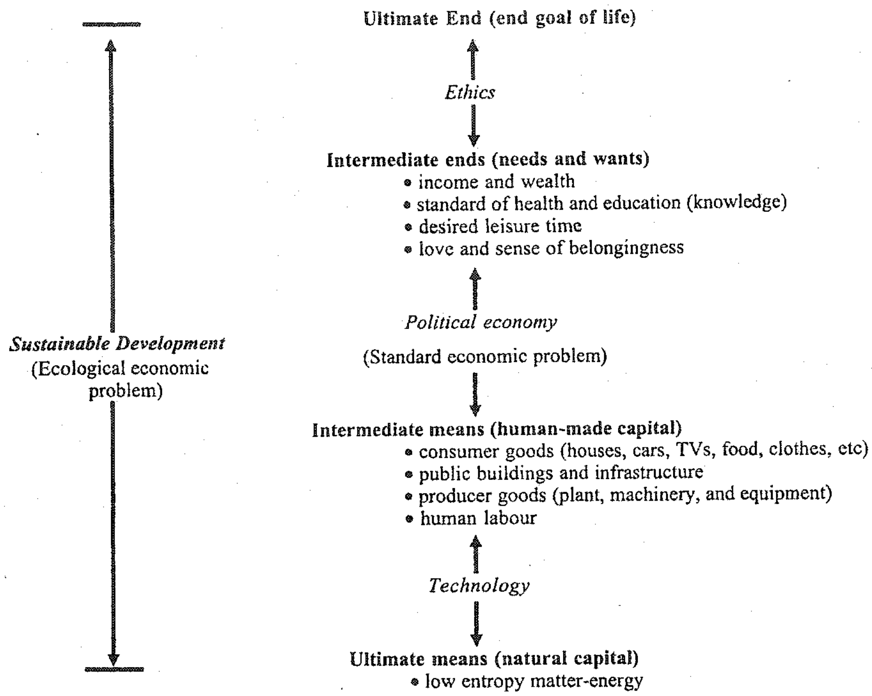

Figure 1.1: The ends-means spectrum

(Source: Lawn 2001)

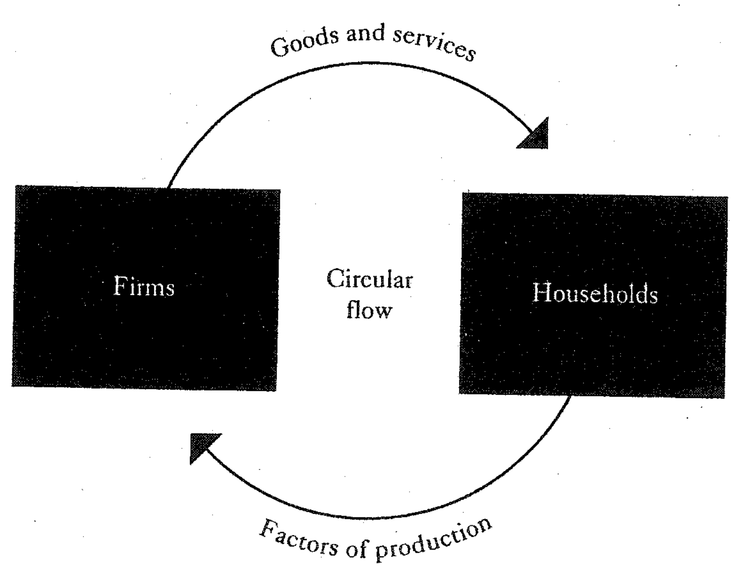

Figure 1.2: The economy as an isolated system

(Source: Daly 1996)

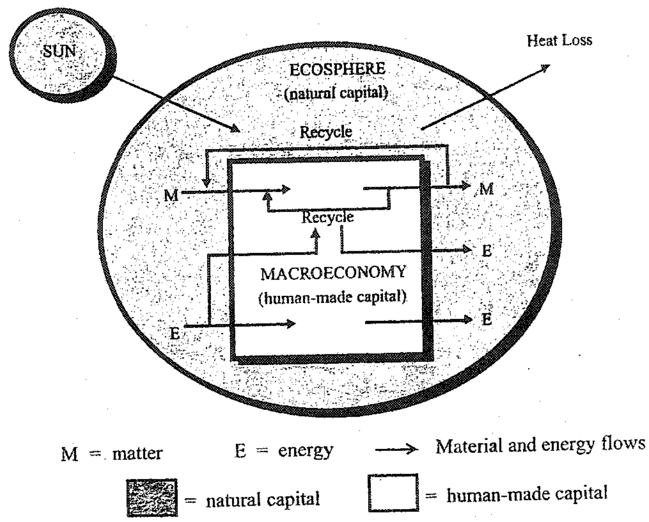

Figure 1.3: The economy as an open subsystem of the ecosphere

(Source: Lawn 2001)

1.3.2. THE IMPACT OF HOMEBUILDING ACTIVITIES ON THE ENVIRONMENT

In Canada, the construction industry contributes greatly to the national economy. In terms of Gross Domestic Product (GDP), 5.5 % of the total GDP (at basic prices) surveyed in March 2002 was related to construction activities, a result 5.1% higher than the same month of the previous year (Statistics Canada 2002a). Vital building activities bring labour into the workforce. In the year 2000, 815,600 employees (727,200 males and 88,400 females) in Canada were involved in construction work—meaning that 5.5% of total employment in Canada was generated by the construction industry (Statistics Canada 2002b). Undoubtedly, building activities considerably affect the Canadian economy and vice versa. In 1997, estimates show that $37.4 billion, or 42%, of total capital expenditures on construction went towards residential building construction—$12.2 billion for detached houses, $1.1 billion for semi-detached houses, and $3.7 billion for apartments and row houses (Statistics Canada 2002c). The housing market in Canada has been vigorous over the past few years. The total number of housing starts in 2001, was estimated at 162,733, and increased by 7.3% from the previous year. In Quebec alone, the number reached 27,682, a considerable increase of 12.1% over the previous year (Table 1.1). This aggregate number of housing starts in Quebec can be broken down into 17,193 detached houses (an increase of 12% from the previous year), 1,309 semi-detached houses (1.4% increase) and 869 attached houses (1.3% increase). These results also indicate that detached housing remains the consumers' predominant preference in housing types available on the market in Quebec. Detached housing is often considered to be less energy-efficient than semi-detached and row housing, due to the larger total area of external walls and roofs that are exposed to the outside climate. Grouping or joining units, such as semi-detached and row houses, is seen as one of the most effective ways of reducing energy consumption, since heat losses are limited to two or three walls and a small roof (Cammaleri and Nicell 1997:31).

	QUEBEC				CANADA
Year	Detached Housing	Semi-detached Housing	Row Housing	Total	Total
1981	14,231	2,419	485	29,645	177,973
1982	9,999	1,854	794	23,492	125,860
1983	22,167	3,877	1,186	40,318	162,645
1984	20,180	3,308	1,264	41,902	134,900
1985	18,442	2,554	2,325	48,031	165,826
1986	23,692	3,463	1,182	60,348	199,785
1987	31,430	3,288	1,837	74,179	245,986
1988	27,724	2,400	1,260	58,062	222,562
1989	24,493	2,609	1,017	49,058	215,382
1990	24,942	2,733	890	48,070	181,630
1991	22,531	4,777	2,563	44,654	156,197
1992	18,564	3,823	3,184	38,228	168,271
1993	17,136	3,909	3,346	34,015	155,443
1994	18,414	4,172	2,364	34,154	154,057
1995	13,428	2,264	1,046	21,885	110,993
1996	14,818	2,384	1,094	23,220	124,713
1997	16,073	2,767	1,433	25,896	147,040
1998	14,685	1,930	1,074	23,138	137,439
1999	15,798	1,586	1,184	25,742	149,968
2000	15,349	1,291	858	24,695	151,653
2001	17,193	1,309	869	27,682	162,733

Table 1.1: Housing starts by dwelling type in the province of Quebec, 1981-2001

(Source: Société d'Habitation du Québec 2001)

Energy is a daily necessity, providing for numerous essential services; however, in many countries, vast amounts of primary energy is wasted due to inefficient designs for the transmission, or conversion of energy into the services required (WCED 1987:168). As stated above, many primary sources of energy are non-renewable: natural gas, oil, coal, peat and nuclear power. Others are renewable, such as wood, plants, dung, falling water, geothermal sources, tidal, solar, wind and wave energy, as well as human and animal muscle-power. Each has particular economic, health and environmental costs, benefits and risks; thus, "choices must be made, but in the certain knowledge that choosing an energy strategy inevitably means choosing an environmental strategy " (WCED 1987:168). In response to changing social values, demands are being made of the housing industry to use fewer resources, both to build and to operate structures, while builders are beginning to employ resource saving strategies as marketing tools (Friedman et al. 1993:3). Housing is constructed with, and operates on products from the surrounding environment. Thus, it is regarded as a major consumer of natural resources in the building stages, as well as a major consumer of energy or matter in the occupancy stages—"housing is an environmental industry" (D'Amour 1991:16). Housing developments should be generated with consideration of environmental issues, and this may affect the way of building homes of tomorrow (Table 1.2).

Inevitably, building a house yields large quantities of waste materials. Wood, drywall and cardboard make up between 60% and 80% of job-site waste, and are considered to be the predominant waste materials of residential construction. Secondary waste materials include shingles, concrete and fibreboard. Even in small quantities, fibreglass insulation, carpet scrap, Kraft paper, sheathing, aluminium siding, vinyl siding, copper wire, PVC pipe, plastic buckets, aluminium duct-work, foam packaging, plastic sheeting or bags, steel banding, paint cans, and flooring scrap may become waste materials at the end of construction. Brick, block and asphalt shingles are often present in significant volume, and hazardous wastes are generated from painting, sealing, staining and caulking (Table 1.3).

ELEMENTS OF ONGOING ENVIRONMENTAL STRESS — **RELATIONSHIPS WITH THE CANADIAN HOUSING SECTOR**

GLOBAL ISSUES	COMMUNITY PLANNING ISSUES	HOUSING-SPECIFIC ISSUES
	ENERGY	
- Climate changes - Air/water/land pollution - Competing uses - Diminishing Resources	-Soft energy paths * Renewable, * Decentralised * Supply systems -Energy efficient urban planning * Buildings * Inter/intra-urban transportation -Residential energy Efficiency per capita * Floor space/person	- In-house energy efficiency * Behaviour * Technology - Energy intensity of building materials * Wood, steel, cement, etc. - Energy intensity of Construction, renovation and demolition * Prefabrication * Reduce, reuse, recycle
	WATER	
- Pollution and consumption - Climate change - Competing uses - Diminishing resources	-Adequacy of municipal waterworks and wastewater systems * Urban runoff wastewater, sewage * Government financing * User-pay principle	- In-house water efficiency * Behaviour * Technology - Landscaping * Plant species
	LAND	
- Land degradation * Deforestation * Loss of fertility * Toxic and municipal waste * Contaminated land - Land use change * Agricultural to urban * Wilderness to recreation - Climate change - Competing uses - Diminishing resources	-Urban sprawl -Urban intensification * Infill housing, granny flats, etc. * Accessory apartment, home-sharing, etc. -Urban growth areas * Demographics * Satellite cities * Growth centres	- House type * Adaptability * Flexibility - Residential construction waste * Reduce, reuse, recycle - Household solid waste * Reduce, reuse, recycle

Table 1.2: Selected key issues surrounding the sustainable housing development

(After D'Amour 1991)

MATERIALS	WEIGHT (in pounds)	VOLUME (in cubic yards)
Solid sawn wood	1,600	6
Engineered wood	1,400	5
Drywall	2,000	5
Cardboard	600	20
Metals	150	1
Vinyl (PVC)*	150	1
Masonry**	1,000	1
Hazardous materials	50	-
Others	1,050	11
Total	8,000	50

* Assuming three sides of exterior clad in vinyl siding
* * Assuming a brick veneer on home's front facade

Table 1.3: Typical residential construction waste estimate for a 2,000 square-foot house (After Smart Growth Network 2002)

In the occupancy stage, housing also requires significant energy inputs to operate a variety of products. Energy is used in dwellings for space heating and cooling, heating water, and operating appliances and lights. With regard to the consumption of electricity, in 1999, residential end-uses accounted for 27%, or 479.8 PJ of total energy demand (1,753.6 PJ) in Canada (Statistics Canada 2002d). Furthermore, Natural Resources Canada (NRCan 2002) reported that in residences, between 1990 and 1997, the share of natural gas consumed increased 14.3% for space heating and 16.7% for water heating. The increases were explained by the wider availability of natural gas and lower prices in comparison with electricity prices. The use of oil for space heating decreased by 4.3% while electricity's share also fell by 14.5%. It is known that more than 80% of residential energy is used for space and water heating, with the remainder of residential energy use going to operating appliances, lighting, and space cooling. Energy consumption often results in the emission of Greenhouse Gas (GHG); from 1990 to 1997, the GHG emissions associated with water heating increased 8.2%, with appliances increasing by 1.9%, and lighting increasing by 12.9%, while GHG emissions associated with space heating decreased by 4.9% (Table 1.4). NRCan (2002) explained efficiency had been improved over the past years, largely because of improvements in the efficiency of space heating and appliances.

In addition, energy demand in the residential sector increased moderately over the 1990s, and the market share for electricity is projected to increase from about 35% in 1997 to 41% in 2020 (NRCan 2002). On the other hand, the share for natural gas may fall 6% and this shift reflects major energy-efficiency improvement mainly for space heating, because of the impact of initiatives such as the introduction of new standards, more stringent existing standards and the resulting changes in housing and appliances stocks.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total Growth 90-99
Total Energy Use (PJ)	**1,309.7**	**1,286.9**	**1,317.4**	**1,366.3**	**1,395.0**	**1,363.7**	**1,460.8**	**1,394.1**	**1,281.3**	**1,327.8**	**1.4%**
Energy Use by Fuel Type (PJ)											
Electricity	467.4	465.8	476	476.7	478.4	473.8	486.9	484.2	465.6	476	1.8%
Natural Gas	528.4	531.9	553.3	593.5	631.5	630.5	696	648.1	577.8	609.3	15.3%
Heating Oil	186.4	162.2	166.5	172.5	163	138	158.9	147.1	126.1	131	-29.7%
Wood	105.7	104	101.2	109.6	108.3	104.6	102.7	99	97.8	99.3	-6.1%
Propane	19.9	21	18.4	12.1	12.3	14.5	14.2	13.8	12.4	10.5	-47.2%
Coal and Other	2	2	2	1.8	1.5	2.3	2.3	2	1.7	1.7	-15.0%
Energy Use by End-Use (PJ)											
Space Heating	788.7	772.9	801.6	835.4	848.1	823.1	899	843.7	733	770	-2.4%
Water Heating	271	267.4	270.9	279.8	290.3	284.8	301.4	294.3	288.9	296.9	9.6%
Appliances	190.3	184.5	186.7	190.9	194.1	191.2	195.1	190.9	191.1	190.6	0.2%
Lighting	54.4	53.7	55.2	54.8	56.6	56.6	58.5	58.7	58.5	60.1	10.5%
Space Cooling	5.3	8.4	3.1	5.5	5.9	8	6.8	6.6	9.8	10.2	92.5%
Activity											
Total Floor Space (million m^2)	1,264.7	1,292.0	1,317.4	1,340.8	1,366.4	1,388.2	1,409.3	1,451.3	1,485.4	1,511.3	19.5%
Total Households (thousands)	10,232	10,530	10,716	10,918	11,082	11,271	11,446	11,606	11,690	11,862	15.9%
Energy Intensity (GJ/m^2)	1.04	1.00	1.00	1.02	1.02	0.98	1.04	0.96	0.86	0.88	-15.4%
Energy Intensity (GJ/household)	128	122.2	122.9	125.1	125.9	121	127.6	120.1	109.6	111.9	-12.6%
Total GHG Emissions Including Electricity (Mt)	**69.7**	**66.9**	**69.7**	**68.9**	**69**	**68.4**	**72.9**	**72**	**69.1**	**69.7**	**0.0%**
GHG Emissions by Fuel Type (Mt)											
Electricity	26.2	25.1	26.7	23.8	23.3	24	23.8	26.3	28.6	27.4	4.6%
Natural Gas	26.4	26.5	27.6	29.5	30.9	31.3	34.5	32.1	28.6	30.2	14.4%
Heating Oil	13.7	11.9	12.2	12.7	12	10.1	11.7	10.8	9.2	9.6	-29.9%
Wood	1.9	1.9	1.9	2	2	1.9	1.9	1.8	1.8	1.8	-5.3%
Propane	1.2	1.3	1.1	0.7	0.7	0.9	0.9	0.8	0.7	0.6	-50.0%
Coal and Other	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.1	-50.0%
GHG Emissions by End-Use (Mt)											
Space Heating	40.9	39.4	41.4	41.9	41.9	40.8	44.9	42.7	37.4	38.9	-4.9%
Water Heating	14.7	14.2	14.6	14.4	14.7	14.6	15.3	15.4	15.9	15.9	8.2%
Appliances	10.7	9.9	10.5	9.5	9.4	9.7	9.5	10.3	11.7	10.9	1.9%
Lighting	3.1	2.9	3.1	2.7	2.8	2.9	2.9	3.2	3.6	3.5	12.9%
Space Cooling	0.3	0.5	0.2	0.3	0.3	0.4	0.3	0.4	0.6	0.6	100.0%
GHG Intensity (tonne/TJ)	53.2	52	52.9	50.4	49.5	50.2	49.9	51.6	53.9	52.5	-1.3%
Total GHG Emissions Excluding Electricity (Mt)	**43.4**	**41.8**	**42.9**	**45.1**	**45.8**	**44.4**	**49.1**	**45.7**	**40.5**	**42.4**	**-2.3%**
GHG Emissions by End-Use (Mt)											
Space Heating	34.3	32.9	33.9	35.4	35.7	34.6	38.4	35.3	30.3	32	-6.7%
Water Heating	8.9	8.7	8.9	9.5	9.9	9.6	10.4	10.2	10	10.2	14.6%
Appliances	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0%
Lighting	0	0	0	0	0	0	0	0	0	0	–
Space Cooling	0	0	0	0	0	0	0	0	0	0	–
GHG Intensity (tonne/TJ)	33.1	32.5	32.6	33	32.8	32.6	33.6	32.8	31.6	31.9	-3.6%

Table 1.4: Residential energy use and GHG emissions by fuel type and end-use

(After Natural Resources Canada 2002)

1.3.3. "CHOICES" OF BUILDING SYSTEMS FOR ENVIRONMENT AND DEVELOPMENT

To a certain degree, the application of new homebuilding technologies affects the major factors, such as cost, quality and time, which homebuilders normally consider when generating housing projects (Lee 1996:15). In 2001, the author surveyed 12 industrialised building systems that are available on the North American market. The systems selected, whose base material is concrete, were analysed in terms of the technical performance including thermal resistance, water-resistance, sound transmission and fire-resistance, as well as the ease of assembly, durability, adaptability to local conditions, product cost, and construction time. Moreover, the systems surveyed were classified into seven systems: stabilised-earth interlocking block, insulated wood-cement block, Expanded Polystyrene (EPS) insulated concrete form, Poly Vinyl Chloride (PVC) block concrete form, PVC extrusion concrete form, cement-base insulated sandwich panel, and EPS insulation core composite concrete panel. Each product has its own strengths and weaknesses. For instance, PVC block concrete forms (including rigid insulation that easily achieves R-22) may perform better, in terms of water and thermal resistance, when compared with insulating wood-cement blocks. However, wood-cement blocks, which achieve as much R-value as walls composed of 2X6 wood studs with fibreglass batt (i.e. R-20), are made from 85% recycled waste wood and 15% Portland cement, thus, responding well to environmental demands for use of resource-saving materials and energy-efficient building systems. This example shows that the selection of a building system applied to housing development has to be carefully made based on the homebuilder's own requirements for the project and that such 'choices' should be made with due consideration given to environmental impact and sustainable development (Friedman and Noguchi 2001:52).

1.3.3.1. INDUSTRIALISED BUILDING SYSTEMS

Industrialised building systems, which affect the characteristics of housing, can be classified into two general types: product-oriented and process-oriented. The former type includes industrialised building systems using innovative building products (structural parts and components) to build a house at the construction site in accordance with the company's technical specifications—e.g. all of the aforementioned industrialised building systems and OSB Structural Insulated Panels (SIP). The latter type includes the industrialised systems that basically use conventional materials and methods (i.e. in Canada, wood and light-frame construction methods). However, an industrialised process-oriented construction process differs from conventional processes to the extent that most of the housing components are pre-cut and/or pre-assembled in a factory. This type of industrialised homebuilding systems can be referred to as "factory-built housing," and includes pre-engineered, panellised, modular and manufactured (mobile) homes (CMHI 2002). According to the CMHI's definitions, a "pre-engineered home" implies a house composed of a package of materials that are factory-cut to design specifications, with the pre-cut materials transported to the building site for assembly. In general, the major prefabricated building components include framing materials, doors, windows, roofing, siding, interior wall partitions and sub-flooring. A "panellised home" is a home comprising wall panels that are either "closed" or "open" [4] and the panels are shipped to the building site for assembly. Panellised homes are designed and built to the CSA Standard A277, as well as to the National Building Code of Canada (NBCC) or the mandated provincial code requirements (CSA International 2001:6). As well, a "modular home" is a factory-built home that is designed and built to the CSA Standard A277 and the NBCC or the mandated provincial code requirements (CSA

[4] A "closed" panel is a complete set of a factory-built wall panels in which windows, doors and siding are already installed, while a "open" panel is a wall panel in which only studs and plates are nailed together and sheathing may be attached to one side (CMHI 2002).

International 2001:6). Modular homes are typically shipped to the building site in two or more sections, and may or may not have a longitudinal frame. Today, a "mobile home" is called a "manufactured home" and is built to the CSA Standard Z240 (CSA International 2001:2). Manufactured homes may be constructed in one or more sections and are complete when leaving the factory except for incidental assembly on site. In addition, manufactured homes are typically built with an integrated frame that allows them to be placed on a surface-mount foundation.

Factory-built housing can be built to the R-2000 Standard, known as one of the highest standards for energy performance in Canada and developed by Natural Resources Canada in partnership with the Canadian Home Builder's Association (CHBA).[5] Because of their process-oriented nature, a renewable primary resource, such as wood, can be fully used for the structural frames of factory-built housing, in which conventional light-frame construction methods that most homebuilders are familiar with are usually applied. Furthermore, the system may require no special or technical effort for renovation of the house after the occupancy, and the tools and materials that are needed for the improvement of conventional site-built housing are applicable. Thus, in comparison with the product-oriented industrialised building systems whose construction methods usually differ from the conventional, the process-oriented industrialised building systems (i.e. factory-built housing) may be more applicable to housing developments in which wood light-frame construction methods, that all housing participants including builders and buyers *know* about, are preferred.

In much of the literature, the advantages of factory-built housing are said to be the lower and more predicable cost, better and more standardised quality, and faster and more punctual construction, when compared with those of site-built housing (Table 1.5).

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[5] In collaboration with CMHC, CHBA also developed affordable, energy-efficient housing called the "Charlie House" and this home was built to the R-2000 Standard in order to demonstrate affordability, adaptability and energy efficiency (CMHC 1991a:30).

POINT OF COMPARISON	SITE-BUILT HOUSING	FACTORY-BUILT HOUSING			
		Pre-engineered	Panellised	Modular	Manufactured
Relative cost per square foot	Highest	High	Intermediate	Low	Lowest
Ability to forecast costs	Low	Low	Moderate	High	Highest
Speed of completion	Slowest	Slow	Some speed in basic structure	Faster	Fastest
Design flexibility	Unlimited	Slightly limited	High	Moderate	Low
Degree of delivered completeness	None	Slight	Moderate	Very	Most complete
Exposure to site hazard	Complete	Very high	Some	Low	Minimal

Table 1.5: Comparison of site-built and factory-built construction methods

(After Hullibarger 2001)

As with site-built housing, the minimum levels of quality and functionality of factory-built housing, regarding the occupant's health and safety, are ensured by the NBCC. In addition, product quality can be further maintained by the CSA Standards, within which the manufacturers are certified to meet the following requirements:

1. Plant quality programme: to ensure that the quality programme and design procedures provide for compliance of the products with applicable technical requirements on a continuing basis;
2. Product: to ensure that the in-plant construction of the product complies with the applicable technical requirements (CSA International 2001:2).

This quality programme, which covers the CSA Standard A277 and Z240, may make factory-built housing more reliable than site-built housing.

In contrast, the quality of site-built housing is more open to question. The house under construction can be rained on, with uncovered lumber, plywood, insulation and other susceptible materials being soaked or blown around during bad weather. Such on-site nuisances naturally degrade the quality of site-built housing. In addition, site-debris piles from packaging, wrapping paper and material scraps, present builders and their insurers with additional worries because of potential liability due to injury in case people, especially children, are injured while exploring or playing on, or near, partially built homes (Hullibarger 2001:12). Theft and vandalism at the building site must be also taken into consideration, because building materials are normally left on-site overnight. Damage or loss of building materials from malicious acts, as well as bad weather is inherent in site-built construction. Hullibarger (2001:12) suggests that the application of industrialised building systems could help reduce or eliminate some of these site nuisances affecting construction cost, quality and time— which, in turn, would also contribute to a reduction of waste and other negative impacts on the environment.[6]

1.3.3.2. THE LEVEL OF INFLUENCE AND VALUE MANAGEMENT

Industrialised building systems can be applied to housing development, only if homebuilders, who generate and supervise the project, prefer their use to more traditional site-built construction. Such decisions are the result of a process consisting of a series of actions and choices over time, through which homebuilders evaluate the new system and decide whether or not to incorporate it into ongoing practice (Rogers 1983:163). This process, which is carried out by an organisation rather than an individual, has to deal with the uncertainty that is involved in deciding about a new alternative to those construction processes that the organisation has previous experience with.

The selection of a building system determines, to some degree, the characteristics of housing

[6] In fact, these advantages were drastically demonstrated at the 1996 NAHB International Builders Show, in which two identical 2,600 sq. ft. houses were constructed—one using panellised construction and the other site built. The results revealed that panellised housing showed a 16% saving in labour and material costs, and used approximately 25% less wood fibre. As well, the shorter construction time enabled homebuilders to complete a house faster; thus, it results in savings on interest and financial costs.

and its production process. Therefore, the selection should be made carefully, in the early phases of a housing project because the choice will greatly influence project costs to which most homebuilders are highly sensitive. Normally, based on the cost estimate, they will proceed with interim (and permanent) financing[7] that is dependent to some degree, on the construction time. This "level-of-influence" concept, describing the interrelationship between the level of management and costs over the life of a project, has been well understood in the construction industry for many years (Barrie and Paulson 1992:177) (Fig. 1.4).

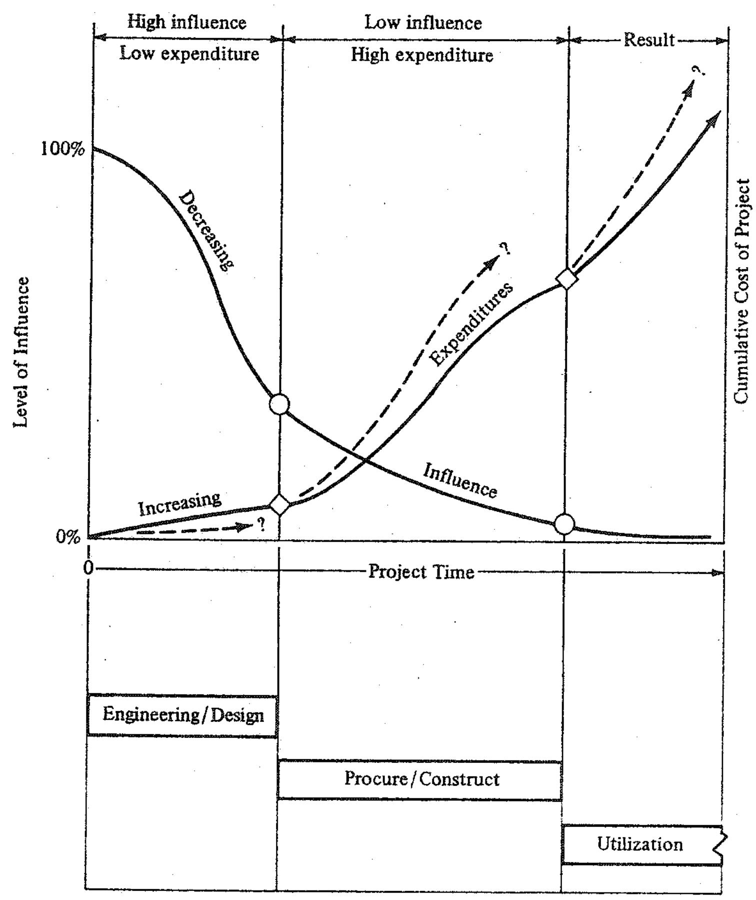

Figure 1.4: Level of influence on project costs

(Source: Barrie and Paulson 1992)

7 Interim financing is also called "bridge" financing and is short-term, one to two years. On the other hand, permanent financing is long-term, five to twenty five years, and typically takes the form of mortgages extended through a mortgage company—in general, 75% of the project costs can be loaned (Sternthal 1993:25).

The lower portion simplifies the life of a project to a three-activity bar chart consisting of: (a) engineering and design, (b) procurement and construction; and (c) utilisation or operation. The upper portion plots two main curves. The curve descending from the left-hand ordinate shows the decreasing level of influence of decisions being made, whereas the ascending curve indicates increased expenditures. This chart indicates that although actual expenditures during the early phase of a construction project (i.e. primary and detail design stages) are comparatively small, decisions and commitments made during this period have far greater influence on what later expenditures will be (Barrie and Paulson 1992:179). The bar chart and both curves are plotted against the same horizontal abscissa: project time.

To facilitate design choices regarding building materials and systems, *value engineering*[8] is one of the readily available, rational value management techniques that could be practised in the early phase of a construction project. Also, it is said that value analysis in design and construction helps realise potential savings of 1 to 3% on total budget, 5 to 10% on large facilities and 15 to 20% on high-cost areas in a construction project (Barrie and Paulson 1992:355). Dell'Isola (1997:xxi), on the basis of a survey, identifies the most significant domains where the search for savings can be directed: the advance in technology (23%), excessive cost (22%), the questioning of specifications (18%), redesign cost (15%), change in user needs (12%), feedback from user (6%) and design deficiencies (4%).[9] This approach to value management emerged during World War II when shortages of critical resources necessitated changes in methods, materials, and traditional designs. After the war, the General Electric Company developed and implemented an organised value

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[8] *Value analysis* and *constructibility analysis* are generally considered to be similar to *value engineering*. Thus, for purpose of this study, these terms are used synonymously.

[9] An initial value-engineering program was conducted in 1965 by the United States Department of Defence to determine the sources of opportunity for value engineering. The purpose of this study was to obtain an indication of range and degree of application (of value engineering) from a sample of 415 successful value changes (Dell'Isola 1997: xx).

analysis program for the industry and this technique was soon adapted by several other companies and government agencies. Value analysis/engineering was defined as:

> "an organized, creative approach which has for its purpose the effective identification of unnecessary costs, i.e., costs which provide neither quality nor use nor life nor appearance nor customer features" (Barrie and Paulson 1992:355).

Furthermore, Dell'Isola (1997:xix) emphases the potential value engineering techniques, explaining that the techniques "...can be used to achieve a number of objectives. They can save money; reduce time; and improve quality, reliability, maintainability, and performance." In addition, according to him, *value* is a result of combined elements such as function, quality and cost, and these elements can be interpreted by the following relationship:

VALUE = (FUNCTION + QUALITY) / COST

In this context, *function* implies the specific work that a design/ item must perform, while *quality* is the owner's, or user's needs, desires, and expectations. Finally, *cost* includes the life cycle cost of the product. Thus, *value* can be considered to be:

> "the most cost-effective way to reliably accomplish a function that will meet the user's needs, desires, and expectations" (Dell'Isola 1997: xix).

In practice, value engineering is an effective, systematic approach to design choices of building materials and systems that sequentially determine the characteristics of the building itself, as well as the construction process—which, in turn, influence environmental impact during construction and after the occupancy of the building. In fact, the value engineering approach has been receiving much attention from sectors of today's construction industry that attach importance to design and construction management in a project (Fig. 1.5). The application of value engineering techniques to project management is to help balance cost-quality-time trade-offs, in order to achieve the objectives and goals ascribed to a given project.

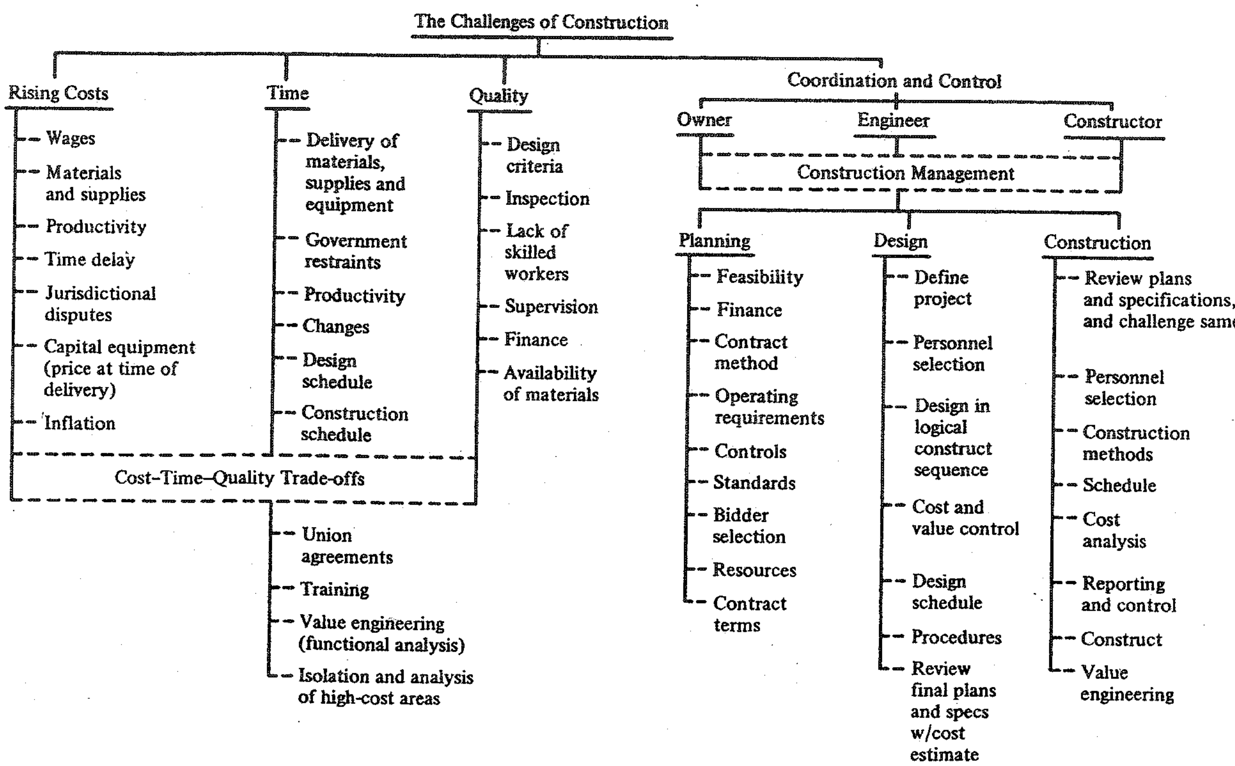

Figure 1.5: The challenges of construction

(Source: Barrie and Paulson 1992)

1.3.3.3. THE NATURE OF THE HOMEBUILDING INDUSTRY

There is, however, a tendency for homebuilders not to apply value-engineering techniques to managerial decision-making for design and construction systems. Typical homebuilding firms are small, consisting of fewer than five employees (Fig. 1.6). Furthermore, the majority of firms produce less than 100 homes per year. Sternthal (1993:27) indicates that the small size of these firms keeps their staff extremely busy and overworked.[10] Individuals within firms must oversee most matters related to the running of their business—i.e. administrative duties including the arrangement of financing, advertising, project management, office management and numerous other tasks (Fig. 1.7). As a result, the aggregate pressures of multi-tasking and of time-constraints present a significant barrier hindering homebuilders from adopting and implementing new ideas (e.g. value analysis in design and construction alternatives) in their business. As well, the nature of the homebuilding process, often referred to as *routines*, contributes to homebuilders rarely applying innovative construction technologies (i.e. industrialised building systems) (Sternthal 1993:27).

It is said that most homebuilders enter the industry with little knowledge of construction, but with a profound understanding of 'profit', and try to manage their businesses in more efficient ways by reducing overhead and by taking on most of the managerial responsibility (Sternthal 1993:39). As mentioned above, the homebuilders' activities quickly develop into *routines.* However, these routines have been streamlined to a point at which homebuilders achieve great 'efficiency' of their activities (Roberts 1970:36). 'Working drawings' are extremely simplified because craftsmen *know* how to carry out their task, based on traditional construction techniques. Housing 'specifications' are also brief, because the designers *know* that craftsmen know how to fit materials together (Davidson 2001, Roberts 1970:38). Furthermore, the nature of the homebuilding industry is characterised by the "closed system" mode of operation, characterised by highly stylised and simplified communication within the system (Fig. 1.8). On the other hand, communication between the system and its surrounding environment (e.g. introduction of industrialised building systems) is relatively complex and difficult, especially when the production and consumption cycle, based normally on *conventions*

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[10] 80% of the building firms have fewer than five fulltime employees in Quebec. The firms that produce 100 or more homes are considered to be large, and constitute only about 1% of the Canadian industry; however, their products cover almost 30% of new single detached houses built across the nation (Lee 1995:14).

that exist in the homebuilding industry, needs to be considerably modified (Roberts 1970:38). Thus, the nature of the homebuilding industry must be taken into consideration when applying industrialised building systems that homebuilders are not familiar with to housing development.

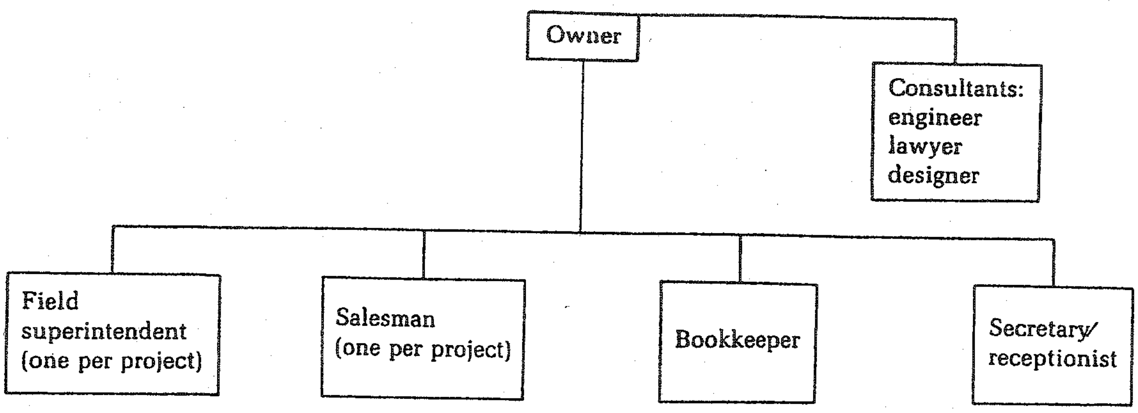

Figure 1.6: Organisational chart of a typical small homebuilding company

(Source: Eichler 1982)

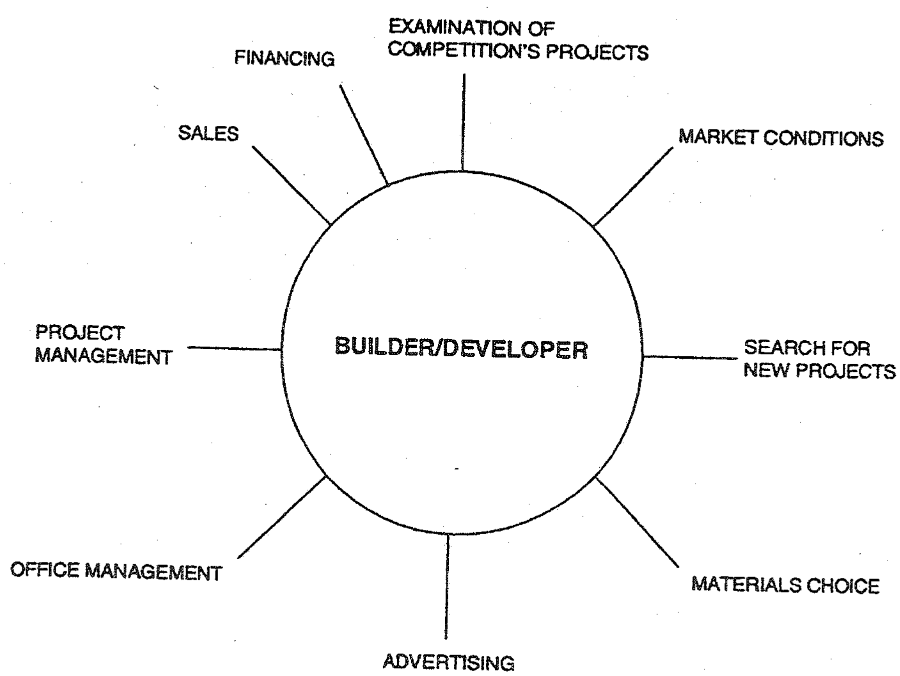

Figure 1.7: Homebuilder's administrative duties

(Source: Sternthal 1993)

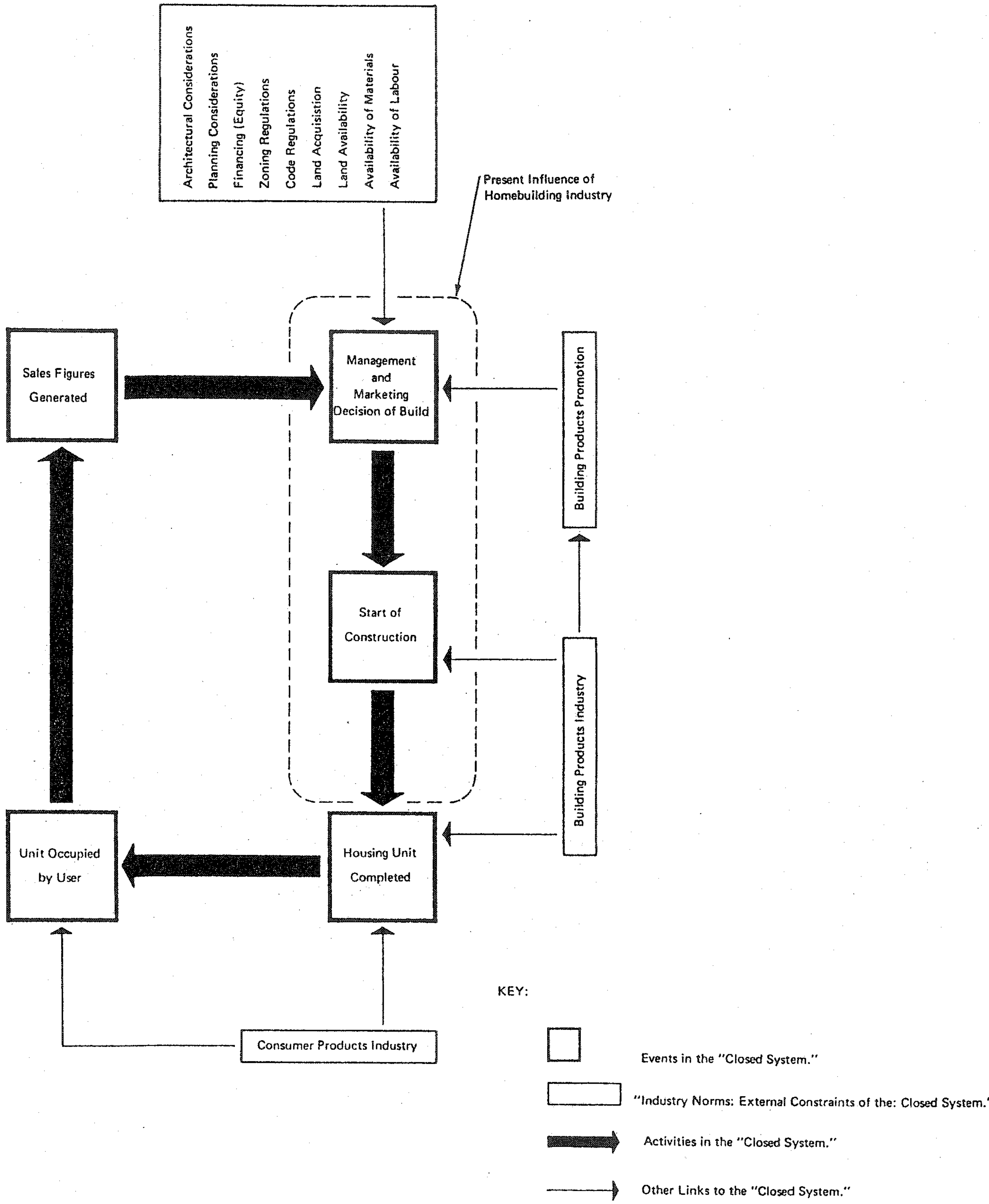

Figure 1.8: The "closed system" of decision-making events occurring in the conventional homebuilding industry

(Source: Roberts 1970)

1.3.3.4. THE PRIME MARKET OF FACTORY-BUILT HOUSING IN QUEBEC

In order to identify market trends of factory built housing, the author randomly selected thirty-eight housing manufacturers in Quebec, whose products can be classified into one of the following process-oriented industrialised systems: pre-engineering, panellised, modular, or manufactured. However, some manufacturers among them also produce products for different systems (Appendix A). The definitions of each type of factory-built homes have been given in section 1.2.3.1, above. According to this market survey of housing manufacturers, the majority of pre-engineered housing manufacturers regard both homebuyers and homebuilders equally as their prime customers. Five of nine pre-engineered manufacturers surveyed answered that over 50% of their total annual production are normally related to working with homebuilders. This tendency may also be seen in the results of panellised housing manufacturers, who market their products to both homebuyers and homebuilders. Of those, nine of twenty-one panellised manufacturers surveyed answered that over 50% of their total annual production are derived from orders placed by homebuilders. With the exception of one company, all the modular housing manufacturers contacted still sell the majority of their products to homebuyers, rather than homebuilders, having opportunities to carry out a lot of infill housing developments, rather than subdivision developments. This tendency also extends to manufactured housing companies. Except for one company, the majority of the manufacturers regard private homebuyers as their prime customers (see Table 1.6).

These results appear to indicate that the higher the in-factory completeness of housing components of factory-built homes, the lower the marketability to homebuilders that normally generate and supervise mass housing development. Thus, the majority of modular and manufactured housing companies have fewer commercial transactions with homebuilders. These results also reflect some important facts. First, the application of factory-built homes, whose in-factory completeness of housing components is relatively high, may, to a considerable extent, affect the homebuilders' administrative duties—especially the organisational framework of design and construction. Second, such changes in project management yield a large number of uncertainties concerning construction cost, time and quality. Homebuilders normally have a better understanding of profit, than of construction technologies, as described in section 1.3.3.3. Thus, in practice, homebuilders are unlikely to venture to employ unfamiliar systems without being convinced that they represent a worthwhile investment of time and resources. Finally, there is a doubt that the value of industrialised building systems is actually understood by homebuilders who rarely conduct value analyses of design and construction alternatives.

In theory, modular and manufactured homes that achieve approximately 90% of in-factory completeness have a great potential to produce high-quality homes at moderate price with less waste, as described in section 1.3.3.1. In practice, pre-engineered and panellised systems, achieving approximately 40% of in-factory completeness, have already been accepted, to some extent, by today's homebuilders. These results suggest that homebuilders can apply some forms of factory-built homes to their mass housing developments; however, the impact of using unfamiliar industrialised systems on the cycle of the homebuilding industry must be taken into consideration. A value-engineering approach, which will be unveiled in Part II, may help homebuilders understand the value of industrialised building systems in comparison to conventional methods. Value methodology may facilitate the homebuilder's choice for a building system in order to produce homes that satisfy the wants and needs of individual consumers, as well as the society.

TYPE OF FACTORY-BUILT HOUSING	NUMBER OF COMPANIES SURVEYED	PRIME MARKET		
		Percentage of Annual Sales (%)	Homebuyers	Homebuilders
Pre-engineered	9	0	0	1
		1 – 25	4	3
		26 – 50	1	0
		51 – 75	0	2
		76 – 100	4	3
Panellised	21	0	2	2
		1 – 25	5	4
		26 – 50	7	6
		51 – 75	0	3
		76 – 100	7	6
Modular	20	0	1	12
		1 – 25	0	4
		26 – 50	1	3
		51 – 75	2	0
		76 – 100	16	1
Manufactured	8	0	1	3
		1 – 25	0	3
		26 – 50	0	1
		51 – 75	1	0
		76 – 100	6	1
TOTAL			58	58

Table 1.6: The prime market of factory-built housing in Quebec, June 2002

1.4. SUMMARY, HYPOTHESIS AND RESEARCH PROBLEMS

In 1987, the World Commission on Environment and Development (WCED)—commonly known as the Brundtland Commission—advocated *sustainable development*, and published a report entitled *Our Common Future*. As a result of this movement towards an ecology-centred development approach, and by putting forth a normative question of sustainability, the Brundtland Commission successfully garnered increased political attention. In 1999, the National Research Council revisited many issues addressed by the Brundtland Commission, and again laid a great deal of emphasis on recognising the interdependence of environmental, social and economic issues surrounding sustainable development. In the CMHC reports, D'Amour (1991:iii) also recognised that *sustainability* is a matter of concern in housing development that encompasses social, economic and environmental problems, to which the housing industry should seek solutions. Also, he suggested means of realising sustainable housing development, and explained the need for balancing differing perspectives regarding what entities should be sustained, and what entities should be developed, as well as a means of measuring the alternatives available from which to make a 'choice' (D'Amour 1992:14). In view of environmental macroeconomics, Daly (1991:19) proposed an "ends-means spectrum" in the 1970s, and indicated that standard macroeconomics concern only the relationship between intermediate means and ends that represent a production and consumption cycle isolated from considerations of the surrounding environment (natural capital). His "ends-means spectrum" helps us to understand the position of various sectors within the housing industry towards sustainable development—and the importance of giving thought to the notion of 'energy efficiency' and 'resource saving' in housing development.

In practice, building a house consumes large amounts of energy during the construction, and after occupancy. Moreover, there are tons of waste materials created in the process of housing development. Hullibarger (2001:12) suggested that less waste materials might be generated by in-factory production than by on-site construction, because of site nuisances such as bad weather, site disturbances, theft and vandalism. A review of the literature revealed that industrialisation of housing has a great *potential* to eliminate or reduce such site nuisances.

Based on the author's survey, industrialised building systems (available on the North American market) can be classified widely into two types: product-oriented and process-oriented. The product-oriented industrialised building systems include stabilised-earth interlocking blocks, insulated wood-cement blocks, EPS insulated concrete forms, PVC block concrete forms, PVC extrusion concrete forms, insulated sandwich panels, and EPS insulation core composite concrete panels. These systems often require special construction materials, tools and skills for the on-site assembly.

This implies that homebuilders may need to spend a great deal of time researching how to apply new systems of housing development, or expend resources by hiring a technical supervisor to oversee the manufactured aspects of construction.

According to the CSA standards, process-oriented industrialised building systems can be sub-categorised into four general types: pre-engineered, panellised, modular, and manufactured. CMHI (2002) defines these homes as "factory-built housing," however, these prefabricated homes can be finished using conventional construction methods with which most homebuilders are familiar. Structural elements of buildings manufactured using process-oriented systems are cut using computer systems in a factory, rather than at a building site, with most parts and components including doors, windows and cabinets, also being assembled in a factory. This in-factory production process results in greater product quality from improved quality assurance and from greater control over the amount of waste materials produced—which may be collected in designated bins within the factory in order to recycle them and further reduce waste.

However, as the author's market survey of housing manufacturers in Quebec shows, homebuilders tend not to apply industrialised building systems, whose in-factory completeness of the components is relatively high, to their housing projects. In particular, this tendency applies to modular and manufactured homes, whose in-factory completeness of housing components is estimated at approximately 90%. Unlike manufactured homes, modular homes comply with the same quality standards as the panellised system, which many homebuilders have already applied to their housing projects. In fact, 43% of panellised manufacturers surveyed stated that over 50% of their company's total annual production are usually related to housing projects generated by homebuilders.

This chapter introduced the importance of the "level of influence" and "value engineering" concepts. The level of influence concept indicates that value management, for instance, should be involved in the early phase of a project—implying that, on the first day, decisions by management have a great deal of influence over later project costs. Value engineering techniques function well as value management tools, facilitating homebuilders' decision-making processes for design choices, and for the selection of building systems. According to the level of influence concept, those choices, which a homebuilder must make in the early phase of a project, considerably affect the characteristics of the house itself, as well as its construction process. These, in turn, help determine the levels of 'energy efficiency' and 'resource savings'. However, there is reason to doubt that homebuilders exercise either significant foresight or managerial responsibility with regard to value analysis, when it comes to design and construction alternatives regarding sustainable development. It is known that the homebuilding industry operates according to *routines*, enabling homebuilders to work in very efficient ways. These routines are particularly beneficial in influencing communications between parties within a "closed system", in which craftsmen *know* how to carry out their tasks and designers also *know* that craftsmen know how to fit materials together (Davidson 2001, Roberts 1970:37). As well, it was shown that most homebuilders have a more profound understanding of *profit*, than of construction technologies (Sternthal 1993:37). In short, the homebuilders operational system can be characterised as highly efficient, slow to change, and as allowing risk to be significantly minimised.

In order to tackle the social, economic and environment problems surrounding today's housing development, this study focuses not only on microeconomic issues within the production and consumption cycle at the level of consumer and industrial marketing, but also on environmental issues related to sustainable development. Thus, this study takes *sustainable housing development* into consideration, taking a view that includes environmental macroeconomics reflecting the needs and wants of individuals, as well as of society.

1.4.1. HYPOTHESIS AND RESEARCH PROBLEMS

Sustainability in housing development will be considered as a normative question with which this study will concern. In order to answer this question, the author assumes as its hypothesis that the application of *industrialised homebuilding technologies* to housing development improves today's housing delivery process, which is currently based on *routines* that do little to help find solutions to the various problems associated with sustainable development. This hypothesis is in part based on the notion of an "ends-means spectrum," which suggests that technology is one means of transforming natural capital into human capital; thus, it plays an important rule in achieving sustainable development. The theoretical benefits of industrialised building systems have been previously articulated in the literature addressing this subject; however, in practice, few homebuilders consider such benefits to be part of their managerial responsibilities within the closed system mode of operation. Thus, they are reluctant to adopt industrialised building systems that may impact considerably on their administrative duties, which are currently based on conventions (Fig. 1.9). In particular, this tendency can be seen in modular and manufactured housing systems, whose in-factory completeness of the components is relatively high. Homebuilders have already partially accepted pre-engineered and panellised housing systems, which resulted in *minor* modifications of their production and consumption cycle, when the industrialisation technologies helped increase productivity (Fig. 1.10). Hypothetically, homebuilders could apply more advanced industrialised building systems to housing development, but only if the decision-making process for the selection of these systems is well programmed in advance, or readily available, and if the process makes no tremendous impact on their closed system mode of operation.

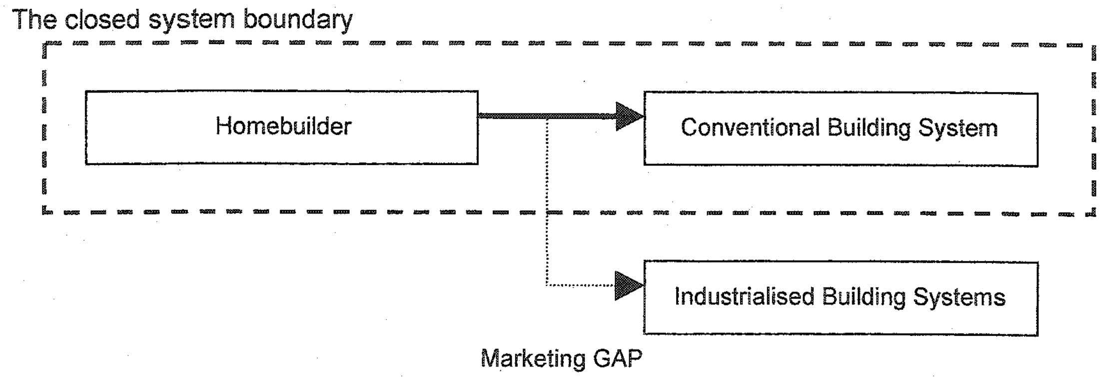

Figure 1.9: A homebuilder's choice for a building system within the closed system mode of operation

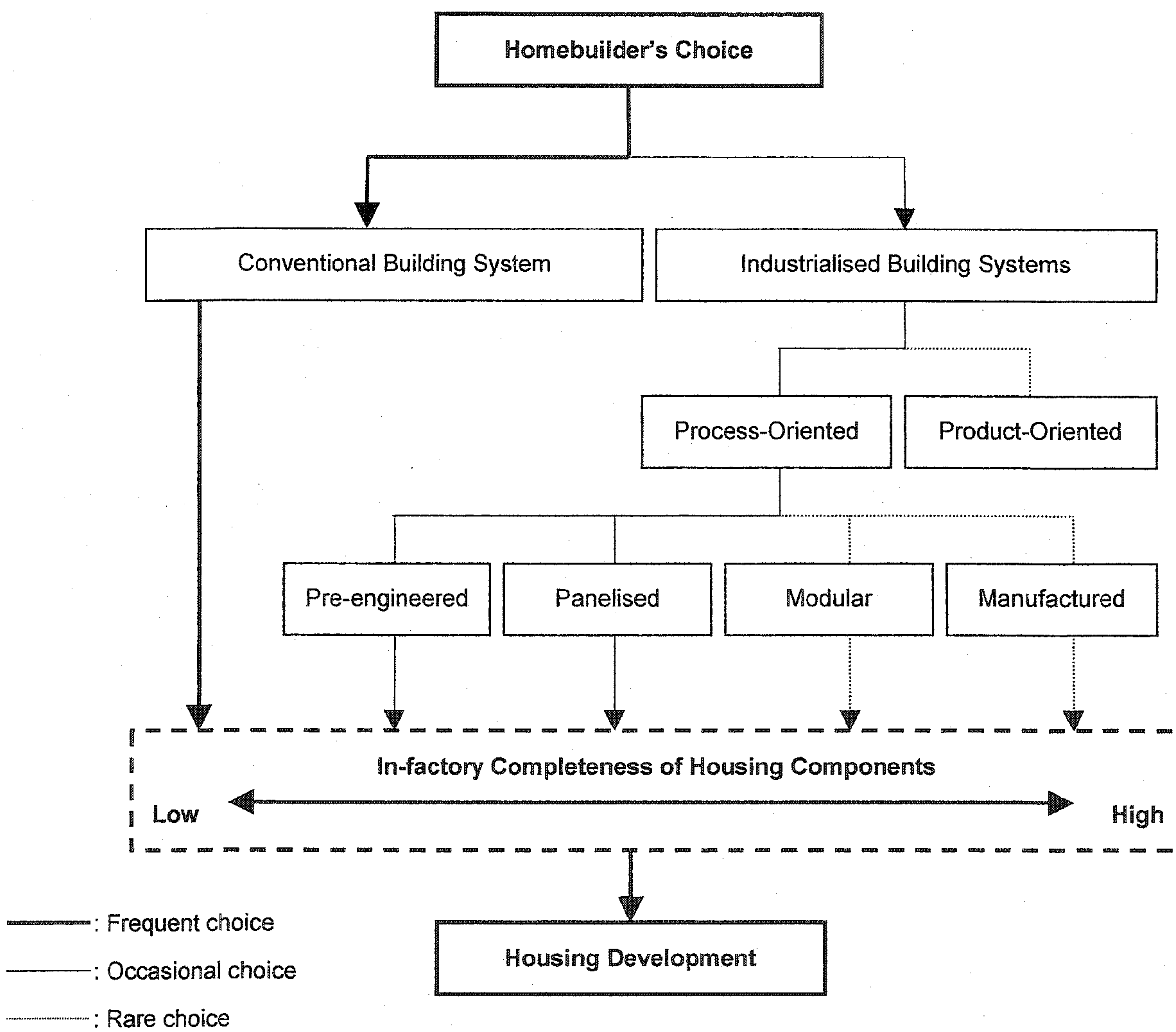

Figure 1.10: The homebuilder choices for building systems and the level of industrialisation

The selection of one or more building system(s) needs to be made in the early phases of a construction project, as it considerably affects the characteristics of the housing and its production process in balancing cost-quality-time trade-offs in the project. The trade-offs involved will, in turn, influence the environmental impact during construction, and after the occupancy. However, homebuilders, whose business is normally based on conventions and whose concerns are relatively short-term, are not likely to take a systematic value analysis approach to the selection of advanced building systems during the design stage. Thus, the absence of the homebuilder's ability to make reasoned *choices* regarding such systems in the early phase of a housing project may be considered a fundamental aspect of the normative question before us—*Industrialisation in housing development*.

The primary research problem for this study may be described as follows:

How can homebuilders in Quebec choose design and construction systems to generate more efficient (i.e. lower-cost & higher-performance) housing development that contributes to sustainability?

The design of housing, in principle, very much affects its marketability; thus, *design systems* need to be included in the research problem; so too some different approaches, such as speculative design, semi-custom design, and custom design—that is to say those approaches that are already applied by today's homebuilders. However, the design approaches need to be scrutinised in some detail; therefore, they will be addressed at length in Chapter 2. In this context, *construction systems* include industrialised building systems, as described in section 1.3.3.1. However, as our primary concern is with sustainable housing, many currently popular, but unsuitable construction systems will not be considered. In order to focus upon, and solve the primary research problem, this study instead aims to develop a **choice model** that homebuilders can use to select design and construction systems that help them generate sustainable housing development in Quebec.

1.5. RESEARCH OBJECTIVES

As has been stated, this study aims to develop a **choice model** that could help homebuilders decide upon the design and construction systems that will generate sustainable housing developments in Quebec. The proposed choice model will be directed mainly at reducing or eliminating the '**goal identification uncertainty**' and '**goal-purchase uncertainty**' often perceived by homebuilders in their selection of a new product (and service). In addition, risk reduction will be of great importance in establishing the new organisational framework between homebuilders and sub-trades. In this context, housing manufacturers will be regarded as sub-contractors.

The objectives of this study can be summarised as follows:

- Identify current market demands for housing
- Scrutinise the state-of-the art construction methods that help generate more efficient housing development that helps increase productivity and output
- Identify the housing configurations and development types that contribute to sustainability
- Investigate the design and production capability of today's homebuilders in Quebec
- Investigate the potential effects of a mass customisation approach on housing development
- Analyse the conceptual issues in the organisational decision making process
- Develop a new choice model that helps homebuilders determine the design and construction systems that generate more efficient housing development, which contributes to sustainability
- Examine the practicality of the proposed choice model by demonstration

1.6. CONTRIBUTIONS

'Organisational buying' is a complex process of decision-making and communication that involves obtaining information about specific products and services, evaluating alternative purchasing actions, and negotiating necessary arrangements with supply organisations. In sub-contracting, homebuilders need to establish new working relationships with other supply organisations—the choice of housing suppliers for their 'products' and/or 'services' is determined by the homebuilder's organisational buying behaviour.

The main contribution of this study is to propose a '**choice model**' that integrates the concept of *mass customisation* with the *value analysis* approach, in order to help homebuilders to produce '**lower-cost and higher-performance housing**' in response to issues of affordability and quality, which exist in the current Canadian homebuilding industry. In the proposed choice model, the concept of mass customisation is used for the generation of some alternatives that contribute to mass customising the end product (i.e. housing unit or development) while the value analysis approach is applied to support the homebuilders' decision-making for the selection of the given alternatives.

In this thesis, a specific housing type (or *configuration*) that helps meet today's societal demands for housing development that contributes to *sustainability* will be first introduced. Subsequently, the choice model itself will be developed, which encourages homebuilders to identify their project objectives for further application of *familiar* and *unfamiliar* housing systems (i.e. design and construction systems) applicable to their mass (or large-scale) housing development that is generally required to meet the wants and needs of homebuyers. Consequently, the choice model is aimed at aiding homebuilders to decide upon the housing systems, whilst also taking into consideration their *task*- and *non task*-related concerns.

In addition, this thesis also proposes a '**mass customisation system**' that attempts to enable Quebec homebuilders (and housing manufacturers) to apply a '**mass custom design**' approach, which is *new* in the Canadian housing industry of today, for the delivery of lower-cost and higher-performance homes (or *quality affordable homes*) that may meet today's diverse market demands for housing.

2.1. INTRODUCTION

This chapter aims to identify social, economic and environmental problems and opportunities encompassed by sustainable housing development. Social problems are examined in terms of demographic changes within Canadian society, with particular attention paid to the conspicuous emergence of non-traditional families, which are usually small in household size and unlikely to be affluent. The emergence of non-traditional families is relevant to contemporary housing demands in both the non-standard wants and needs of and the limited financial resources available to these non-traditional households. Accordingly, this chapter considers issues of housing affordability; especially, external economic factors influencing mortgage interest rates, and housing prices. These are analysed according to the 'time value of money' (or actualisation) concept in which the value of a given sum of money depends not only on the amount of money, but also when the funds are received. This chapter's focus on environmental issues is energy efficiency, which includes the necessity of saving resources in building and operating a house.

Based on a demographic analysis of Canadian society, the members of non-traditional households will be identified as a category of *prime potential homebuyers*—a target market to which homebuilders adapt their decision-making processes regarding design and construction systems in housing projects. Accordingly, today's housing demands will be discussed with due consideration given to those issues of particular importance to this demographic group, that is, *housing affordability* and *housing quality.* For this study, *housing quality* exclusively refers to 'design customisation' to meet the wants and needs of individuals and 'energy efficiency' to meet the wants and needs of society, while *housing affordability* is considered a decisive factor hindering an increase in homeownership rates. As a result of applying demographics to an analysis of housing market requirements, the author has found that '**quality affordable homes**' are, and will continue to be, in great demand. Additionally, this chapter will review some issues of housing design and production arising from the methods today's homebuilders apply. The chapter will conclude with a few propositions concerning types of housing development better suited to the delivery of quality affordable homes.

2.2. DEMOGRAPHIC PROFILES OF POTENTIAL HOMEBUYERS

Traditionally, Canadian society has relied on the *family*[1] to ensure its social growth and renewal. The family is the living environment of most of individuals, during most of their lifetime. Today, much of the economic activity of *men* and *women* focuses on generating the resources needed to support their family. The profile of a contemporary family's life cycle has become more complex than was the case in the past—men and women are less subject to the biological and social constraints of earlier times, and are now more likely to pursue a path of self-fulfilment (Péron et al. 1999:xxvii). Additionally, since the early 1960s, in response to social, economic, and technological changes, most Canadian couples have been having fewer children than was the case in previous generations; and so, the average household size has decreased from 3.7 in 1971, to 3.0 in 2001 (Statistics Canada 2002e). Technology has made highly effective methods of birth control available to couples. A variety of electrical appliances and conveniences, frozen food for instance, has made housework less demanding today than in the past. Together with rising levels of education, these factors have resulted in Canadians have both a greater desire, and greater opportunity, to pursue their individual goals. With greater personal autonomy, resulting from, or driven by, social and economic changes, there has been a de-institutionalisation of social roles. Closely related to this has been the emergence of a mass consumer society with its ability to generate new wants and needs, generating new aspirations and

[1] The terms *household* and *family* are often used interchangeably, and this confusion may derive from Canadian censuses in the distant past, in which *family* was the term used for *household* (Péron et al. 1999:1). Today, the *household* is used to describe a group of persons living together in the same dwelling, while the *family* designates a group of related persons belonging to or constituting the same household.

means of pursuing them; the growth of the women's liberation movement; increased participation in the labour market by women; and the secularisation, and waning, of religious values (Péron et al. 1999:xxvii).

Thirty years ago, marriage was very popular, and most couples married with the intention of starting a family of their own. With strong societal disapproval of divorce, most children were born to, and grew up with, legally married parents in a *nuclear family*; that is, a family consisting of a married couple and their offspring, living separate from the grandparents. Over the next three decades, Canadians' lifestyles changed drastically. Today, a large number of couples tend to live *common law*[2] before marrying, or have no intention of ever marrying—in 1996, 920,640 Canadian families (400,265 families in the Province of Quebec alone) were reported to be common-law couples (Statistics Canada 1999a:50). In addition, between 1951 and 1993, the total marriage rate per 1,000 Canadian singles decreased by 54% for males and 50% for females (Fig. 2.1). Many children are now born outside of marriage, while others' parents divorce while they were still very young (Péron et al. 1999:48).

The divorce rate per 10,000 marriages rose from 1,367, in 1969, to 3,763, in 1991 (Fig. 2.2). Values extrapolated from the total divorce rate since 1976 suggest that 30-40% of couples will divorce before their 26th wedding anniversary. Revisions of the *Divorce Act* in 1985, simplified divorce procedures, and reduced the minimum period of separation required for recognition of marital breakdown to one year. That legislation came into force in June 1986; in the months following, there was a significant rise in the number of divorces. After peaking at nearly 4,800 divorces per 10,000 marriages, in 1987, the total divorce rate settled back down to approximately 3,800 in 1990 and 1991. Most recently, Statistics Canada (2002f) reported in 2001, that 1,509,771 Canadians (641,734 males

[2] A *common law* relationship refers to a relationship in which a man and a woman live together for a certain period of time without legally marrying. Legally, common law relationships do not have the same status as marriages, and married partners have more rights and obligations than do common law partners.

and 868,037 females) had been divorced at some time, meaning that roughly one out of every twenty Canadians, or 4.9% of the national population of 31,081,887, have divorced. Péron (1999:48) indicates that contemporary Canadians face a "marriage crisis", and as a result, the proportion of births outside of marriage increased drastically from 11% in 1977 to 27% in 1991.

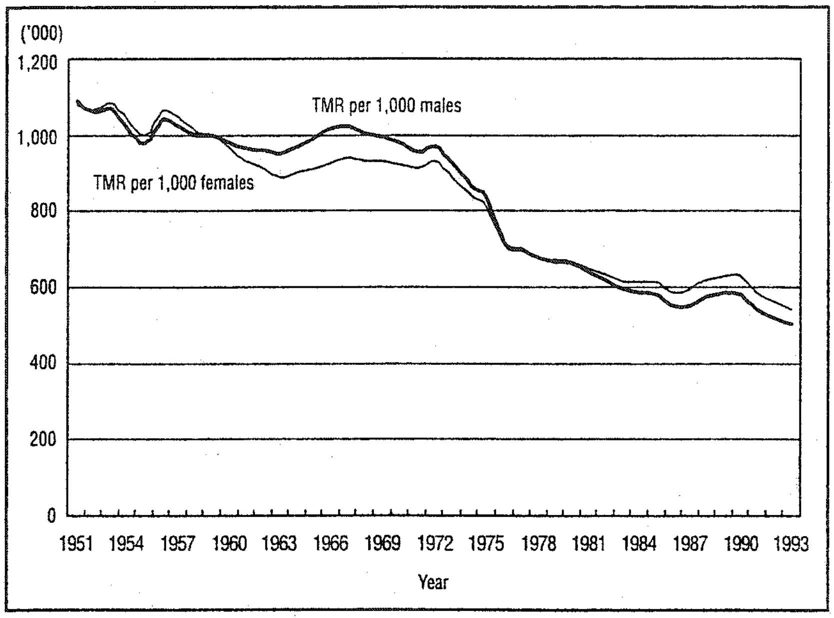

Figure 2.1: Total marriage rate, 1951 to 1993

(Source: Péron et al. 1999)

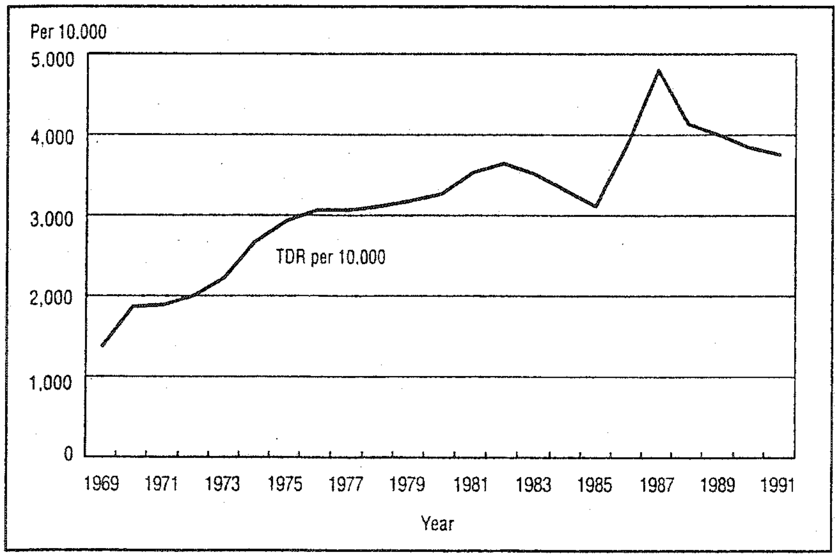

Figure 2.2: Total divorce rate, 1951 to 1993

(Source: Péron et al. 1999)

Furthermore, one of the most important features in the changing nature of Canadian families has been the rapid growth in *lone-parent families*[3] that resulted primarily from the break-up or dissolution of a marriage or common-law union, as well as never-married singles choosing to raise children on their own. Between 1971 and 1991, lone-parent families almost doubled from 477,525 to 954,710, while two-parent families increased only by 39.9% from 4,575,640 to 6,401,460 (Engeland et al. 1997:1). Most recently, Statistics Canada (1999a:50) reported that, in 1996, 1,137,510 Canadian families were lone-parent families, while 6,700,355 were two-parent families. Of lone-parent families, the vast majority (84%) have women as the household-head. This can be explained by the following reasons: first, 34% of lone-parents were divorced, and another 24% were separated, and mothers tended to retain custody of their children following a separation; and second, 18% of lone-parent mothers were never married (Engeland et al. 1997:6). Also, it is worth noting that, in general, female lone-parents tend to be younger, and support younger children, than their male counterparts (Table 2.1).

The term *census family* is used to describe "a group of at least two persons living together in a housekeeping unit, who are related and form a family unit." (Péron et al. 1999:24). It normally consists of a couple—married or common law—with never-married children or no children at all, or a lone parent and his or her never-married children. All other household members, and persons living alone, are regarded as *non-family persons*. According to Statistics Canada (2002g), between 1997 and 2001, the number of singles increased 4.9% from 12,726,339 to 13,344,138, while the number of married persons increased only 1.3% from 14,495,622 to 14,689,258.

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[3] A *lone-parent family* consists of a mother or father, with no spouse or common-law partner, living with one or more never married children (Engeland et al. 1997:1).

Age Group	LONE-PARENT FAMILIES					
	Total		With younger Children		With all children older than 17	
	Number	%	Number	%	Number	%
Total	727,290	100.0	458,340	100.0	268,950	100.0
15 to 24	38,150	5.4	39,120	8.5	30	0.0
25 to 34	158,040	21.7	157,795	34.4	245	0.1
35 to 44	223,495	30.7	196,185	42.8	27,310	10.2
45 to 54	137,430	18.9	57,645	12.6	79,785	29.7
55 to 64	79,000	10.9	6,745	1.5	72,255	26.9
65 and over	90,175	12.4	850	0.2	89,325	33.2
Male Lone Parents						
Total	109,805	100.0	59,110	100.0	50,695	100.0
15 to 24	580	0.5	575	1.0	5	0.0
25 to 34	10,350	9.4	10,265	17.4	85	0.2
35 to 44	34,935	31.8	30,510	51.6	4,425	8.7
45 to 54	31,615	28.8	14,710	24.9	16,905	33.3
55 to 64	16,100	14.7	2,630	4.4	13,470	26.6
65 and over	16,230	14.8	420	0.7	15,810	31.2
Female Lone Parents						
Total	617,490	100.0	399,240	100.0	218,250	100.0
15 to 24	38,575	6.2	38,545	9.7	30	0.0
25 to 34	147,695	23.9	147,525	37.0	160	0.1
35 to 44	188,560	30.5	165,670	41.5	22,890	10.5
45 to 54	105,815	17.1	42,935	10.8	62,880	28.8
55 to 64	62,905	10.2	4,125	1.0	58,780	26.9
65 and over	73950	12.0	435	0.1	73515	33.7

Table 2.1: Age distribution of lone parents, Canada, 1991 Census

(Source: Engeland et al. 1997)

Rare in the 1950s, today, many Canadians tend to stay single or live common law rather than legally marry—and the emergence of lone-parent families is tied to these changing demographic characteristics of Canadian society. With technological advances, and dwellings no longer existing as individual units isolated from the outside world but as cells connected to service and communication networks, living alone has become more feasible. In addition, the enhanced value of personal *autonomy* and *privacy* may have also played an important role in forming new Canadian lifestyles. According to Statistics Canada (2002h), the population in Canada will increase steadily from 31,002,200 in 2001 to 35,381,700 in 2021, and the proportion of young adults (currently, approximately 30% of the population), aged 20 to 40, will remain relatively steady, declining only slightly over the next 20 years (Table 2.2). This study, which focuses on new sustainable housing development rather than the resale market, regards these young adults as becoming prime potential homebuyers of new residential constructions built in the near future. It can be assumed that, due to their differing family situations, housing demands within this demographic group will be complex and irregular; thus, there is a potential demand for customised homes. However, in advance of discussing group specific requirements regarding *housing quality*, economic restraints, i.e. *housing affordability*, should be examined.

	NUMBER OF TOTAL POPULATION					
	2001		2011		2021	
	thousands	%	thousands	%	thousands	%
All ages	31,002.2	100	33,361.7	100	35,381.7	100
Under 4	1,715.9	6	1,666.4	5	1,734.8	5
5 to 9	2,026.6	7	1,715.8	5	1,783.6	5
10 to 14	2,076.6	7	1,863.6	6	1,815.7	5
15 to 19	2,081.0	7	2,175.0	7	1,873.0	5
20 to 24	2,097.0	7	2,241.4	7	2,034.7	6
25 to 29	2,100.3	7	2,263.5	7	2,355.7	7
30 to 34	2,252.5	7	2,293.0	7	2,430.7	7
35 to 39	2,641.7	9	2,278.1	7	2,431.9	7
40 to 44	2,659.1	9	2,370.3	7	2,411.5	7
45 to 49	2,384.9	8	2,681.7	8	2,341.4	7
50 to 54	2,114.7	7	2,637.4	8	2,370.2	7
55 to 59	1,625.9	5	2,318.3	7	2,611.6	7
60 to 64	1,291.1	4	2,011.3	6	2,516.3	7
65 to 69	1,137.8	4	1,495.8	4	2,140.4	6
70 to 74	1,012.0	3	1,112.7	3	1,745.7	5
75 to 79	815.2	3	879.7	3	1,181.6	3
80 to 84	525.7	2	666.2	2	756.8	2
85 to 89	295.2	1	422.5	1	472.5	1
90 and over	149.2	0	269.0	1	373.6	1

Table 2.2: The projections of Canadian population for 2001, 2011 and 2021, July 1

(Source: Statistics Canada 2002h)

2.3. HOUSING AFFORDABILITY

Housing is one of the most revealing indicators of a family's lifestyle, reflecting choices and constraints the family faces. There is a consistent connection between variations in income and housing conditions for different family types. Economic factors often discourage low- and middle-income households from aspiring to homeownership. The purpose of this section is to address the particular problems of housing affordability associated with variable interest rates, and housing prices influenced by economic fluctuations. As well, the effect of the mass production approach to delivery of affordable homes will be re-examined, in order to propose a new design/production approach to affordable housing.

Today, homeownership levels have remained fairly constant in Canada. In the year 2000, 64.2% of all dwellings were owner-occupied (Statistics Canada 2002i). For most Canadians, owning their own home is a lifelong dream, and affordability is one of their chief concerns regarding the housing industry (CMHC 2002a). Why do people wish to be homeowners? Is the quality of life of a homeowner necessarily better than that of a tenant? In outlining the advantages of homeownership, Carter (1990:15) places great emphasis upon the security of tenure, the accumulation of wealth, and greater control over the dwelling. For many households, these factors offset the disadvantages of owning a home, such as transaction fees, the risks of selling at a loss, or of being unable to make payments, and the costs associated with maintaining the dwelling (Péron et al. 1999: 274).

Securing tenure by ownership means that residents will not lose their homes due to unexpected economic changes, such as the loss of employment, or higher inflation and interest rates. Homeowners also need not fear a forced move, except in the unlikely event of expropriation. Tenants, meanwhile, at least, in some jurisdictions, can be legally evicted from their apartment unit if the landlord chooses to occupy, renovate, or demolish the unit (Carter 1990:16). Security becomes more important still when accommodation is scarce, as this may increase the search and rental costs of a decent apartment.

A second reason that people may wish to become homeowners is the role that homeownership plays in the accumulation of wealth. Owner-occupied homes reliably increase in value over time, making a house a sound financial investment (CMHC 2002b). For example, the land price of a new house built in 2001, increased by 3.7 % on the nationwide average, in comparison to that of 1992 (Statistics Canada 2002j). To some degree, such increases in land price contribute to increases in the resale price of owner-occupied homes. In addition, a mortgage-free home provides protection against economic devastation during the spells of unemployment, to which low-income households are often subject.[4] Importantly, homeowners also have control over which improvements are made to the dwelling, and their cost (CMHC 2002b). This is a powerful attraction for low- and middle-income households, whose members often feel they have little control over many aspects of their lives (Carter 1990:15).

The rate of homeownership rose slightly as the baby boomers came into the housing market in the past. For single-family households, the proportion of families owning their home rose from 68% in 1961 to 73% in 1991 (Fig. 2.3). Moreover, Canada Mortgage and Housing Corporation (CMHC) notes that housing in Canada's major urban centres was far more affordable in 1997 than it was in 1970 (CMHC1998a:5). In 1970, 23% (a national, weighted average) of 'prime buyers' (renters aged 20 to 40) could afford to buy a starter home—a level that soared to a record 40.5% by 1997 (Fig. 2.4).

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[4] A labour force survey conducted by Statistics Canada in 2002 indicates that employment rose by an estimated 76,000 in January, the first major increase in more than a year. The unemployment rate dipped 0.1 percentage to 7.9%. During 2001, job gains did not keep pace with population growth—the percentage of the population with work was 61.2% in January, well below the 61.6% posted in January 2001. Similarly, the unemployment rate was a full percentage point higher than in January 2001.

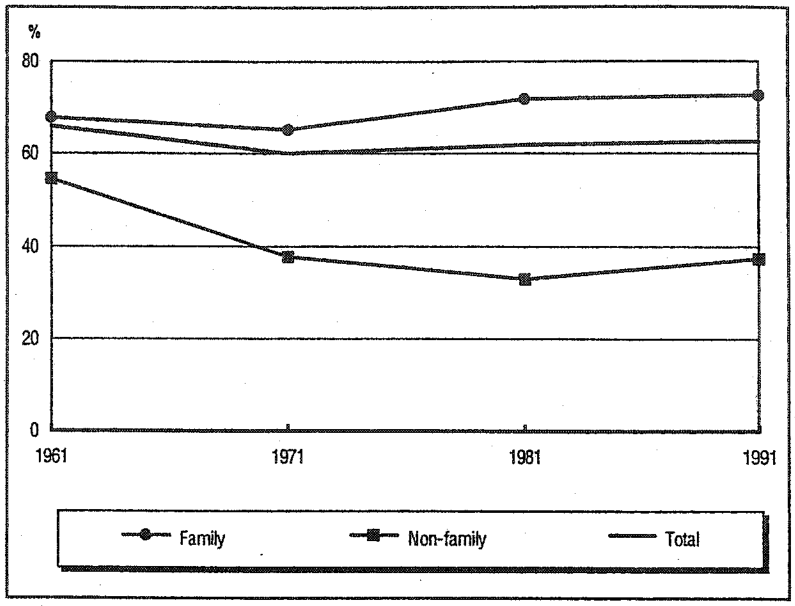

Figure 2.3: Proportion of owners by type of household between 1961 and 1991

(Source: Péron et al. 1999)

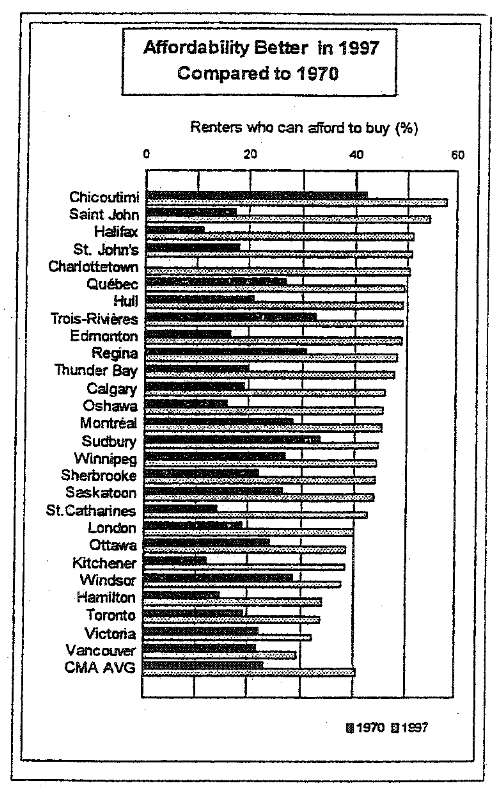

Figure 2.4: Renters who can afford to buy housing (%)

(Source: CMHC 1998a)

In comparison to the 1980s, people are now better educated and are earning higher salaries. Between 1986, and 1996, the number of individuals obtaining a bachelor's degree increased by 58%. In terms of salary, the average total income of an economic family (defined as a group of individuals sharing a common dwelling unit, who are related by blood, marriage including common-law relationships, or adoption) was estimated at $58,592 in 1996. In 1999, it was estimated at $63,818, corresponding to an increase of income by 8.9% (Statistics Canada 2002k). These statistics suggest that Canadian households are, on average, becoming wealthier (at least if inflation of the goods and services they purchase is neglected). Such economic and social factors have been assets in their becoming homeowners (CMHC 1998a).

Mortgage rates contribute to housing affordability; thus, an interest rate may be a critical factor in potential homebuyers' decision whether or not to purchase a home (CMHC 2002c). A mortgage is security for a loan on property that will be owned by the buyer, and is repaid in 'blended payments' composed of the principal and the interest. Mortgage rates normally vary in rate types, terms, and other options. For example, according to the Bank of Canada (2002), as of January 2002, the interest rate for a traditional 5-year mortgage is 7.0%, while the 1-year and 3-year rates are 4.55% and 6.05% respectively. The Bank of Montreal (2002a) offers the interest rate at 5.35% (fixed rate) for a one-year open mortgage and at 6.85% for a five-year closed mortgage.[5] Mortgage rates are usually subject to prevailing market interest rates, and are either fixed or variable.[6] Current mortgage rates are consistently lower than those of the early 1990s and this consistency may help more Canadians gain access to mortgage financing (Figs. 2.5 & 2.6).

[5] 'Open mortgage' implies that the borrower can repay the loan, in part or in full, at any time without any penalty. Interest rates are normally higher on this mortgage type. An open mortgage is attractive to homebuyers planning to sell their home in the near future. Most lenders allow them to convert it to a closed mortgage at any time. In contrast, a closed mortgage normally offers the lowest interest rate available. It is suitable for homebuyers who want to work their budget around a fixed rate for some years. Closed mortgages are not flexible and there are often penalties or restrictive conditions attached to prepayments or additional lump sum payments.

[6] A fixed rate is locked in so that it will not rise for the term of the mortgage, while a variable rate can fluctuate. The rate is set each month by the lender, based on the prevailing market rates.

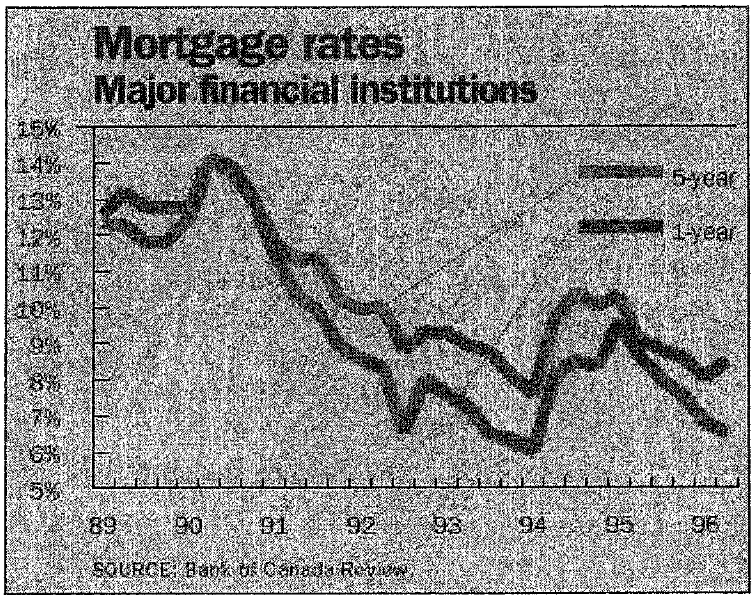

Figure 2.5: Mortgage rates between 1989 and 1996

(Source: CMHC 2002c)

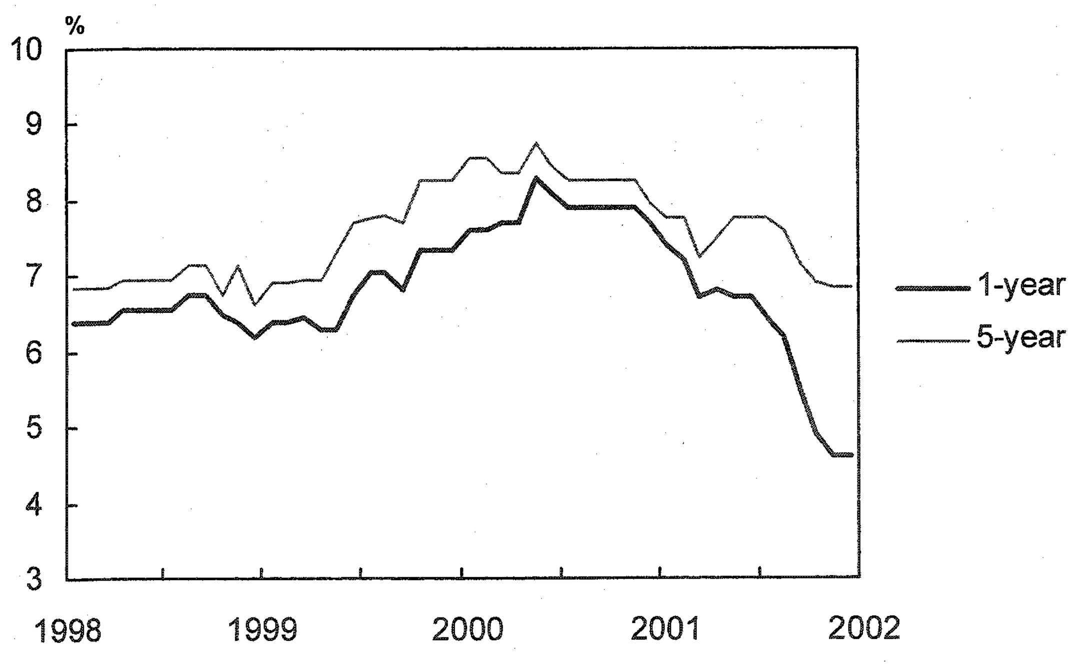

Figure 2.6: Mortgage rates between January 1998 and December 2001

(Source: Bank of Canada 2002)

2.3.1. HOUSING AFFORDABILITY PROBLEMS

Despite such favourable factors, there remain a large proportion of Canadian households (35.8%) who are renters. In Quebec alone, 43.4% of occupied private dwellings were reported to be rented, rather than owned, in 1996 (Statistics Canada 1999a:48). The low rate of homeownership in Quebec can barely be accounted by its largely urbanised population—78% of Quebeckers live in urban areas, a larger share than in any other province (Péron et al. 1999:275). This can be explained by cultural, political and economic factors. Cultural or social factors in part include demographic changes such as the emergence of non-traditional households (young singles living alone or with other singles, those who are separated, widowed, or living alone, and single-parent families), as described in section 2.2. In general, these groups are small families and are usually not very affluent (Péron et al. 1999:274). As well, these families are also living on fixed incomes (particularly in the case of the elderly) making economic considerations, already the greatest barrier to homeownership, a still greater factor.

Housing affordability has been defined as the maximum proportion of income that a household should spend on shelter. However, the recommended maximum has varied through time. Originally this maximum was estimated at 25%, based on underwriters' generally accepted maximum of one out of every four weeks' wages (CMHC 1991b:4). In 1986, this amount was altered when the CMHC and the provinces developed the 'core need' definition, which held that monthly rent should amount to no more than 30% of household income. Mortgage lenders normally apply two basic rules, in order to determine what a borrower can afford to pay per month in mortgage principal, interest, taxes, and heating expenses, or PITH (CMHC 2002d). The first rule is that the monthly housing costs should not exceed 32% of the borrower's gross monthly income, a sum that also includes, if applicable, half of all monthly condominium fees, and all of the annual site lease. The second rule is that the entire monthly household debt load should not exceed more than 40% of the borrower's gross monthly income. This includes both the mortgage debt and other debts, including car loans and credit cards.

Based on the 1991 Census of Population in Canada, lone-parent families are only half as likely as two-parent families to own their dwellings. Lone-parent homeowners tend to be either male or 55 years of age or older—66,220 or 60.3% of male lone-parent families. Homeownership falls outside the economic reach of most other lone parents—in particular, females and those with younger children. In fact, the ownership rate of them was reported to be 244,355 or 39.6% of female lone-parent families and 141,320 or 30.9% of lone-parent families with young children (Engeland et al. 1997:11). Furthermore, one out of every four (26.4% or 80,135) lone-parent dwelling owners pays 30% or more of their household income, while the renters find it twice as difficult as these owners to afford their housing without spending more than the norm. As a result, 219,710 or 53.2% of lone-parent renters spend 30% or more of income on shelter. Almost all (84.7% or 186,190) have incomes below Statistics Canada's Low Income thresholds (LICOs). The majority of these are female parents raising young children, whose average annual income amounts to only $9,953 (Table 2.3).

	ALL LONE PARENTS		MALE PARENT		FEMALE PARENT		WITH YOUNG CHILDREN	
	Number	%	Number	%	Number	%	Number	%
Total	727,300	100.0	109,805	100.0	617,495	100.0	456,800	100.0
Owners	310,575	42.7	66,220	60.3	244,355	39.6	141,320	30.9
Renters	414,710	57.0	43,105	39.3	371,605	60.2	315,480	69.1

Table 2.3: Lone-parent family households by tenure, 1991 Census
(Source: Engeland et al. 1997)

On the other hand, given their greater economic resources, young-couple families with no additional persons—a census family in which both spouses (married or common-law) are younger than 35—are more likely to own their home than lone-parent families. In fact, 56.9% of these couples were reported to be homeowners, and, unlike lone-parent families, young couples with children are likely to own their home (Engeland et al. 1997:22). In terms of housing affordability, 21.3% or 156,965 of young-couple family owners spend 30% or more of income on shelter; however, most of them are in a position to choose this economic situation. By contrast, young-couple family renters generally spend far less on shelter than the owners; however, 19.9% or 111,690 of the renters still spend more than 30% or more of income on shelter. One major reason why they need to spend more than today's norm can be explained by their lower income; in fact, 70% of those have low incomes, as measured by LICOs, and 17.3% or 47,755 are bringing up their children on incomes that averaged $ 13,090 in 1990. With such low-income levels, it is difficult to find adequate housing without spending in excess of the recommended maximum.

In addition, high transaction costs further discourage potential homebuyers. The purchase of a house typically includes 7% GST, [7] appraisal fees, property taxes, survey fees, property insurance, prepaid taxes or utility bills, land transfer tax, service charges, lawyer (notary) fees, mortgage loan, the mortgage broker's fee, moving costs, condominium fees, and a home inspection fee. Such high transaction costs are among the disadvantages of homeownership, and may make tenancy attractive for some households—"a major risk associated with homeownership is capital risk" (Carter 1990:19).

2.3.1.1. THE PROBLEM OF VARIABLE INTEREST RATES AND HOUSING PRICES

Additional affordability problems are caused by government regulations and production costs. The argument is often made that sophisticated servicing and building standards, as well as zoning regulations, rule out low- and modest-cost houses (such as mobile, modular or very small units) (Filion and Bunting 1990:17). During periods of high demand, the cost of both materials and labour rises. Workers take advantage of a tight labour market to press for even higher wages; likewise, developers and builders seek higher profits. In general, construction costs are greatly influenced by the length of time spent in on-site construction—the longer the time spent on-site during construction, the more the labour cost needs to be paid. Consequently, housing costs increase.

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[7] 7% GST is applied to new housing; however, there is a rebate, to a maximum of 2.5%, if the house costs less than $450,000. There is no GST on resale housing unless the house has been substantially renovated.

According to Roberts (1970:36), the development and construction costs of a conventional single-family dwelling can be classified generally into the following components: land development (25% of total costs), materials (36%), on-site labour (19%), overhead and profit (14%) and miscellaneous (6%). Materials and labour costs combined amount to 55% of the total, and are considered 'predominant' cost components. Construction costs are also composed of 'direct' and 'indirect' costs (Barrie and Paulson 1992:317). Direct costs are those that can be immediately associated with work directly contributing to the physical completion of the permanent facility contracted by the owner. Indirect costs are those that contribute to the support of a project as a whole, but cannot be identified directly with specific work items in the permanent facility.[8]

In addition, procurement and procurement-related activities occur during all phases of a construction project. Procurement usually includes purchasing of equipment, materials, supplies, labour, and services, as well as related activities: tracking and expediting, routing and shipment, materials and equipment handling, accountability and warehousing, final acceptance documentation, and ultimate disposal of surplus items at the end of jobs (Barrie and Paulson 1992:332).

Most costs related to procurement and its activities in a construction project are subject to economic fluctuations—particularly inflation. Inflation is defined as a persistent rise over time in the average price of goods and services (Bank of Canada 2002). This is measured with the Consumer Price Index (CPI), which reflects changes in the total price of a representative 'basket' of commodities such as housing, food, transportation, furniture, clothing, and recreation. During the last few decades, the average price of these items has risen consistently (Table 2.4). In 2002, consumers paid 19.0% more than they did in 1992, for the goods in the CPI basket (Statistics Canada 2003). As of January 2002, the all-items (excluding energy) index had risen 2.2% compared to January 2001 (Statistics Canada 2002l).

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[8] These are included in the prime accounts 00 and 01 of the *Masterformat*, which is a well-recognised breakdown of construction work, published by the Construction Specification Institute.

To a considerable extent, inflation also affects housing affordability during the standard mortgage design, as homebuyers may encounter the "tilt" phenomenon (Carter 1990:26). This occurs when rising income and inflation cause the mortgage payment to decline as a share of income over the term of the mortgage. For instance, suppose that a borrower's initial mortgage-payment-to-income ratio is 30%. If there is no inflation, this ratio remains the same over the life of the mortgage. If the rate of inflation is, say, 5% and income rises accordingly, the ratio will fall to 29% by the end of the first year and to 23% by the end of the fifth year.[9] In this case, inflation confers a large benefit to the borrower.

	All Items	**Change from Previous Year**	**Year**	**All Items**	**Change from Previous Year**	**Year**	**All Items**	**Change from Previous Year**
Year	1992= 100	%		1992= 100	%		1992= 100	%
1973	28.1	7.7	1983	69.1	5.8	1993	101.8	1.8
1974	31.1	10.7	1984	72.1	4.3	1994	102.0	0.2
1975	34.5	10.9	1985	75.0	4.0	1995	104.2	2.2
1976	37.1	7.5	1986	78.1	4.1	1996	105.9	1.6
1977	40.0	7.8	1987	81.5	4.4	1997	107.6	1.6
1978	43.6	9.0	1988	84.8	4.0	1998	108.6	0.9
1979	47.6	9.2	1989	89.0	5.0	1999	110.5	1.7
1980	52.4	10.1	1990	93.3	4.8	2000	113.5	2.7
1981	58.9	12.4	1991	98.5	5.6	2001	116.4	2.6
1982	65.3	10.9	1992	100.0	1.5	2002	119.0	2.2

Table 2.4: Percentage changes in consumer price index, 1972 – 2001

(Source: Statistics Canada 2003)

In fact, when inflation is anticipated, lenders demand a higher interest rate. They apply an inflationary premium that equals the expected rate of inflation, compensated for by the decline in the real value of the principal—"the nominal interest rate minus this inflationary premium is the real rate of

[9] The formula used, derived from Carter (1990:26), is $MR=M/\{I(1+i)^n\}$ in which MR is the mortgage-payment-to-income ratio, M is mortgage, I is the borrower's income, i is the rate of inflation, and n is the number of years of the amortisation term.

interest" (Carter 1990:26). Supposing that the real rate of interest is 7% and a homebuyer's annual income is $35,000, when the rate of inflation is 8%, the nominal interest rate will be 15%. Therefore, for a mortgage of $65,000, the annual payment over an amortisation period of 25 years will be $10,056, or 28% of income.[10] However, if the rate of inflation is zero, the annual payment will be only $5,578, or 15% of income. Given the mortgage lending rules outlined in 2.3.1, inflation can hinder potential homeowners from gaining access to mortgage financing.

A problem associated with inflation is the high variability of housing prices (Carter 1990:27). According to the new housing price index, Canadians paid 6.1% more for the purchase of a new house in 2001 than they did in 1992 (Statistics Canada 2002m). In Montreal, the increase was estimated at 13.8%. Borrowers are no longer secure in the knowledge that their mortgage payment is fixed for 25 or more years; instead, the rate may change considerably in five or fewer years. This implies that someone borrowing at 7% today on a five-year mortgage may face a much higher rate at renewal in 2008. It is well established that the housing industry relies much more heavily on the availability of credit than most other industries (Roberts 1970:36). In theory, 55% of the total land and construction costs of building a single-family house go to materials and labour (Table 2.5). However, in practice, 75% of the costs are actually related to financing, land cost, profit and overhead, and taxes—things that are considered to be external factors contributing to increasing housing prices under inflation. The developers and builders who initiate residential housing developments cannot control such external factors; they can, however, work towards reducing the cost of materials and labour by increasing their productivity and output.

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[10] The formula used, derived from White et al. (1998:55), is $A=P[(1+i)^n/\{(1+i)^n-1\}]$ in which A is the size of equal annual payments, P is the principal, i is the interest rate, and n is the number of years of the amortisation term.

	CONVENTIONAL SINGLE-FAMILY UNIT (%)
Land development	25
Materials	36
On-site labour	19
Overhead and profit	14
Miscellaneous	6
Total	100

Table 2.5: Rough breakdown of initial development and construction costs

(Source: Roberts 1970)

2.3.2. THE MASS PRODUCTION APPROACH TO AFFORDABLE HOMES

Homebuilders are responsive to housing market conditions, and so it should be expected that demands for affordable housing would stimulate homebuilders to undertake such projects. This section examines how a mass production approach to housing development can raise *productivity* in design and construction, by identifying the relationship between working hours and productivity—i.e. the "learning curve", so as to enable homebuilders to be responsive to market demands while maintaining profitability. To demonstrate this, one of the most successful mass housing developments in the North American history of housing will be discussed.

2.3.2.1. LEARNING CURVE

It is known that continually working on repetitive operations helps increase productivity (Barrie and Paulson 1992:225). This can be demonstrated by experimental data, which shows that within the 'learning curve' phenomena, there is a relationship between working hours and productivity (Fig. 2.7). The data attests to the fact that productivity improves with experience and practice. For estimating purposes, the learning curve should be integrated through the number of units to be constructed, defined as *n*. This is expressed graphically as the shaded area under the curve. The total number of worker-hours divided by the number of units gives the average worker-hours required per unit, shown as *w*. The learning curve shows that if the number of units is greater, shown as *n'*, the average worker-hours per unit should be less, shown as *w'*. This result indicates that a mass production approach helps increase productivity and output when the construction process is well standardised.

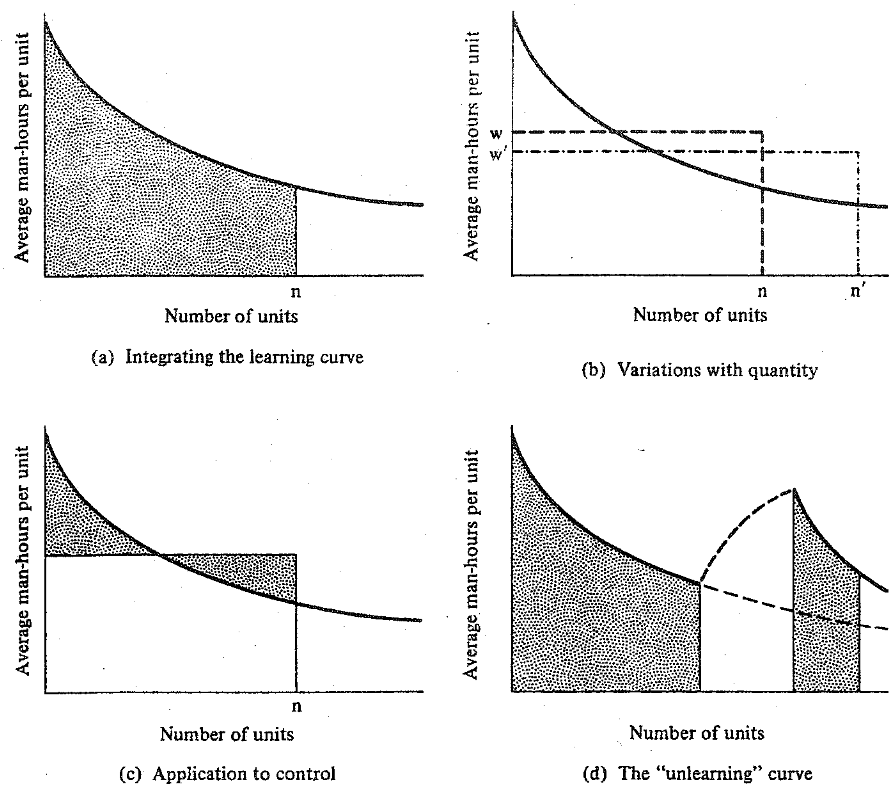


Figure 2.7: Learning curve relationship in estimating and control
(Source: Barrie and Paulson 1992)

2.3.2.2. MASS HOUSING DEVELOPMENT

Mass housing development—providing a large number of dwellings in a given area—is one of the most popular methods of building residential housing today. As a concept, it is quite old and was well known even in Roman times (Habraken 1972:7). After World War II, mass housing development became more popular than ever in North America; at the same time, houses were designed to be more compact and efficient. Innovative materials and construction techniques were used to maximise affordability and productivity of construction, while effective marketing strategies convinced people that mass-produced housing was the ideal. The popularity of mass housing led to the creation of communities made up of virtually identical, small, and low-cost houses (Friedman and Niessen 1991:28). The rate of homeownership increased accordingly, reaching 55% in 1950, 60% in 1957, and 66% in 1970. Most of the new houses "were built in suburbs, sprawling over the countryside near urban large cities" (Schoenauer 1994:27).

The Long Island development later known as Levittown, built by Abraham Levitt with his sons William and Alfred, may be considered one of the most successful mass housing projects of the post-war era. The Levitts greatly reduced construction costs by using mass-produced standard components, and assembling them on site in a conventional way. They provided three types of houses: a four-bedroom "Cape Cod" selling for $11,500; a three-bedroom one-story "Rancher" for $13,000; and a two-story "Colonial," with three or four bedrooms, costing $14,000 and $14,500 respectively. Each housing type was built in two alternative elevations, but with the same floor plan. Exterior colours were varied, in order to create variety in the facades (Gans 1967:7). However, due to the limited choice of models and colour options, Levittown also contributed towards creating an "instant suburbia" composed of homogeneous mass-produced homes for the homogeneous masses—all pre-planned and standardised (Schoenauer 1994:29).

Mass housing development yields *economies of scale*, and, because of the high-volume of construction, it functions as an effective means of reducing housing costs when components, as well as construction processes, are well standardised. The key factor enabling the *mass production* of housing is *standardisation*. Based on continually repeating the same operations, mass production is characterised by the principle of 'flow' that helps increase productivity and output, which, in turn, contributes towards lowering costs and prices. As the name suggests, *mass* production processes require economies of scale—"the greater its output, the lower its costs" (Pine II 1993:16). At the same time, *housing quality* may need to be taken into account, because today's consumers prefer custom-built, quality homes, to mass-produced, identical ones. In the following sections, issues of housing quality will be discussed. The effects of *standardisation* on housing design and production need to be examined in depth, and thus, they will be discussed in Chapter 4.

2.4. HOUSING QUALITY

In 1991, the CMHC published 'core housing need' indicators to measure a minimum level of housing services, based on *adequacy*, *suitability* and *affordability*. *Adequacy* concerned the integrity of major systems such as heating, ventilation, plumbing, and electrical, measured by the occupant's response to a question on the need for repairs. *Suitability* was measured by whether or not the bedrooms of a dwelling accorded with norms of size and composition, according to the National Occupancy Standard (NOS). Finally, *affordability* was measured by a comprehensive shelter-cost-to-income ratio, as outlined in section 2.3.1. These indicators help define fundamental housing needs and are considerably interrelated. Thus, the core housing need model, which has been used since 1986, identifies these three standards or norms against which a household's situation is assessed in a two-stage process. The first stage establishes whether or not the household in question falls below one or more of the standards, and the second stage examines whether or not households living below any of the three housing standards could afford adequate and suitable rental units in their market areas without expending 30% or more of their incomes (CMHC 1998b:11).

In terms of core housing need, the majority of households have affordability problems, as described in section 2.3. The second most frequently cited problem for people in core housing need relates to adequacy. In 1991, approximately 10% of all occupied dwellings, in Canada, were in need of major repair, though less than 1% lacked basic plumbing facilities; however, most of the occupants could afford to remedy these conditions by themselves (CMHC 1998b:12). CHMC (1998b:12) also reported that 10.7% of all homeowners were living below adequacy standards, while only 1.8% of all homeowners are actually in core housing need; and 10.0% of all renters were living below adequacy standards, while 3.5% were actually in core housing need (Table 2.6). Like most Canadians, the majority of lone-parent families live in dwellings in adequate condition. However, 11.6% (47,270 renters and 36,445 owners) reported that major repairs of plumbing and/or electrical systems in their dwellings were required (Engeland et al. 1997:12). Statistically, young-couple families are likely to be living in dwellings that are in better condition than lone-parent families; in fact, in 1991, only 8.6 % of young-couple families experienced adequacy problems. Nonetheless, 112,000 young couple families lived in dwellings in need of major repair, and the renters spending more than the norm for their shelter had the lowest average income (Engeland et al. 1997:23).

	STAGE 1: TOTAL HOUSEHOLDS BELOW STANDARDS		STAGE 2: HOUSEHOLDS IN CORE HOUSING NEED	
STANDARDS	Owners (%)	Renters (%)	Owners (%)	Renters (%)
Affordability	11.8	29.0	3.6	22.9
Adequacy	10.7	10.0	1.8	3.5
Suitability	3.8	7.9	0.3	2.7
One or more of above	24.1	41.3	5.1	24.9
Total in core housing need (households)			315,000	849,000

Table 2.6: Households living in housing below standards by tenure and core housing need, 1991 (Source: CMHC 1998b)

In 1991, the third, and least likely, source of core housing need was crowded living conditions, known as suitability problems. 3.8% of all owners were living below the suitability standard, while only 0.3% of all owners were actually in core housing need; and 7.9% of all renters were living below the suitability standard, while 2.7% of all renters were actually in core housing need. However, CMHC (1998b:13) indicates that the cases revealed by this indicator continues to diminish. According to the 1996 Census, the average number of persons per room was reported to be 0.4 in Canada (the same rate in the Province of Quebec), and the average number of bedrooms per dwelling was estimated at 2.6 (and 2.5 in Quebec). By contrast, the average household size, between 1971 and 2001, had also drastically been decreased, and was reported to be 3.0 in 2001, as described in section 2.2.

In short, these three indicators help define basic housing needs of Canadians, and the CMHC survey identified that very few households today live in crowded or inadequate housing; that having been said, 'affordability' still tends to be a significant problem—especially for renters. As well, these indicators are, in part, used for measuring the *quality of life* concern, which is also taken into account in sustainable development (Figs. 2.8 & 2.9). There has been a debate in the literature over the definition of quality of life; however, most definitions of it include some recognition of the concepts of "well-being", "happiness" or "satisfaction" (Maclaren 1996:26). Schwab (1992:184) provided an elaboration of this diverse notion as follows:

> "Quality of life is the difference between what should be and what is in a community – the difference between goal and appraisal states. Therefore...quality of life is defined as the measurement of the conditions of place; how these conditions are experienced and evaluated by individuals, and the relative importance of each of these to individuals."

This definition in some degree suggests an indirect association between the *quality of life* concern and *sustainability*—the idea of a desirable set of conditions resembles the forward-looking attribute of "inter-generational equity", which embraces the notion that the needs of future generation are as important as the needs of the current generation (Maclaren 1996:2).

In terms of the market *demand* for housing, today's consumers are no longer satisfied with minimal quality housing, which merely corresponds to *adequacy* and *suitability* problems. Housing choices are seen as major lifestyle and investment decisions (CMHC 2002a). Thus, a definition of *housing quality* may need to incorporate not only a home's function as a shelter, which meets the minimum levels of housing services, but also the design's adaptability, that is, the homebuilder's ability to *customise* plans to meet the individual requirements of today's diverse households. Furthermore, this study also focuses fundamentally on sustainable housing development; thus, environmental issues of housing design, as well as of housing development should be discussed—especially, the effect of *medium-density housing development* on sustainability.

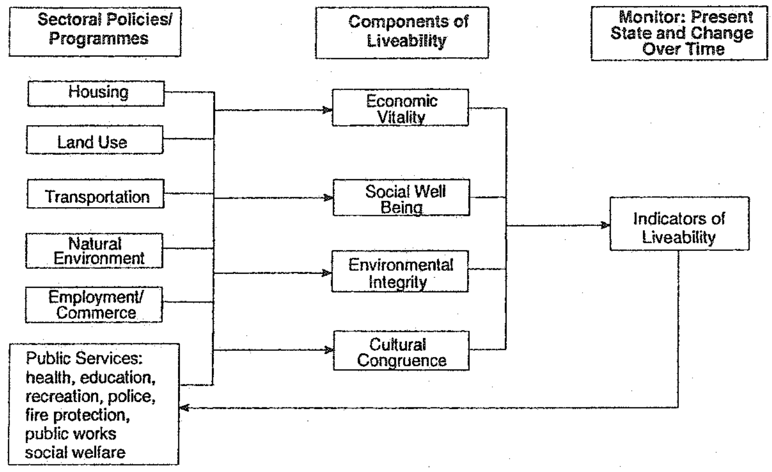


Figure 2.8: A community oriented model of the lived environment

(Source: Bates et al. 1996)

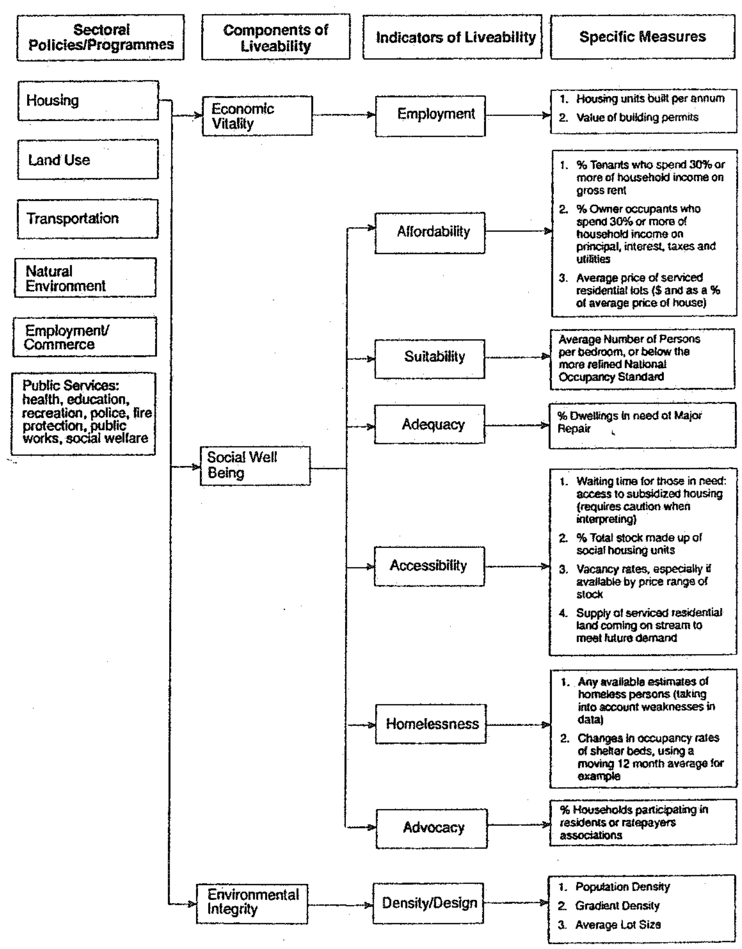


Figure 2.9: Indicators and specific measures of liveability: housing

(Source: Bates et al. 1996)

2.4.1. CUSTOMISATION

By the 1980s, the high quality of end products had become a requisite for market entry. The concept of quality had grown from *reliability*, popular in the 1970s, to the *individualisation* of products—thus, there is a tendency for today's consumers to prefer to purchase customised products (Anderson 1997:7). Also, it has been said that design and marketing are interconnected and often share the same objective: to develop the "right product, for the right market, at the right price" (Bruce 1997:6). However, these ends require different skills to achieve their objectives. In the competitive marketplace, homebuilders need to use cutting-edge marketing techniques to sell products. The housing industry has the same lifeblood as all businesses—customer satisfaction (CS). The successful homebuilders focus on customer features and benefits, identifies the target market and they may conduct some consumer research. In order to survive, homebuilders may now be required to create the value of their homes through consumer relationships and custom designs that meet the customer's individual requirements—tomorrow's sale will come from the reputation built with today's satisfied customer (Hutchings 1996:49).

Based on design approaches, today's homebuilders can be categorised into three general types: production, semi-custom and custom (Smith 1998:26&27). Production builders are organised for higher volume construction; thus, they develop several model homes, normally designed on a speculative basis, in response to the market demand. The ***production* (or *speculative) design*** approach allows homebuilders to produce a model home, in which the buyers can study the quality and attributes of their new home in a way that blueprints alone cannot achieve—thus, helping to assure the buyers' satisfaction. The advantages of speculative design also extend to reducing the elapsed time and cost of construction. The total time to build a standardised house is much shorter than for a one-of-a-kind design, because construction personnel are familiar with the plans. *Routines* allow for simplified communication between parties, and suppliers are able to stock regularly used items—thus, making material delays less likely to occur. Higher volume work, such as a subdivision housing development, also offers trade contractors advantages in scheduling that result in significant cost savings. *Economies of scale* can be achieved by the application of a speculative design approach to mass housing development; however, there is a danger of creating an instant community of monotonous, mass-produced homes, like the Long Island development or Levittown. In general, the available design choices (e.g. selection of floor coverings, tiles, countertops, light fixtures, cabinets, and exterior finishes) that the buyers can make to personalise their new home are very much limited. As well, the alteration of structural components that require reengineering and resubmission is not normally included among the design choices, because these expensive and time-consuming steps disrupt the momentum of high-volume construction (Smith 1998:26).

The builders, who apply the ***semi-custom design*** approach for their housing development, are often called semi-custom builders, and they combine characteristics of ready-built and custom-built homes. Like production builders, they usually work with pre-existing plans or ready-designed model homes; however, they are flexible regarding changes of the designs that even include those that require engineering and building department approval. As a result, even though the customers begin with an existing floor plan, many more opportunities exist for them to modify and customise the interior and exterior finishes, and structure (or volume) of their new home. Starting with an existing plan often helps customers feel confident of ending up with something that will reflect what they need and want. Smith (1998:27) indicates that revising existing plans is faster, and less costly, than creating a new set of blueprints. However, economies of large-volume work are lost, resulting in higher prices. When the construction of a home starts from unfamiliar plans, crews need more time.

Custom builders specialise in starting from a blank sheet of paper, or computer screen, to create a unique home according to the user's wants and needs. Some custom builders establish relationships with one or more independent architects for plan development, while, for others, the builder is also an architect, or has an architect or draftspersons on staff—these builders are called "design-build firms" (Smith 1998:27). Obviously, the ***custom design*** approach is the best solution to the customisation of a new home, and it helps create one-of-a-kind homes that correspond to the consumer's individual requirements for housing. However, custom-built homes typically take the longest to complete. As well, supervising scattered site work, which is combined with the longer time that is needed to build a new custom home, increases construction costs. In addition, because of the unique nature of each home, the economies of large-volume work are also lost; thus, it results in the higher prices of a new custom home (Smith 1998:28).

2.4.2. MEDIUM-DENSITY HOUSING DEVELOPMENT TOWARDS SUSTAINABILITY

To some degree, the development patterns of housing and community have a direct impact on Canada's economic, environmental, and social future. In general, since the 1950s, the Canadian image of an urban ideal has predominantly been of a detached dwelling in a low-density community; however, today's economic, environmental and social costs called the sustainability of such development patterns into question (Quadrangle Architects 2000:i). There are strong, positive correlations between the attributes of medium-density housing and current demographic social trends. For instance, although the number of households is increasing, households are becoming smaller. As well, household makeup is broadening from the traditional model of nuclear families—the marriage crisis that today's Canadians face also helps increase the diversity of household characteristics.

Medium-density housing development can be defined as residential developments with a range of 12 to 36 dwelling units per acre (30 to 90 units per hectare), while low-density housing developments contain about 6 dwelling units per acre (less than 15 units per hectare) (Quadrangle Architects 2000:i). Thus, the *townhouse* is considered as one of the most accepted forms in medium-density housing developments, and normally has a simple, rectangular plan with one to two storeys. The concept of a 'townhouse' has existed in the western society over a long period of time. Schoenauer (1994:69) profoundly suggested that:

> "The origins of town houses are to be found in fortified medieval cities where circumvolution restricted city areas and building lots had to be narrow."
>
> "Although town houses, too, are viable alternatives to detached and semi-detached houses, they were rarely used in suburban residential developments during the first decades of the postwar period."

Based on his categories of housing, townhouses can be referred to as row houses, in which several dwelling units are attached to each other in a row—thus, for purpose of this study, the terms such as *townhouse* and *row house* are used synonymously. Furthermore, the prototypes of townhouses, which are used with success in many countries, can be classified generally into four types: *single-storey*, *split-level*, *linked*, and *narrow-front* townhouses.

Because of the attached units, the *single-storey* townhouse has distinct features: with the elimination of two side yards, the cost of municipal service can be reduced; the shorter street frontage results in savings in the initial outlay for the building site; and the sharing of party walls reduces, to some degree, heating and cooling costs of the home (Schoenauer 1994:74).

Unlike the single-storey type, the *split-level* townhouse is no longer an attached version of its detached or semi-detached counterparts. It normally has sophisticated floor arrangements having a single storey front placed on the side of a narrow pedestrian path and a two-storey garden side on the private backyard.

The *linked* townhouse is closely related to other types of townhouse arrangements, and it can be designed to be single-storey, two-storey, and split-level dwellings—however, neighbouring units are attached only with the garages. The greatest benefit of this arrangement derives from the absence of traditional party walls, providing the occupants with the same acoustical privacy that detached dwellings achieve (Schoenauer 1994:75).

The *narrow-front* townhouse is the fourth attached dwelling prototype—the street frontage is about 12 to 18 feet. This dwelling type somewhat reflects two-bay wide townhouses built for artisans and industrial workers in the 19th century, and, today, it can be designed for low- to middle-income families—"A Canadian narrow-front town house concept was advanced in 1990 by Witold Rybczynski, Avi Friedman and Susan Ross. Called the "Grow Home," ...these stripped down versions of two-story row houses...were proposed to make them affordable to low- and moderate-income families." (Schoenauer 1994:78).

The notion of sustainable development is based on the conversion of natural resources, and there are several design factors inherent in townhouse development that help conserve resources by reducing the amount of building materials required, and by improving the thermal efficiency of the building envelope. In particular, the building configuration of a townhouse can be considered as one of the most effective factors in increasing the levels of energy efficiency and resource savings. The simple, rectangular plan normally applied to a townhouse ensures that there are fewer corners and windows,[11] which considerably increase energy consumption and construction costs (Figs. 2.10 & Table 2.7). Simple configurations generally require less cutting, and fitting, of building materials; thus, this results in reducing waste production (Friedman 2001:150).

Furthermore, joining units into groups of two or more can provide significant savings in both construction and energy. For instance, joining four detached units into semi-detached, reduces the wall area exposed to the outside climate by 36%, while grouping all four units as townhouses allows for an additional 50% savings to be achieved (Friedman 2001:155). Attaching two dwelling units provides a 21% reduction of heat-loss; when three or four dwelling units are joined as townhouses, a further 26% saving may be achieved (Fig. 2.11).

---

[11] Heat losses through the building envelope can occur through any of three mechanisms: conduction, convection and radiation. In all three cases, windows are the weakest link in the thermal performance of a building envelope, achieving only R-4 at maximum (Friedman 1993:1.6.1, Miguel 2002).

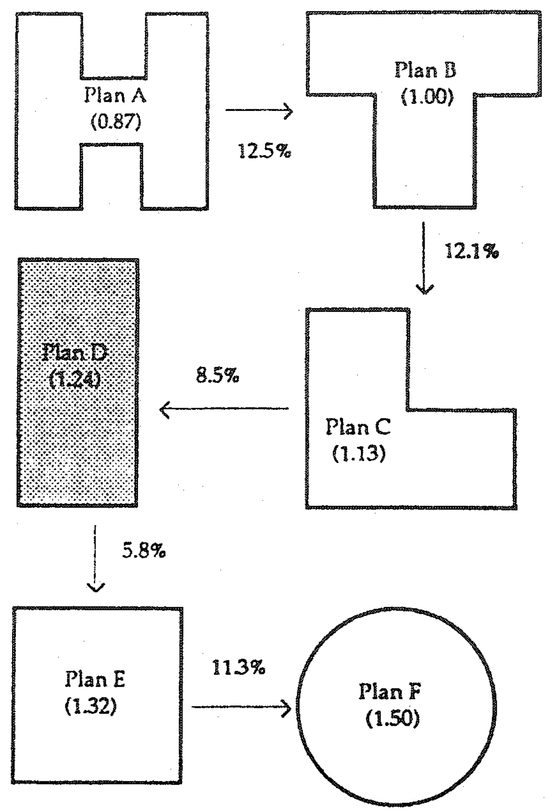


Figure 2.10: Effect of building configuration on ratio of floor area (100 m^2) to perimeter wall area

(Source: Friedman 2001)

Plan Configuration	Wall Area (m^2)	Energy Required (KWh)	Monthly Heating Cost ($)
Plan A (H)	160	2856	134
Plan B (T)	140	2501	117
Plan C (L)	123	2198	103
Plan D (rectangle)	112	2001	94
Plan E (square)	106	1894	89
Plan F (circle)	94	1679	79

Table 2.7: Effect of building configuration on energy consumption

(Source: Friedman 2001)

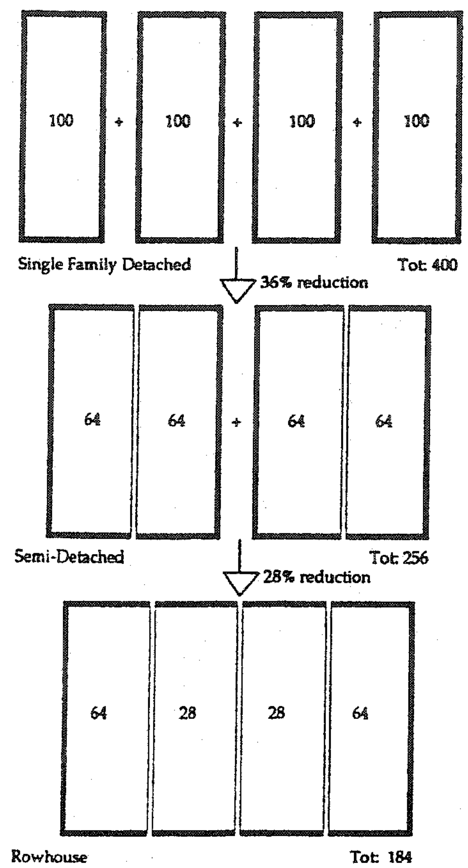


Figure 2.11: Effect of grouping on exposed wall area

(Source: Friedman 2001)

Thus, the medium-density housing development consisting of townhouses has the positive effect on achieving not only 'sustainability' but also 'affordability', because of its potential of high land-use efficiency that helps reduce construction costs. In particular, single-storey or narrow-front townhouses, which have simple, rectangular plans, can be considered as the most energy-efficient housing forms in comparison to split or linked townhouses, while they can be also built with less construction materials and time that, in turn, reduce construction costs. Thus, the medium-density housing, particularly single-storey or narrow-front townhouses, may be applicable to a mass housing development that yields *economies of scale*, when both *sustainability* and *affordability* in housing development are taken into account.

2.5. SUMMARY AND CONCLUSIONS

In Canada, the profile of contemporary households is more complex than in the past. Today, people are less subject to the biological and social constraints of early times, and tend to pursue self-fulfilment before social norms. In response to social and economic changes, non-traditional households, of fewer children, are becoming more conspicuous, but more fragmented. Typically, these households are relatively small in size, and are often not affluent. Thus, because of the imbalance between low-income and high-priced housing, people in these groups are unlikely to become homeowners. Based on demographic trends reflecting a *marriage crisis*, for this study, young adults, aged 20 to 40, of non-traditional household types, with diverse housing demands, should be considered **prime potential homebuyers**.

Since 1986, a 'core housing need' model, developed by CMHC, has been used for the measurement of minimum levels of housing services regarding *adequacy*, *suitability* and *affordability*. *Adequacy* problems concerned the integrity of major systems such as heating, ventilation, plumbing, and electrical, measured by the occupant's response to a question on the need for repairs. *Suitability* problems were measured by whether or not the bedrooms of a dwelling accorded with norms of size and composition based on the National Occupancy Standard (NOS). *Affordability* problems were measured by a comprehensive shelter-cost-to-income ratio. These indicators help define the fundamental housing needs of all Canadians. Today, housing suitability and adequacy are much improved, but many Canadians still face **housing affordability** issues related to economic problems. Furthermore, economic fluctuations, such as inflation, affect interest rates and housing prices, and have hindered an increase in rates of homeownership.

In theory, the development and construction costs of housing are composed of developed land, materials, on-site labour, overhead, and profits. In practice, a large portion of the costs is actually related to financing, land cost, profit, overhead, and taxes. These cost components, which are considered external factors, are susceptible to inflation that contributes to increasing housing prices.

Homebuilders, who initiate housing developments, cannot control these *external* factors. On the other hand, materials and labour costs are *internal* factors that homebuilders can control for the purpose of reducing housing costs, while increasing productivity and output. In order to increase productivity and output, **mass housing development** strategies, considered as one of the most effective means in producing affordable homes, might be applied, as was popular after World War II. According to the *learning curve* that represents the relationship between worker-hours and productivity, the continuity of work on repetitive operations helps increase productivity, while the standardisation of housing components, as well as of construction processes, is the key factor that enables mass production of housing. Post-war housing developments bear this out, but tend to create generic homes and an '**instant community**.'

On the other hand, today's consumers, whose requirements for housing are diverse, may no longer be satisfied with minimum levels of housing quality—i.e. adequacy and suitability. They often prefer customised products to monotonous ones (Ross 1998:42). Thus, homebuilders are facing a contradiction between consumer demands for *lower pricing* and *customisation*. In order to supply lower-priced '**custom homes**', homebuilders may need to develop strategies to overcome the contradictions and simultaneously implement *mass production* and *customisation*. Instead, today's homebuilders generally apply three design approaches to their homes—i.e. *speculative*, *semi-custom* and *custom*. However, none of them adequately address emerging market demands. The *speculative design* approach realises high-volume construction (i.e. mass production of housing) and homebuilders produce model houses, which are designed on a speculative basis, before actually selling the units. On the other hand, the *semi-custom design* approach is usually based on the modification of an exiting plan, while the *custom design* approach helps create one-of-a-kind homes. Thus, the semi-custom and custom design approaches, which correspond to the market demand for customisation of a new home, disrupt the momentum of high-volume construction that contributes towards reducing production costs. As a result, the two opposite concepts such as 'mass production' and 'customisation' are hardly integrated in the home design approaches applied by today's homebuilders. In other word, this situation can be considered as a *design-production gap* that necessitates developing a new design approach that will be discussed further in Chapter 4.

Furthermore, in response to environmental problems that today's society faces, the housing industry is also required to produce '**energy-efficient homes**', in which *resource savings* in construction is also of concern. Accordingly, a medium-density (*row*) housing development, which helps achieve higher levels of sustainability, was also presented. In addition, the application of single-storey or narrow-front townhouses that are often used for medium-density housing developments was considered as an effective means to produce such homes. Townhouses normally contain fewer corners and windows, as well as less area of exterior walls exposed to the outside climate, and these parts, for instance, drastically reduce the levels of heat loss, as stated in section 2.3.2. In order to meet needs and wants of individuals, as well as of society, a medium-density housing development, which is composed of townhouses that to some extent contribute to *sustainability*, should be integrated into a mass housing development that yields the economies of scale that affect housing *affordability*. Thus, for this study, a mass housing development should be re-defined as a medium-density housing development that consists of bungalow or narrow-front townhouses, in order to produce energy-efficient homes at a moderate price.

Accordingly, for this study, 'housing quality' will exclusively include 'design customisation' that meets the needs and wants of individuals, as well as 'energy efficiency' that meets some of society's needs. On the other hand, 'housing affordability' is still considered as a decisive factor in hindering an increase in rates of homeownership, while the emergence of non-traditional households, who are usually small in household size and are often not affluent, has become conspicuous in Canadian society. Thus, based on the demographic changes of society, *young adults* of these household types are considered as prime potential homebuyers. In short, '**quality affordable homes**' are in great potential demand in response to the market demands of today and tomorrow.

In addition, in order to understand the actual situation of today's mass housing development composed of townhouses, the interrelationship between 'housing affordability' and 'housing quality' as well as the occupant's satisfaction levels in design should be surveyed. Furthermore, according to the literature reviews, factory-built homes have the great potential to reduce construction time and cost, while increasing housing quality. As well, the reduction of material wastes and other site nuisances can be achieved by the application of industrialised building systems, as stated in Chapter 1. Thus, the state of factory-built homes, especially modular constructions that today's homebuilders 'rarely' apply to mass housing development, should be also re-examined in depth.

CHAPTER 3: THE STATE OF MASS HOUSING DEVELOPMENT: CASE STUDY

3.1. INTRODUCTION

Based on the literature reviews, the preceding chapters suggested that, in theory, mass housing development might help lower construction costs. As well, the industrialisation of housing helps increase product quality, while reducing construction time. In addition, today's consumers are in the market for customised end products rather than generic or repetitive ones. This trend towards the individualisation of products and services may prompt today's homebuilders to produce homes which can be customised, in response to the wants or needs of their individual clients. In short, every housing project concerns the cost, quality and time factors described in Chapter 1. However, at this point in time, the actual situation of a mass housing development, which brings with it large-volume work, has not yet been examined. Thus, with consideration of the three major factors, the current state of a mass housing development needs to be identified.

Accordingly, the author selected one of the typical mass (or large-scale) housing developments in the Montreal area and documented the existing state of this residential development. In particular, he surveyed typical townhouse developments located in the selected project, comparing the 2002 housing model with a similar 1999 model, in order to assess whether or not the selling price of housing remained constant over a period of time. As a result, the author found that the builder has already succeeded in ***semi-customising*** his townhouses, adopting a ***conventional*** means of building homes. That is, the builder employed on-site construction methods, under which construction time and quality are considerably affected by weather conditions and labour skills. In fact, between 1999 and 2002, the selling price of the most recent townhouse model increased by a staggering 47%. In the context of the project in question, the builder did *not* increase productivity and output, which might have affected a reduction of material and labour costs; accordingly, their mass housing approach alone could *not* maintain the selling price of housing over the past three years.

In addition, this chapter briefly examines the profile of homebuyers in this townhouse development, while special attention will be given to the family structure, income levels, levels of design customisation and user satisfaction regarding the housing design.

3.2. THE PROJECT PROFILE: "BOIS FRANC" DEVELOPMENT IN MONTREAL

In response to demands in today's Canadian housing market, homebuilders generating mass housing developments have begun to focus on design customisation for each dwelling unit, as described in Chapter 2. In terms of producing a unit identity that corresponds to direct user choices of housing components, the "Bois Franc" project—still under construction—is one of the typical mass housing developments in Montreal today (Fig. 3.1).

Figure 3.1: Bois Franc, Village Renaissance in 1999

The attractiveness of this project is often explained not only by its convenient location, but also by classical design arrangements that will never fall out-of-date—rather, beauty captured through the "sieve of history" (Clément 1995a). In order to distinguish the front façade of a house from that of its neighbouring units, a variety of standard exterior components (such as doors, windows, bay windows, roofs, dormers, and sheathing materials, such as brick) is applied individually to each unit. The result is a community itself that *appears* as if it had developed naturally by users' renovations over a period of years, as in the Plateau district in Montreal (Fig. 3.2). However, the actual circumstances of the development will be unveiled later in this chapter.

Figure 3.2: Plateau Mont-Royal, Rue Laval in 1999

The Bois Franc development is located in the former municipality of St. Laurent in the Greater Montreal area, and dates back to 1993. Originally ten builders were involved in the development (Chartrand 2002); however, today, only three builders remain (Groupe Montclair, Groupe Maltais, and Groupe Sotramont). These three builders continue to pursue the original vision of the project, which consists of a total of 2,800 dwelling units—this estimate excludes the number of homes that will be provided particularly for senior citizens. These houses are being built on 22,000,000 sq.ft. (2,000,000 m^2) of land, the location of which allows residents to gain easy access to major highways and the Metropolitan Boulevard (Fig. 3.3). In addition, a direct bus service between the Bois Franc development and the nearest metro station has recently been inaugurated (though currently available only Monday through Friday during the morning and evening rush hours). The project was planned to bring together greenery and nature, lakes and waterways, recreation and services (Info Bois-Franc 2002a). As well, the land is now dotted with large and small parks, four squares, and a commercial centre. Moreover, a golf course, in which some lakes also serve as winter skating rinks, recently opened next to the residential areas. In total, green spaces account for more than 12% of the total land area, and 20,000 trees are planted throughout the area (Info Bois-Franc 2002a).

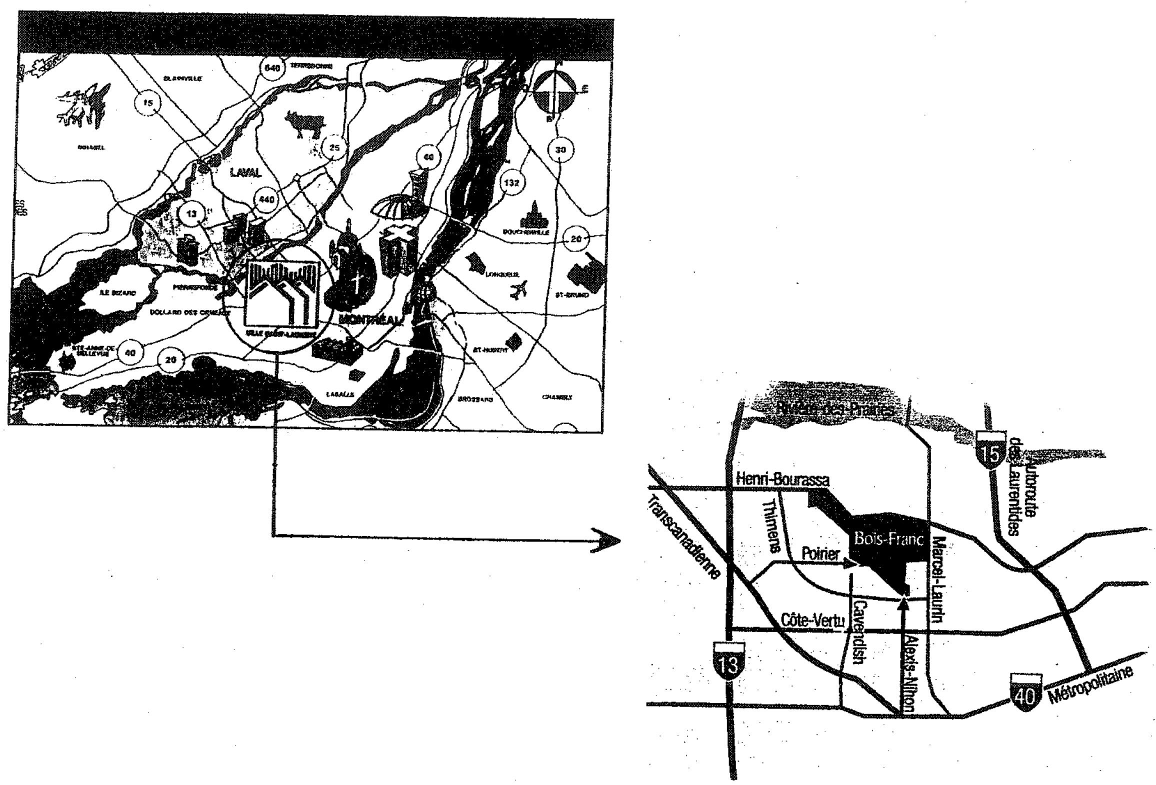


Figure 3.3: Location of the Bois Franc mass housing development in St. Laurent, Montreal (Source: Info Bois-Franc 2002a, 2002b)

Development of this mass housing project has been executed in two phases (Fig. 3.4). The first phase of 1,200 dwelling units, is now complete, while the second phase, comprising 1,600 dwelling units, has been under construction since the fall of 2000 (Info Bois-Franc 2002a). Based on their marketing survey, the Bois Franc project may be considered one of the most successful mass housing developments in the Montreal area (Info Bois-Franc 1999). In 1999, the builders reported that, during 1995, more than 160 families purchased homes in the project and nearly 1,000 families moved to this new town between 1993 and 1999. According to these results, approximately 83% of the dwelling units were sold before the first phase of the development was completed in 2000.

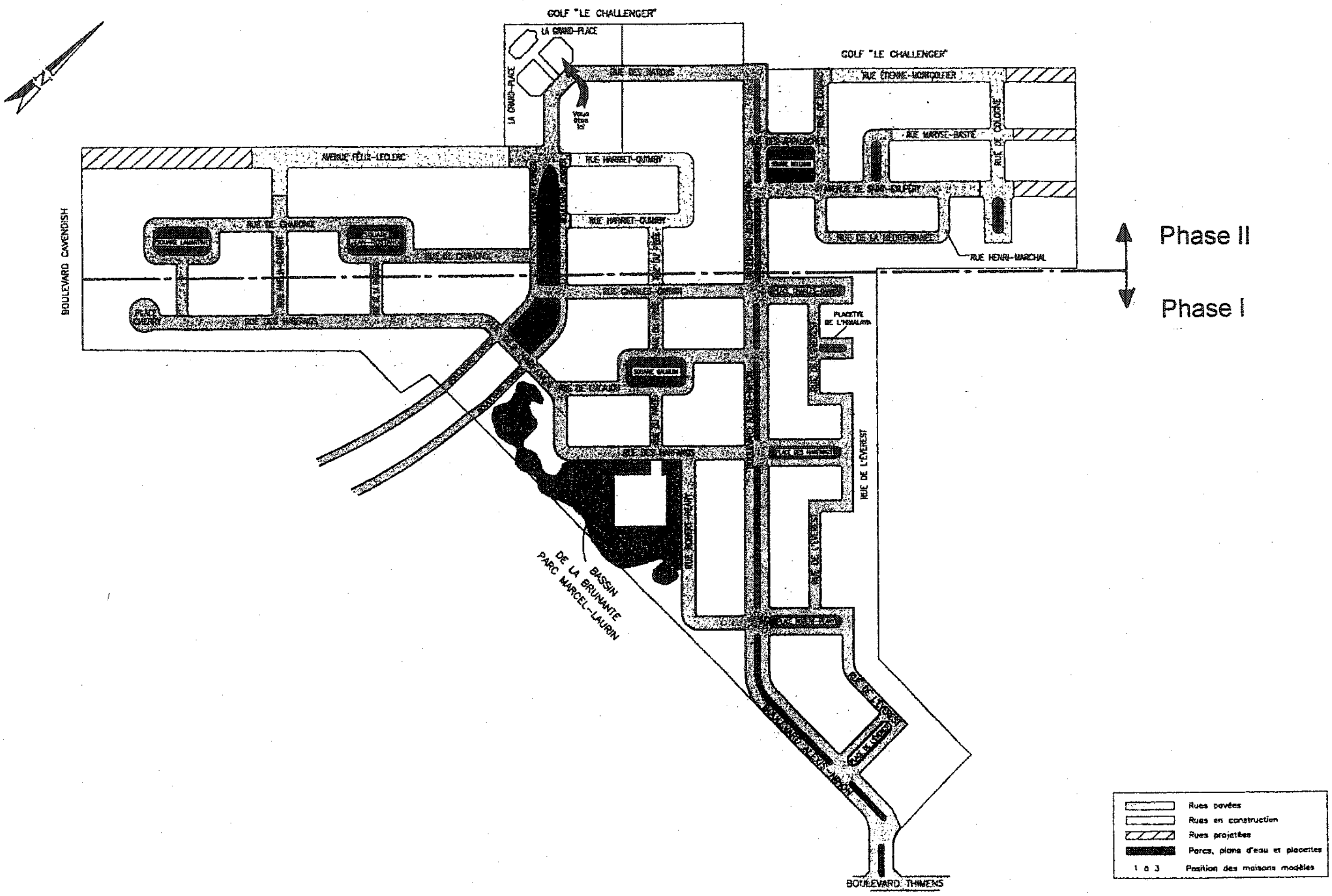


Figure 3.4: Layout of the Bois Franc mass housing development
(Source: Info Bois-Franc 2002c)

The Bois Franc mass housing development consists of townhouses, semi-detached houses, detached houses, and condominiums. The selling price of housing ranges from \$129,900 to \$915,000 (Chartrand 2002). In addition, two apartment buildings offering 3 1/2 to 5 1/2 roomed apartments are available for rent between \$890 and \$1285 per month. Today, all three builders construct townhouses, and semi-detached houses are produced solely by Montclair (Table 3.1). Two builders, Montclair and Sotramont, build detached houses, while condominium developments are carried out by Maltais. However, the "Les Terrasses du Golf" townhouses, developed by Sotramont, are treated as condominiums, because the occupants are obliged to pay special condominium fees (Chartrand 2002).

BUILDER'S NAME	HOUSING TYPE			
	Townhouse	Semi-detached	Detached	Condominium
Groupe Montclair	Yes	Yes	Yes	No
Groupe Maltais	Yes	No	No	Yes
Groupe Sotramont	Yes	No	Yes	Yes

Table 3.1: Builders' names and their housing types offered in the Bois Franc project, 2002

(Source: Info Bois-Franc 2002c)

3.2.1. THE FEATURES OF SELECTED TOWNHOUSE MODELS: "VILLAGE RENAISSANCE"

The "Village Renaissance" is representative of a typical Montclair's townhouse development in the Bois Franc project (Fig. 3.1). In the fall of 1999, the builder reported that they had already sold more than 100 townhouse units and that they were planning to upgrade the housing model by making the interiors even more *spacious* and *attractive* (Info Bois-Franc 1999). In fact, the size of the interior space of their townhouses has slightly increased over the past three years. The dimensions of the first and second floors of a *Village Renaissance* townhouse model, sold in 1999, were 18' 00" x 32' 10" (591 sq. ft. each floor). The basement, composed of a 216 sq. ft. multipurpose room (including a laundry space) and 370 sq. ft. garage, had an estimated floor area of 586 sq. ft. Thus, the unit's total floor area, including the garage, was 1,768 sq. ft., of which the total '*habitable floor area*', excluding the garage, was 1,398 sq. ft.[1] Similarly, the dimensions of the first and second floors of a 2002 model are 18' 00" x 35' 10" (645 sq. ft. each floor) and the basement floor area is an estimated 591 sq. ft. Thus, the total floor area of this most recent model is 1,881 sq. ft., with a total habitable floor area of 1,511 sq. ft (Table 3.2).

All the figures stated above exclude the optional mezzanine and loft which homebuyers may request the builder to provide at an additional charge. These figures show that the first and second

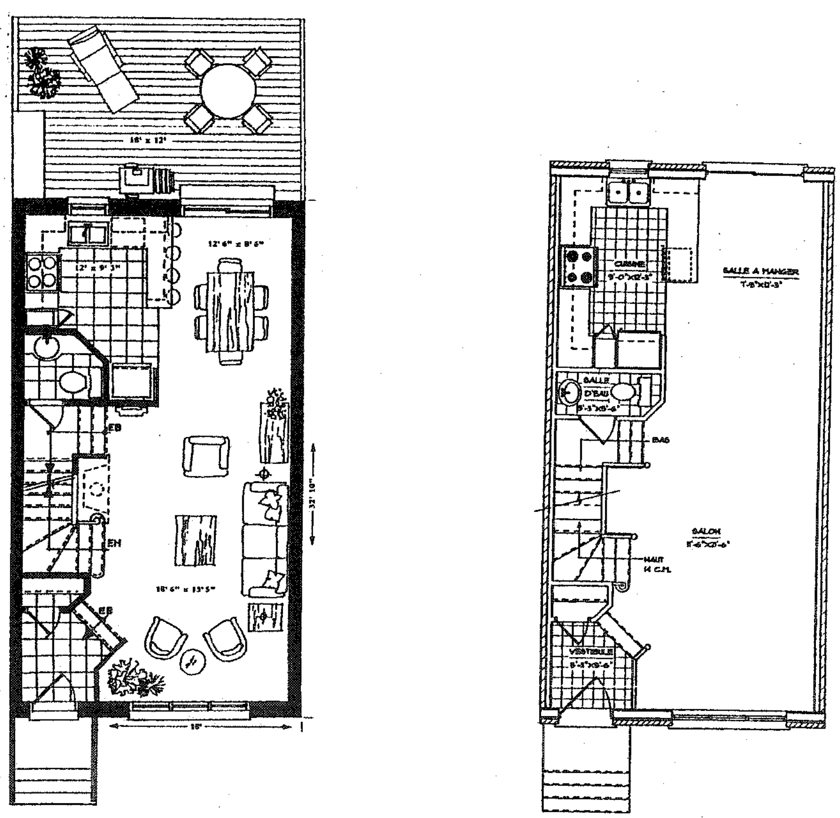
[1] For purpose of this study, the *habitable space* is defined as all interior spaces of housing excluding the garage.

floors of the 2002 townhouse model have 9% more floor space as compared to those of the 1999 model. However, including the basement, garage, first and second floors, the total floor area of the newer model shows an increase of only 6%, with the total habitable floor area increased by 8%.

	SIZE OF AN OLD MODEL: OPEN KITCHEN & THREE BEDROOM TYPE (A) (Sq. ft.)	SIZE OF A NEW MODEL: OPEN KITCHEN & THREE BEDROOM TYPE (B) (Sq. ft.)	SPACE RATIO OF THE NEW MODEL TO THE OLD MODEL (B/A) %
BASEMENT			
Multipurpose room	--- (216)	--- (221)	2.32
Garage	--- (370)	--- (370)	0.00
Total floor area of the basement	586	591	0.85
FIRST FLOOR			
Vestibule	--- (--)	05'03" x 05'06" (25)	N/A
Salon / living room	18'06" x 13'05" (234)	11'06" x 21'06" (231)	-1.28
Dining	12'06" x 08'06" (96)	07'09" x 12'03" (84)	-12.5
Kitchen	--- (--)	09'00" x 12'03" (108)	N/A
Lavatory	--- (--)	05'03" x 05'06" (25)	N/A
Total floor area of the first storey	591	645	9.14
SECOND FLOOR			
Bedroom 1	09'06" x 08'02" (72)	--- (96)	33.33
Bedroom 2	08'06" x 08'02" (64)	--- (80)	25.00
Bedroom 3	12'06" x 11'02" (132)	--- (144)	9.09
Total floor area of the second storey	591	645	9.14
TOTAL FLOOR AREA (basement, first and second storeys)			
Garage included	1,768	1,881	6.39
Garage excluded (habitable space floor area)	1,398	1,511	8.08

Table 3.2: The sizes of the 1999 and 2002 *Village Renaissance* townhouse models in the Bois Franc Project (Source: Montclair 1999, 2002a)

Despite an 8% increase in habitable floor space in the 2002 townhouses, the floor area of family rooms, such as the living and dining rooms, actually *decreased* by 1 to 2%, according to Monclair's estimates (1999, 2002a). On the other hand, bedrooms have been significantly enlarged. In fact, the floor area of the new model's main bedroom has increased by 9%, while other two bedrooms are 25 to 33% larger. According to the author's observations of the earlier and current model homes, as well as the plans and specifications provided by the builder, no 'major' modifications in the interior arrangement have been made between the earlier and current models, except for the location and shape of a lavatory (or powder room) on the first floor, which was previously embedded in a kitchen area (Fig. 3.5). Thus, the kitchen in the new model is more spacious, and provides more places for the instalment of kitchen facilities; however, counter space is not much increased.



1999 Model

2002 Model

Figure 3.5: Ground floor plans of the *Village Renaissance* townhouse model, sold in 1999 and 2002

(Source: Montclair 1999)

A small vestibule is provided at the front entrance for residents to leave outdoor garments before entering the house. The floor level of the inner rooms is slightly elevated relative to the entrance, so that small wooden stairs composed of two treads and risers, lead from the vestibule to the salon or living room located next to the entrance. The first floor has been arranged with an open floor plan (i.e. unpartitioned space) so that the dining space is located next to the kitchen in conjunction with the salon without any partitions. The kitchen and dinning room overlook a private backyard, which is often enclosed by wooden fencing. For both new and old townhouse models, homebuyers have the option of requesting the placement of a partition between the kitchen and eating areas (i.e. open or closed kitchen options). A powder room is also provided on the first floor, located between the kitchen and the staircases that lead to the upper floor and the basement. The basement consists of a multipurpose room, laundry space, and a two-car garage. The basement is typically unfinished, when the house is sold; however, the multipurpose room may be completely finished at the client's request. In terms of the floor arrangement, homebuyers can choose either two or three bedrooms for the second floor. Regardless of which option is chosen, a bathroom, containing a toilet, sink, shower stall and bathtub, is located centrally on the second floor, between the front and rear bedrooms. A large bedroom located at the front of the house usually serves as a master bedroom, while children and/or guests may occupy the bedroom(s) located at the rear. Again, both old and new models allow homebuyers to request the provision of a mezzanine or loft in the large attic, and the additional room may function as a multipurpose room (Fig. 3.6).

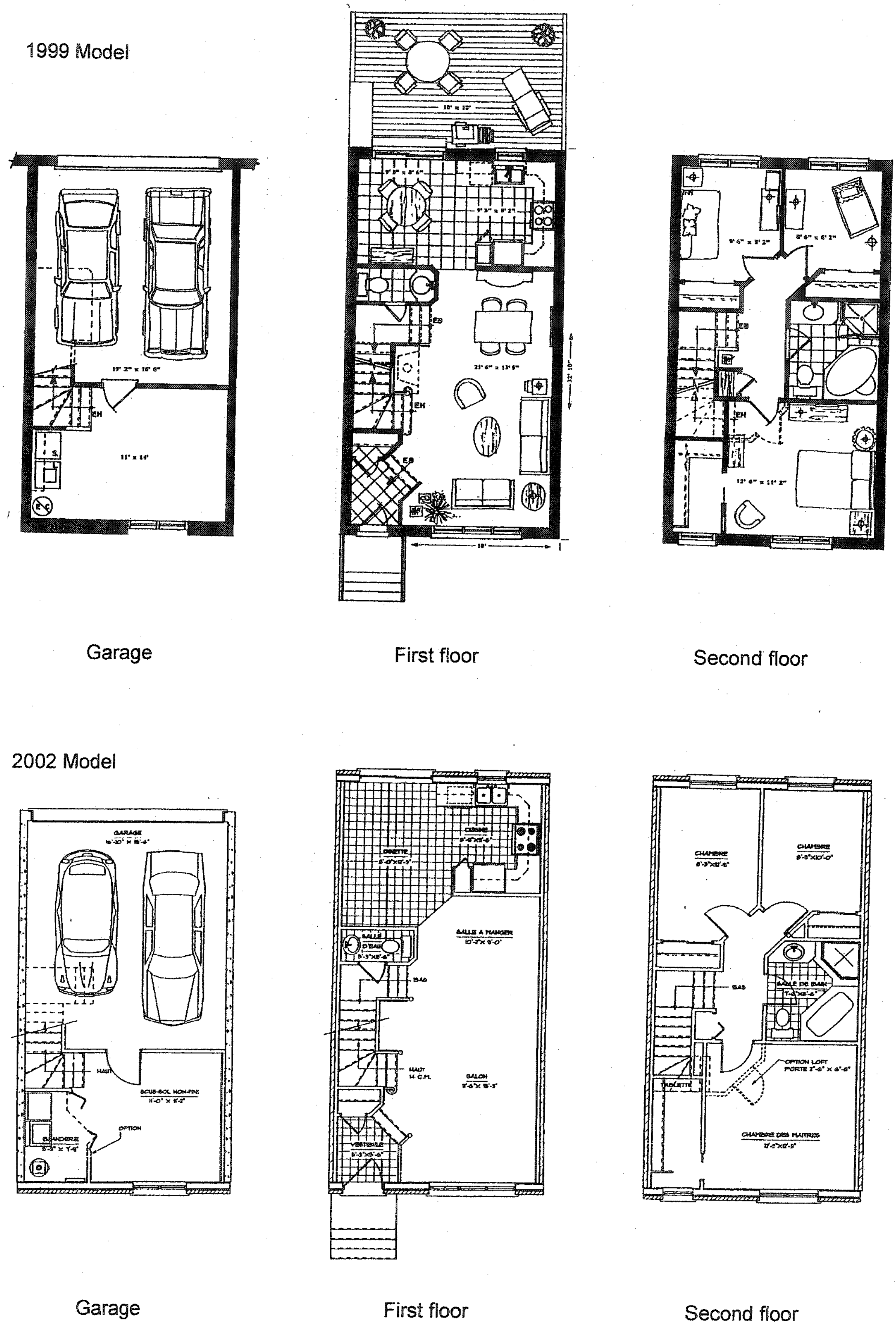


Figure 3.6: Floor plans of the *Village Renaissance* townhouse model, sold in 1999 and 2002

(Source: Montclair 1999)

When the technical housing specifications used for the construction of 2002 townhouse models are compared to those used for the construction of the 1999 models, no considerable modifications of basic building materials and systems were identified (Appendix B). However, there have been some minor changes that marginally improve the interior design. For instance, in the older model, the interior partitions could be composed of either 2" x 3" studs or 2" x 4" studs, while only 2" x 4" studs are used for the interior partitions of a newer model. To some degree, this might help increase sound insulation performance between the rooms. In addition, the 6% enlargement of the 2002 townhouses necessitated the re-arrangement of each room, especially the size, as described in the preceding section. More importantly, the enlargement of housing size naturally increases the total amount of building materials used in construction, which may, in turn, contribute to an increase in the selling price.

Accordingly, with consideration of the design modifications of the interior and the 6% increase in housing size, as well as inflation, the selling price of the townhouse models needs to be examined and discussed further in the following section.

3.2.2. SELLING PRICES

Infrastructure costs reflect development costs for the roads, sidewalks, sewers, water mains, underground electrical and street lighting, as well as individual connections to water, sanitary and storm water sewers, cable, telephone and electricity entrances. In this mass housing project, these costs are included in the selling price of housing. In 1999, the standard 18' 00" x 32' 10" model (an open kitchen and three-bedroom type) was sold at $139,900, while the extended 18' 00" x 34' 10" model was sold at $144,900. These prices excluded optional rooms, such as a mezzanine, the installation of which required an additional $13,600 for the standard model. In 2002, the selling price of the 18' 00" x 35' 10" standard model was estimated to be $206,000, according to the builder's salesperson. A house's selling price reflects total construction costs, composed of direct and indirect costs for the land development, material and labour, as well as the financing, taxes, profit and overhead, as described in Chapter 2. Accordingly, based on the selling price, the unit cost per square foot for the 1999 model can be estimated at 79.13 $/sq. ft. when the floor area of a garage is included and 100.07 $/sq. ft. when calculated using only the inhabitable area. Similarly, the cost of the 2002 model can be estimated at 109.52 $/sq. ft. including the floor area of a garage, and 136.33 $/sq. ft. when calculated using only the inhabitable area.

The selling price of townhouse surveyed in the Bois Franc development increased drastically by **47.25%** over the past three years (Table 3.3). However, this calculation ignores the fact that the house's size increased by 6%. Thus, when the enlarged size of the house is taken into account, the unit cost of a 2002 model reveals a price increase of **38.41%** when the garage floor area is included and **36.23%**, when looking only at the inhabitable space.

	CONSTRUCTION COST OF THE OLD MODEL, SOLD IN 1999 (A)	**CONSTRUCTION COST OF THE NEW MODEL, SOLD IN 2002 (B)**	**COST RATIO OF THE NEW MODEL TO THE OLD MODEL (B/A) %**
Selling Price	$139,900	$206,000	47.25
Garage floor area included	79.13 $/sq. ft.	109.52 $/sq. ft.	38.41
Garage floor area excluded (habitable space only)	100.07 $/sq. ft.	136.33 $/sq. ft.	36.23

Table 3.3: Construction costs of the old and new townhouse models of the *Village Renaissance* townhouses in the Bois Franc Project, between 1999 and 2002

The 38% increase in total construction cost between 1999 and 2002 can hardly be explained by the 6% increase in total floor area. As well, it is doubtful whether the 'minor' interior and exterior design improvements caused the 2002 townhouse model to require tremendous amounts of time for the design reviews and modifications. It can be assumed that the construction costs of this townhouse development were considerably affected by external factors such as profit, overhead, financing and taxes; however, the builder refused to disclose the specific rate of each external factor. In general, it is known that homebuilders have little control over most external factors, while the cost of material and labour can be reduced by increasing productivity and output, as described in Chapter 2. However, at the Bois Franc development, house erection depends mostly on on-site construction work. According to the author's review of company specifications, and observations of the construction site in 1999 and 2002, their construction and design approaches have not changed considerably since 1999. Thus, with consideration not only of the material and labour costs, but also of the external costs that partly reflect the builder's *profit*, the rise of the total construction costs might encourage the builder to drastically increase the selling price of their new townhouses so as to yield more profits.

Housing affordability is considered to be one of the most revealing indicators of a family's lifestyle, as described in Chapter 2. The selling price of housing greatly affects affordability, which includes not only the initial cost (e.g. down payment) but also the running cost (e.g. mortgage payment) which needs to be maintained for a certain period of time for amortisation. Thus, in order to understand the effects of the higher selling price found in this townhouse development on the housing affordability, the homeowners' profile will be unveiled in the following section.

3.2.2.1. HOMEOWNERS' PROFILE

In order to identify the homeowners' family structure, as well as their income levels, the author conducted personal interviews with three households, all of whom purchased *Village Renaissance* townhouses, and visited one of the houses in order to observe its current condition. At the same time, the author randomly sent 75 questionnaires to residents of the townhouse development. Of those questionnaires sent, 15 were returned, one of which contained a reply from a renter, rather than a homeowner; thus, the questionnaire replied by the renter was not taken into consideration for this survey.

One of the interesting aspects, which can be seen in the townhouse development, is the diversity of homebuyer groups, which includes both traditional and non-traditional households: nuclear families, lone-parents and common-law unions, as described in Chapter 2 (Tables 3.4 & 3.5). According to the results of the 14 valid questionnaires, the largest group live as couples with no children, accounting for 42.86% of the respondents. Couples with children- (or nuclear families) and lone-mother households were the second largest group, accounting for 21.43%. Male and female singles stood third, estimated at 7.14%. In addition, common-law and retired couples were also included among the households surveyed. The age of the homeowners varied, and the youngest homeowner among the respondents was a 27 year-old male maintaining the house with his female spouse aged 31.

The income levels of homeowners also varied, in part according to the number of wage earners within the household. Net monthly income thus ranged from $1,500 to $18,000. At the low end of the income ladder was a lone mother, aged 41, caring for three children at home; at the high end was a common-law couple, ages unknown. Of the 14 households, the average family annual income was estimated at $81,745.71. This result indicates an annual income, on average, 65.94% higher than the average Quebec family income of $49,261, or 49.76% higher than the average Canadian family income of $54,583 (Statistics Canada 1999a). With their higher income levels, most of the households surveyed pay less than 30% of their monthly net income on mortgage payment, while only two households pay over 30% of their income for housing. The two households, exceeding the 30% threshold, consist of a lone-mother (file no.7) and a young couple with no children (file no.8). Under current conditions, the young couple may have some difficulty maintaining their heavy financial burden as almost half (46.67% or $1,400) of their monthly net income ($3,000) is dedicated to the mortgage disbursement. In addition, the stated amortisation period of their mortgage payment was 20 years, and as they purchased the home in 1994, they may need to maintain the mortgage for the next 12 years.

File No.	No. of Household Members					Net Monthly Income ($)	No. of Income Earners	Sex and Age of Occupants (Excluding Children)		No. of Children				
	1	2	3	4	5			Male	Female	0	1	2	3	4
1			x			8,000	2	40	38		x			
2			x			7,000	1	---	50			x		
3*		x				18,000	2	---	---	x				
4	x					8,000	1	---	37	x				
5					x	4,200	2	54	50				x	
6**		x				4,000	---	---	---	x				
7				x		1,500	1	---	41				x	
8		x				3,000	2	34	28	x				
9		x				6,000	2	60	56	x				
10		x				7,000	2	42	39	x				
11		x				9,170	1	---	48		x			
12	x					12,000	1	32	---	x				
13				x		4,000	---	38	34			x		
14		x				3,500	2	27	31	x				

* Common-law couple

** Retired couple

Table 3.4: The occupants' income and household structure profiles

in the *Village Renaissance* townhouse development: Bois Franc, 2002

File No.	Net Monthly Income (A) ($)	Mortgage Monthly Payment (B) ($)	Shelter-Income Ratio (B/A) (%)	Down Payment (%)	Amortisation Period (Years)	Year of Purchase
1	8,000	900	11.25	15.00	25	1997
2	7,000	700	10.00	50.00	15	1997
3	18,000	900	5.00	25.00	25	1997
4	8,000	870	10.86	25.00	20	2002
5	4,200	---	---	40.00	---	1993
6	4,000	806	20.15	25.00	20	1994
7	1,500	462	30.80	60.00	25	2001
8	3,000	1,400	46.67	5.00	20	1994
9	6,000	---	---	60.00	20	2000
10	7,000	1,200	17.14	15.00	11	1994
11	9,170	1,200	13.09	25.00	25	2002
12	12,000	900	7.50	10.00	25	1999
13	4,000	600	15.00	30.00	20	1998
14	3,500	1,000	28.57	33.00	25	2000

Table 3.5: The occupants' mortgage payment profile

in the *Village Renaissance* townhouse development: Bois Franc, 2002

According to the questionnaire results, the average mortgage payment of homeowners surveyed in the *Village Renaissance* townhouse development is actually much higher than the provincial and nation-wide average homeowner's major payments. On average, a homeowner's monthly payment in the townhouse development is $911.50, or 34.84% higher than the Quebec average of $676, or 20.89% higher than the Canadian average monthly payment of $754 (Statistics Canada 1999a). These results might indicate that the higher selling price of these townhouses discourages potential homebuyers, whose income levels are less than the provincial or national average, from proceeding with the purchase of a home in this development.

In addition, the design approach that homebuilders apply to their mass housing development also affects to some degree the selling price, which is, in part, attributed to the unit cost, quality and time, as stated earlier. Thus, according to today's market demands for housing (i.e. customisation), the level of design customisation of housing in this residential development needs to be also identified, and will be discussed in the following section.

3.2.3. THE LEVEL OF DESIGN CUSTOMISATION

Based on the builder's specifications, homebuyers may customise certain parts of the housing design, including the colour of carpeting, ceramic tiles and other flooring materials. As well, they may select housing types corresponding to the number of bedrooms (two or three bedrooms) and kitchen forms (closed or open kitchen) desired, request the builder to provide a mezzanine and loft, and finish the basement. According to the sales representative, some exterior design components, such as dormers and bay windows, can also be customised at the homebuyer's request (Fig. 3.7). In short, the builder has already succeeded in ***semi-customising*** their townhouses, in which they modify an existing housing model according to the clients' individual requirements.

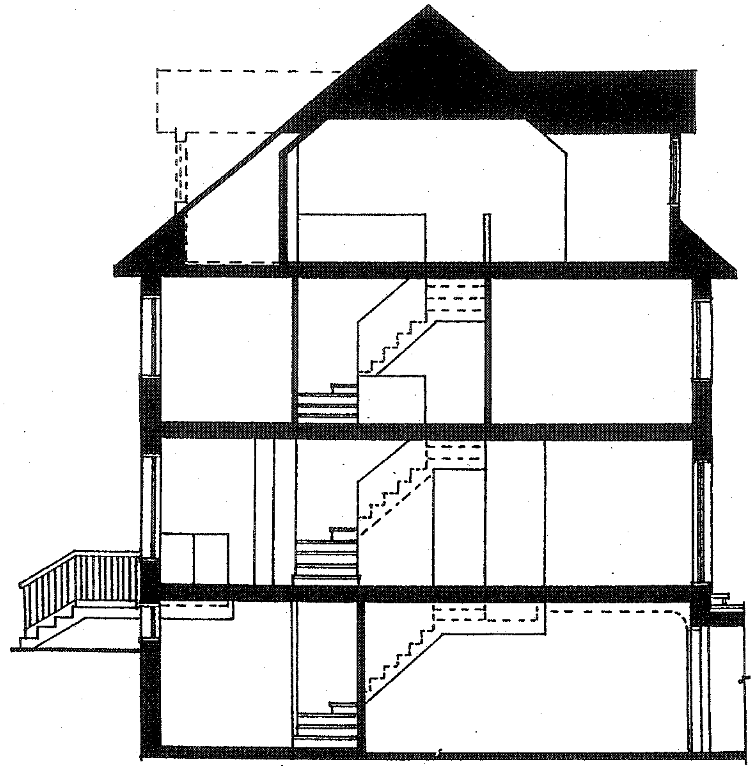


Figure 3.7: Section of a typical *Village Renaissance* townhouse in the Bois Franc project, 1999
(Source: Montclair 1999)

Based on the homebuyer's survey of the *Village Renaissance* townhouse development, most homebuyers tend to customise the interior designs of their new home, as to the colour of carpet and ceramic tiles, as well as the flooring material, as described in the builder's specifications (Table 3.6). Clients also have some design variations to choose from as to the fireplace, closets, bathroom, heating and air conditioning facilities. Doors, on the other hand, are uniform. Of the 17 households surveyed, two requested the builder finish the basement, while five increased the total floor area by adding either a mezzanine or a loft. One household, consisting of a middle-aged couple, indicated that they paid an additional $11,000 to have a loft; another answered that they were charged an extra $150 for the replacement of an existing electric outlet, which is not prescribed in the builder's specifications. Interestingly, the homebuyers whom the author interviewed affirmed that they were willing to pay extra to customise their new home. This may be reflective of today's market demands for design customisation of housing.

On the other hand, except for one household that changed patio doors facing the backyard, none of the respondents customised the exterior components of their home, such as adding dormer or bay windows, or changing the entrance door, brick, windows, shutters, and roof shingles. The respondents also indicated that most of the exterior design components were already installed before actually purchasing their new home. This implies that the exterior design depends on the housing type the homebuyer chooses, confirming that the exterior components of the *Village Renaissance* townhouses are *not* actually particularly customised but rather designed on a speculative basis by the builder's architect before the homes are put on the market.

HOUSING COMPONENTS CUSTOMISED WHEN PURCHASING A HOME	RESPONDENTS' REPLY		NO. OF RESPONDENTS (%)
	Yes	No	
Interior components	11 (79%)	3 (21%)	14 (100%)
Exterior components	1 (7%)	13 (93%)	14 (100%)
Volume components*	4 (29%)	10 (71%)	14 (100%)

* Volume components include the additional provision of a mezzanine or loft

Table 3.6: The level of design customisation in the interior and exterior designs, as well as the expansion of floor areas of the *Village Renaissance* townhouses surveyed: Bois Franc, 2002

3.2.3.1. USER SATISFACTION IN HOUSING DESIGN

According to the results of the questionnaires returned, none of the respondents are dissatisfied with the housing design, even though the level of design customisation is quite limited. At any rate, all of the respondents identified themselves as 'satisfied' with their home designs, and half of the respondents stated they were 'very satisfied' (Table 3.7). As well, all households that the author interviewed were agreeable to the builder's design approach—i.e. 'semi-customisation' that allows the users to directly participate mainly in the interior designs by the offering of constructor's samples that facilitate the user selection of colours and materials. Also, additional modification of housing designs is allowed based on the clients' request and the replacement of outlets, as described in the preceding section, can be considered one of the examples.

FILE NO.	USER SATISFACTION IN HOUSING DESIGN		
	Very Satisfied	Satisfied	unsatisfied
1	x		
2		x	
3	x		
4	x		
5		x	
6		x	
7		x	
8		x	
9	x		
10		x	
11	x		
12	x		
13		x	
14	x		
TOTAL	7	7	0

Table 3.7: User satisfaction in housing design of the *Village Renaissance* townhouses surveyed: Bois Franc, 2002

On the other hand, some respondents complained about the inflexibility of the exterior designs. For example, all three interviewees had a dislike of functionless, fake dormers. In fact, some dormers, which the builder installs before selling the units, are just placed on the roof; thus, the interior rooms behind the dormers do not actually get any light. Such dormers can be easily identified because the window appears unnaturally dark at all times. However, homeowners are not allowed to remove such dormers regardless of their preference, or taste, due to community regulations established by the builders in the Bois Franc Project.

These regulations, however, help harmonise the appearance of the community, which, in turn, helps maintain the resale value of the homes (Chartrand 2002). According to the interviewees, the regulations do, to a considerable extent, restrict the homeowners' freedom to improve their homes. The home occupants may not modify external designs of housing and they are obliged to maintain the colours and styles of the original designs. For example, when painting is necessary, the front handrails and banisters at the entrance stairs and landing may only be painted black. However, more freedom is given to homeowners when it comes to renovating exterior components located at the rear of the house. Homeowners are allowed to change the patio doors, as well as to build fences, so long as they are painted either green or black. The community also permits homeowners to install a swimming pool in their backyard. That said, those interviewed complained that they were unable to renovate the exterior components of their home, which they desired to do.

These results indicate that a townhouse development of today (such as Bois Franc) hardly allows for the total customisation (e.g. volume, exterior and interior arrangements) of a new home since this would hinder the achievement of economies of large-volume construction that reduce construction costs. This semi-custom (or production) design approach, which the builder applies to the exterior design, may help increase his profit however. As well, the occupants' after-purchase home renovation tends to be restricted, in order to maintain the higher selling price of housing. These facts resulted in making the *Village Renaissance* townhouses only 'appear' as if they are totally customised or renovated by the homebuyers themselves, as stated earlier in this chapter. Then, a question still remains:

Can the opposite approaches of mass production and customisation be well integrated in a townhouse development which greatly contributes to sustainability?

3.3. SUMMARY AND CONCLUSIONS

The *Village Renaissance* townhouse development, which is part of the Bois Franc mass housing project, is mainly carried out using ***conventional*** means of building ***semi-customised*** houses at the building site. As a result, the builder's customary practice was *not* effective enough to maintain the selling price of homes under inflation; in fact, over the past three years, the selling price of the *Village Renaissance* townhouses has risen 47% from $139,900 to $206,000. This drastic increase of the housing price was partly explained by the 6% enlargement of the size of the 2002 model house, in comparison to that of the similar 1999 model. The increased size also necessitated the 'slight' modification of the interior designs. To some degree, inflation might contribute towards increasing the cost of material and labour. On the other hand, the builder might only have been able to offset part of the increased cost, due to inflation, if they could increase productivity and output by applying ***more-efficient*** design and production approaches to their mass housing development.

However, according to the author's observation of the *Village Renaissance* townhouse development, productivity and output were *not* much increased between 1999 and 2002. In fact, except for prefabricated joists and roof trusses, the builder still relies heavily on a site-built construction system without applying the industrialised building systems that produce factory-built homes—in-factory production of housing components may considerably affect productivity, as described in Chapter 1. It can be assumed that the rise of material and labour costs, due to inflation over the past three years, could not be alleviated under the builder's existing state of productivity. As well, the external factors including their *profit* (that the builder did not wish to reveal) might help increase the selling price of their new homes. Furthermore, the builder's 'semi-custom' design approach, to some degree, also hindered achieving the economies of large-volume work. The combination of these factors may have lead to the observed drastic increase of the selling price of housing.

In order to increase productivity and output in today's mass housing development, ***more-efficient*** design and production methods that help maintain the economies of large-volume work, while meeting the market demand for design customisation of housing, should be taken into consideration, and will be further discussed in Chapter 4.

4.1. INTRODUCTION

As discussed in Chapter 1, the industrialisation of housing, which has the potential to eliminate building site inconveniences such as bad weather, vandalism and theft that affect construction time, quality and cost, also helps produce homes more efficiently, when compared to site-built counterparts. However, today's mass housing development in Quebec, as surveyed in Chapter 3, does not make much use of prefabricated building systems except for trusses and joists. In addition, in order to meet homebuyers' individual requirements for housing, today's homebuilders, as well as housing manufacturers in Quebec, apply either a semi-custom design or a custom design approach. It is known that these approaches, to some degree, hinder the high-volume construction of housing which yields economies of scale that, in turn, help reduce production costs, as stated in Chapter 2.

This chapter is aimed at introducing a new design and production approach, known as "mass customisation", in order to bridge a design-production gap between the need for *mass production* on the one hand and *customisation* on the other. The gap still remains wide in the homebuilding industry of today, as described in Chapter 2. Accordingly, this chapter first addresses the concept and principles of mass customisation before narrowing the focus onto *how* to apply mass customisation techniques to housing design and development, while integrating the principles into a new 'system'.

The mass customisation system model proposed can be applied not only at the 'unit' design level, but also at the 'organisation' design level in mass housing projects. However, this chapter concerns only the former and is based on the author's survey of Japanese housing manufacturers, who have already been successful in the mass customisation of homes. Moreover, the proposed system will function as the theoretical foundation of a homebuilder's "choice model" that will be developed in Part II.

4.2. THE CONCEPT OF "MASS CUSTOMISATION"

"*Mass Customisation*" is a complex term, for how can one combine *mass production* and *customisation*? As a technological capability, Mass Customisation was anticipated in 1970 by Alvin Toffler in his book entitled "*Future Shock*"—"Uniformity will give way to diversity" (Toffler 1970:237). He also asserted that maximum "individual choice is regarded as the democratic ideal" and expressed anxiety at the emergence of more standardised mass culture and lifestyles in the future (Toffler 1970:233). He warned that:

> "Science and technology have fostered standardization. Science and technology will advance, making the future even more standardized than the present. *Ergo*: Man will progressively lose his freedom of choice" (Toffler 1970:234).

Toffler also directed his attention to trends in industry, indicating that companies were discovering wide variations in the wants and needs of individual customers, adapting their production lines to accommodate them—"Every architect wants his own shade of green" (Toffler 1970:236). This implied that the rigid uniformity and long runs of identical products, which characterised traditional mass production plants, were becoming less important. According to his explanation, two economic factors encouraged this trend: first, consumers have more money to lavish on their wants; and second, the cost of introducing variations declines, as technology becomes more sophisticated. However, Toffler (1970:236) emphasised that the latter factor is even more important than the former, and he added that it is "only primitive technology that imposes standardization." However, in this context, he seems not to be aware that standardisation for very simple items, or parts of a whole, can be accepted as offering the advantages of standardisation without limiting "creative design" (Movshin 1970:16). Furthermore, the rate of technological advance of the construction industry was considered to be far below that of other industries in the post-war era—or indeed even today. Toffler (1970:237) indicated that "construction has scarcely reached the level of mass production; it remains, in large measure, a pre-industrial craft."

In 1987, the term "Mass Customisation" was actually coined by Stanley M. Davis in his book entitled "*Future Perfect*" and he delineated the concept as follows:

> "The world of mass customizing is a world of paradox with very practical implications. Whether we are dealing with a product, a service, a market, or an organization, each is understood to be both part (customized) and whole (mass) simultaneously....For mass customizing of products, markets, and organizations to be possible, the technology must make it economically feasible in every case." (Davis 1987:140 & 141)

Like Toffler, Davis (1987:155) also stated that technology would make 'mass customisation' a practical possibility; however, he knew that they would not be sufficient by themselves. Thus, he emphasised the need for the principle of mass customisation, which reflects "the paradox of the simultaneity of opposites, particularly of the whole and its parts", to be well understood so as to facilitate the widespread application of a mass customisation approach to many 'products' and 'services'.

In addition, he gives the example of the Japanese prefabricated housing industry, indicating that it "has apparently learned the mass-customising message much better than their U.S. counterparts" (Davis 1987:158). Moreover, he briefly described Japanese manufacturers' way of mass customising their new homes as follows:

> "The general sense of the public is that what you save on costs you lose in quality and in customization. If you are to buy a mass-produced house, your choices are limited to gross differences, such as two- or three-bedroom model. The Japanese, however, have applied mass customizing to housing business. Their effort began in the 1960s and has become quite sophisticated since then."

> "The process begins by sitting down with a sales representative for a couple of hours and pretty much designing your own home on a computer screen. You choose from 20 thousand different standardized parts, like life-sized Lego blocks, and you can put those parts together pretty much as you want. Shall we add a foot to the length of living room? No problem. A small addition to add a Jacuzzi in the corner? Presto. You'd like the tea room on the other side of the house. Just press the button and the computer will make necessary adjustment in the plans and materials needed." (Davis 1987:158).

In comparison with fully mass-customised, prefabricated housing in Japan, which usually consists of some engineered materials (e.g. a wall material, which does not burn and provides better insulation than concrete) that the manufacturers developed, Davis (1987:158) regarded mass-produced, prefabricated housing in the U.S. merely as "not highly esteemed". Also, he warned that "If U.S. home builders don't turn to mass customizing, they may end up out of business before they ever see 2001" (Davis 1987:160). His prediction for American homebuilders was somewhat intuitive or hyperbolic; however, the questions, which Davis conceived in 1987, still remain unsolved, even today:

> "Will the $6 billion U.S. housing industry adopt this [wall] material and other processes from the Japanese?"
> "Will American housing become mass customized?".

In 1993, B. Joseph Pine II integrated the concept of Mass Customisation in his book entitled "*Mass Customisation*", providing the guideline for this new frontier, as well as the fundamental methods of mass customisation of products and services. He regarded Mass Customisation as an emerging management system, which evolved from the "factory system" and the system of Mass Production. The factory system, common to the United States, Great Britain and the other newly industrialised nations of Europe in the nineteenth century, was a continuation of the basic idea of Craft Production—i.e. the end products themselves are not standardised. However, it allowed the production process to be standardised (and *routinised*) as the Industrial Revolution brought a general replacement of hand tools with machinery and mechanisation.[1] According to Pine II (1993:11), the factory system in the United States was characterised by the following principles: interchangeable parts, specialised machinery, reliance on suppliers, focus on the process of production, the division of labour, the skills of American workers, flexibility, and continuous technological improvement. The eight characteristics differentiated the factory system of the United States from both craft production methods and the factory systems applied in Europe (Pine II 1993:11).

However, in the twentieth century, these characteristics of the factory system alone become insufficient to support the growth of large enterprises that sought to meet the demands of an increasingly geographically dispersed economy in the late 1800s (Pine II 1993:14). At the dawn of the new century, a new system of 'Mass Production' was unveiled. Mass Production, or *Fordism* (after Henry Ford), made its first appearance in the world at Highland Park near Detroit in 1913. In order to mass-produce commodities (i.e. cars in his case), Henry Ford focused on seven principles: power, accuracy, economy, continuity, system, speed, and repetition (Nevin and Hill 1957:6). Furthermore, he combined these principles into three creative components: the first was the planned, orderly, and continuous progression of the commodity through the shop; the second was the systematic delivery of the work to the mechanic, instead of bringing the mechanic to his work; and the third component was the break-down of all the operations into their constituent parts, with a suitable division of labour and material. In consequence, in comparison to the former production approach, the total amount of labour time spent making a single car dropped from 12 hours 8 minutes to 2 hours 35 minutes, when Ford's engineer introduced the assembly line in October 1913. Accordingly, sales of his car, known as the "Model T", increased tremendously (Table 4.1). In addition, the new system, to a considerable extent, helped accomplish the continual lowering of its retail price and, between 1908 and 1916, the

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[1] The factory system was also called the "American System of Manufacturers" or simply "American System" and it fuelled the economic growth of the United States. In fact, between 1875 and 1899, the system began to dominate the American economy and commodity output per capita grew at an annual rate of 2% versus just 0.3% for the first three quarters of the ninetieth century (Pine II 1993:10).

price of the Model T Ford produced was reduced drastically by 57.65%.

CALENDAR YEAR	RETAIL PRICE (TOURING CAR) $	CHANGE FROM 1908 %	TOTAL 'MODELT' SALES	CHANGE FROM 1908 %
1908	850	0	5,986	0
1909	950	11.77	12,292	105.35
1910	780	-8.24	19,293	222.30
1911	690	-18.82	40,402	574.94
1912	600	-29.41	78,611	1213.25
1913	550	-35.29	182,809	2953.94
1914	490	-42.35	260,720	4255.50
1915	440	-48.24	355,276	5835.12
1916	360	-57.65	577,036	9539.76

Table 4.1: Price and sales of Model T Fords, 1908-1916

(After Pine II 1993)

However, the system of Mass Production focuses essentially on producing standardised products for a *homogeneous* market. Pine II (1993:17) indicates that one of the primary reasons that the system of Mass Production (as well as the factory system) was developed so extensively in the United States was that the American market tended to be more homogeneous than the markets of the industrialised nations of Europe.

Furthermore, he stated that:

> "America never had the class distinctions common in Europe; therefore Americans did not have to differentiate themselves from other classes by what they purchased. Along the same lines, income distribution was also more equitable in the United States, resulting in more people clustered around similar needs and desires" (Pine II 1993: 17).

However, there is no doubt that today's consumers have become more demanding than ever before, looking for variety and uniqueness in the products or services that they buy. Moreover, they also demand high quality and low cost (Oleson 1998:146). Anderson (1997:3) suggests that "business must respond to succeed in today's turbulent climate, none is more difficult, more perilous, nor more vital than being customer-oriented." In other wards, the imperative in business today is to understand and fulfil the wants and needs of each individual customer (Fig. 4.1). The initiatives of most companies are usually market-focussed, rather than customer-focused, because companies also need to meet an equivalent imperative for achieving low costs—i.e. efficiency of production. Thus, Anderson (1997:4) concluded that "Mass Customization is the new imperative in business, one that puts the identification and fulfilment of the wants and needs of individual customers paramount within the company without sacrificing efficiency."

In addition, Pine II (1993:44) emphasises that, today, many companies no longer focus solely on producing merely standardised products or services for homogeneous mass markets (Fig. 4.2). Accordingly, he suggests that a new paradigm (i.e. Mass Customisation) may help industries supply a variety of customised products or services through flexibility and quick responsiveness (Table 4.2).

In summary, "Mass Customisation" appears to be an oxymoron, but is actually a synthesis of the two long-competing systems of management—i.e. "the mass production of individually customised goods and services" (Pine II 1993:48). Thus, the concept of Mass Customisation can be explained as follows:

MASS CUSTOMISATION = ACHIEVING MASS + CUSTOMISATION

In the system of Mass Production, low costs can be achieved primarily through ***economies of scale***—i.e. lower unit costs of a single product or service through greater output and faster throughput in the production process. On the other hand, in the system of Mass Customisation, low costs can be achieved primarily through ***economies of scope***—i.e. the application of a single process to produce a greater variety of products or services more cheaply and more quickly (Pine II 1993:48).

In the following sections, the principles of a mass customisation approach will be discussed, in order to identify how the concept can be applied to the delivery of mass customised goods and services.

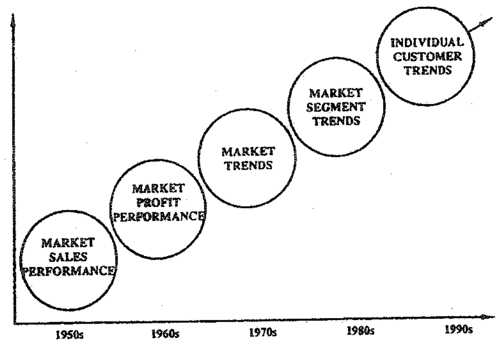

Figure 4.1: Trends of data requirements

(Source: Kelly 1996)

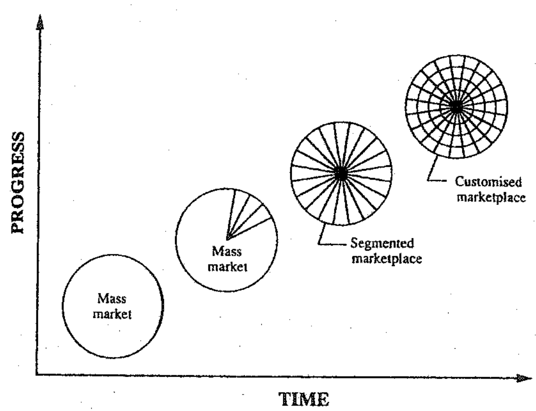

Figure 4.2: From mass to customised market

(Source: Kelly 1996)

	MASS PRODUCTION	MASS CUSTOMISATION
Focus	- Efficiency through stability and control	- Variety and customisation though flexibility and quick responsiveness
Goal	- Developing, producing, marketing, and delivering goods and services at prices low enough that nearly everyone can afford them	- Developing, producing, marketing, and delivering affordable goods and services with enough variety and customisation that nearly everyone finds exactly what they want
Key Features	- Stable demand - Large, homogeneous markets - Low-cost, consistent quality, standardised goods and services - Long product development cycles	- Fragmented demand - Heterogeneous market niches - Low-cost, high-quality, customised goods and services - Short product development lifecycles

Table 4.2: Mass Customisation contrasted with Mass Production

(Source: Pine II 1993)

4.3. THE PRINCIPLES OF MASS CUSTOMISATION

Based on state-of-the-art reviews of mass customisation, this section is aimed at bringing together the techniques—i.e. *how* to apply the concept. As stated in the preceding sections, mass customisation can be classified by reference to the two opposite notions of mass production and customisation. In the broadest sense, 'standardisation' is considered one of the most effective means of achieving the mass production of *products*, while 'customisation' is usually related to a process, or a *service*, that enables an end product to meet customers' individual requirements. This section focuses mainly on reviewing the two principal aspects, standardisation and customisation, in order to combine the principles of mass customisation for subsequent application to housing design and development, to be discussed later in this chapter.

4.3.1. STANDARDISATION TOWARDS MASS PRODUCTION

Standardisation is considered the key factor in establishing efficient *mass production* of products and services; however, standardisation is a discipline (albeit not a static one since materials are continuously improved; knowledge and understanding grow and needs change over the time) involving many factors (Fig. 4.3). According to the Oxford English Dictionary (OED), the word *standard* is used in connection with military or naval ensigns, and the ninth OED example describes it as "standard of measure or weight." The word *standardisation* is considered "the action of standardising." However, the etymology of these words is still somewhat obscure.

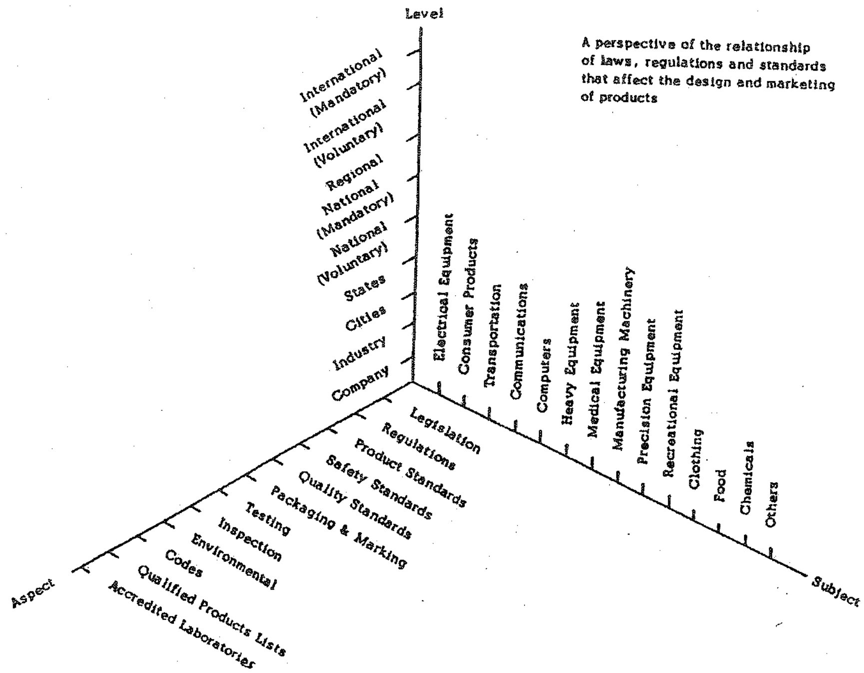

Figure 4.3: Lal Verman's diagrammatic representation of standardisation space

(Source: Spivak and Brenner 2001)

Broadly speaking, a complete set of definitions for *standardisation* and *standard* covers performance, testing and certification, laboratory accreditation, and quality control. Notably, the International Organisation for Standardisation (ISO) defines the process of standardisation as:

> "... activity of establishing with regard to actual or potential problems provisions for common and repeated use, aimed at the achievement of optimum degree of order in a given context. Note: In particular, the activity consists of the processes of formulating, issuing and implementing standards" (ISO cited by Spivak and Brenner 2001:1).

Movshin (1970:13) emphasises that there are many sources of standards applicable to the homebuilding industry; however, there is also concern as to their effect on *creativity*. Standardisation is usually accompanied by *simplification* that facilitates communication among the parties involved in a housing project and also help to reduce the number of varieties of any given item. These factors yield economies of scale which, in turn, help lower design and production costs. According to Movshin (1970:14), the advantages of standardisation and simplification, from the standpoint of manufacturers, can be summarised as follows:

1. Less capital needs to be tied up in raw materials, finished inventory, dies, jigs, templates, floor space, and repair parts;
2. Manufacturing processes can be more economical though larger production runs—there are opportunities for introducing automated and specialised equipment, while development and experimentation costs can be reduced;
3. Labour efficiency can be improved through organising the kinds of information that employees need, as well as through providing more specialised training on the products and items being produced;
4. Stock depreciation and obsolescence can be reduced. (However, the notion of economy in standardisation is not a static idea; rather, it is dynamic, because it inevitably involves quality and time factors); and
5. Improved and simplified communication can be developed throughout all phases of the production and distribution processes.

Furthermore, he also adds some advantages from the standpoint of the user:

6. As a communication device whereby information can be readily disseminated;
7. As a means for ensuring that products can be readily obtained, with a known quality and at a minimum cost;
8. As a way of allowing the designers to concentrate their interests and efforts on specific and significant aspects of the design; and
9. As a factor in improving the maintainability and replacement characteristics of a design.

An important aspect of standardisation is the fact that it is associated with the feasibility of high-volume production—i.e. mass production. However, there is a question that hinges on expanding standardisation:

Can standardisation permit the maximum opportunity for creativity, or customisation?

The meaning of "creativity" has been discussed extensively. Taylor (1964:2) concedes the complexity of developing a single definition of creativity that suits all situations in different fields, summing up the notion as follows:

> "Creativity at its highest level has probably been as important as any human quality in changing history and in reshaping the world…Man's current degree of enlightenment, particularly in certain fields, as well as his vast production of material goods, can be traced in large part to the creative performances of individuals during the course of history—to man's striving to improve his knowledge, to conquer the unknown, and to create new ideas and new, more useful things."

His description of creativity includes some interesting phrases such as "create new ideas" and "useful things". The former may be considered a generally-recognised expression of creativity, while the latter may reflect the following definition of creativity—"*a novel work that is accepted as tenable or useful or satisfying by a group at some point in time*" (Taylor 1964:6). In addition, he recognises two existing definitions of creativity as proposed by Ghiselin and Lacklen:

> "Ghiselin proposes that the *measure of a creation product be the extent to which it restructures our universe of understanding*. Lacklen, of the Space Agency, uses *the extent of the area of science that the contribution underlines*: the more creative the contribution, the wider its effects" (Taylor 1964:6).

Conclusively, Taylor (1964:7) admits that there is "no single definition has yet been prepared that suits all workers in the field", urging researchers "either to choose tentatively an existing definition of creativity or to develop a definition of their own that will enable them to move ahead in their work."

From the Value Engineering's standpoint, Dell'Isola (1997:91) sees "creativity" as behaviour that "uncovers a relationship where none previously existed; a relationship between people, objects, symbols, or any combination of these." Similarly, Parrot (2002), a Certified Value Specialist of SAVE

International, indicates that the definition of "creativity", which is applicable to Value Engineering, falls into either of the following notions:

> "Intellectual process resulting in the production of new and valid ideas" ;
>
> or
>
> "Innate aptitude of man in creating new combinations starting with existing elements"

Again, the first definition of creativity may be commonly recognised—i.e. "to produce where nothing was before"—as described in the Oxford English Dictionary. In the homebuilding industry, a one-of-a-kind house might be of this type, in which all features of a home are customised, according to the wants and needs of individual clients, based mainly on a 'dialogue' between the user and the designer. Generically, these homes are usually called "**custom homes**" (Peter Asher Designs 2002). The latter definition of creativity connotes the use of existing elements to develop new combinations that make an end product something new. In this case, the existing elements (i.e. parts of a whole) can be standardised, while the myriad combinations of these standard parts still permit great scope for creativity. Thus, a homebuyer, for example, can directly choose the standard housing components, which can be mass-produced, while the combinations of the user's 'choices' of these components make a house customised—viz. these homes can be termed "**mass custom homes**" (Noguchi 2001).

In contrast, those homes, which are customised by modification of an existing model house in response to a dialogue between the user and the designer (where the house can be considered a whole, rather than the parts) to meet the wants and needs of individual clients, can be called "**semi-custom homes**." In addition, those that are totally mass-produced, before they reach the market, are termed "**ready-built homes**."

Because of the nature of a ready-built home, the entire house itself can be standardised; thus, the level of product customisation is extremely low (Table 4.3). The characteristics of a custom home are totally opposite to those of a ready-built home. A custom home is a one-of-a-kind house, completely customised; thus, the level of standardisation in both products and processes can be considered as very low. Semi-custom homes combine the positive features of ready-built and custom homes—the model house is usually prepared on a speculative basis like a ready-built home, while, in response to the user's demands for housing, the modification of the model house allows, in part, for product customisation. On the other hand, mass custom homes may achieve, in theory, the high level of standardisation of all the housing components from which homebuyers can directly select in customising their new home. The user's choices of mass-produced, standard components may actually increase the level of customisation in housing design (Fig. 4.4).

Up to this point, the principles of standardisation for tangible elements of the design have been discussed. In summary, standardisation can be applied either to the whole of a complex product or to the parts. However, the consequences are different, in terms of the scope for design customisation of a house—i.e. it will be a ready-built, semi-custom, custom, or mass custom home. Movshin (1970:13) suggests that the "design represents an integration of *standard* and *special* components in a unique combination." On the other hand, the action of combining standard components connotes a *process*; thus, standardisation of intangible elements (i.e. processes or services) should also be taken into account, in order to make the best use of the advantages of standardisation for the efficient creation of an end product. On the assumption that customisation accompanies a *standard* process, the principles of customisation towards mass customisation will be discussed in the following section.

	STANDARDISATION LEVEL	CUSTOMISATION LEVEL
Ready-built home	High	Low
Semi-custom home	Medium	Medium
Custom home	Low	High
Mass custom home	High	High

Table 4.3: The levels of standardisation and customisation compared by housing type

(Source: Noguchi 2003)

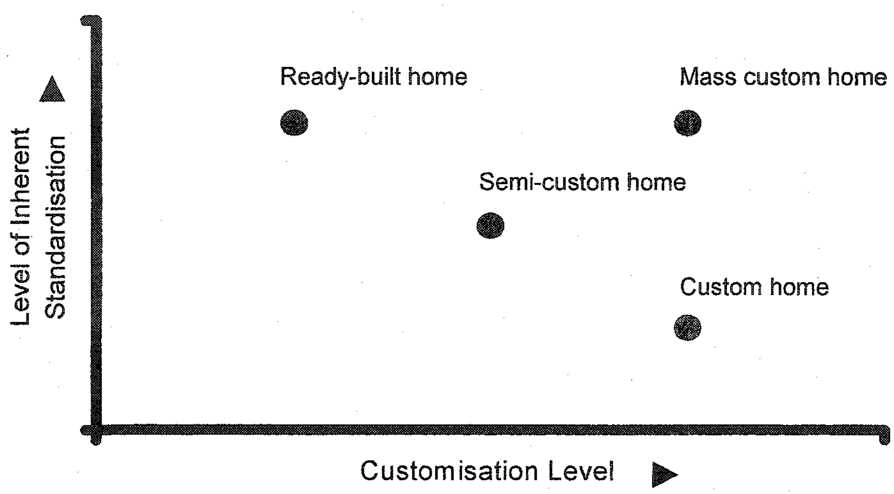

Figure 4.4: Standardisation - customisation relationship compared by housing type

(Source: Noguchi 2003)

4.3.2. CUSTOMISATION TOWARDS MASS CUSTOMISATION

Pine II (1993:171) integrated five fundamental methods, which are applied by a variety of industries, to mass customise *end products.*[2] Accordingly, the author selected four of these methods, which he considers to be applicable to today's homebuilding industry in Quebec.[3] Thus, the four principles of customisation that aim to mass customise an end product can be summarised as follows:

1. Customising services around standard products and services.
2. Mass-producing customisable end products.
3. Providing point-of-delivery customisation.
4. Modularising components to customise end products.

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[2] For purpose of this study, the term *end products* is often used to describe both goods and services.

[3] One of the mass customisation principles that the author did not include in this section was "the provision of quick response through the value chain." An organisation's value chain basically concerns the development, production, marketing and delivery phases of end products and represents the key links of these. The vision of Quick Response is to have "the right product at the right place at the right time at the right price" (Pine II 1993:191). This concept is somewhat obscure, but it might be of importance in creating an organisation that gains a time-based competitive advantage through its value chain.

However, none of these methods are mutually exclusive and, in practice, they often overlap. In fact, many companies use a combination of several methods and occasionally all of them (Pine II 1993:171). The order of the list described above goes from the *easiest* place to start, and it progresses through to more pervasive and fundamental techniques that require more drastic changes and improvement in a company's organisation. In the following sections, these four methods will be summarised and analysed for future application to the delivery of quality affordable homes.

4.3.2.1. CUSTOMISING SERVICES TO INTEGRATE STANDARD PRODUCTS AND SERVICES

Pine II (1993:172) suggested that the first method can be considered to be the easiest and most popular method for producing low-cost, individually customised end products without a requirement for radical changes and improvements in an organisation's value chain (Fig. 4.5). Before the delivery of end products to customers, completely standardised products can be customised during the marketing stage. Thus, this method can be implemented in the last two links of an organisation's value chain (Fig. 4.6).

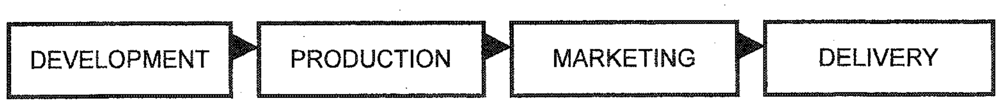

Figure 4.5: Key links in an organisation's value chain (general)
(After Pine II 1993)

In fact, this method is often applied by companies who customise their services around standardised offerings; for example, travel services are usually standardised, allowing a customer to choose mass-produced commodity services—these include an airline seat, hotel room, and rental car. As well, the availability of first- and business-class seats provides one rather small level of variety. In addition, the choices available in traditional in-flight services such as meals, drinks, headphones, movies, newspapers, duty-free magazines, telephones and modems allow customers to enjoy a variety of experiences around standardised offerings.

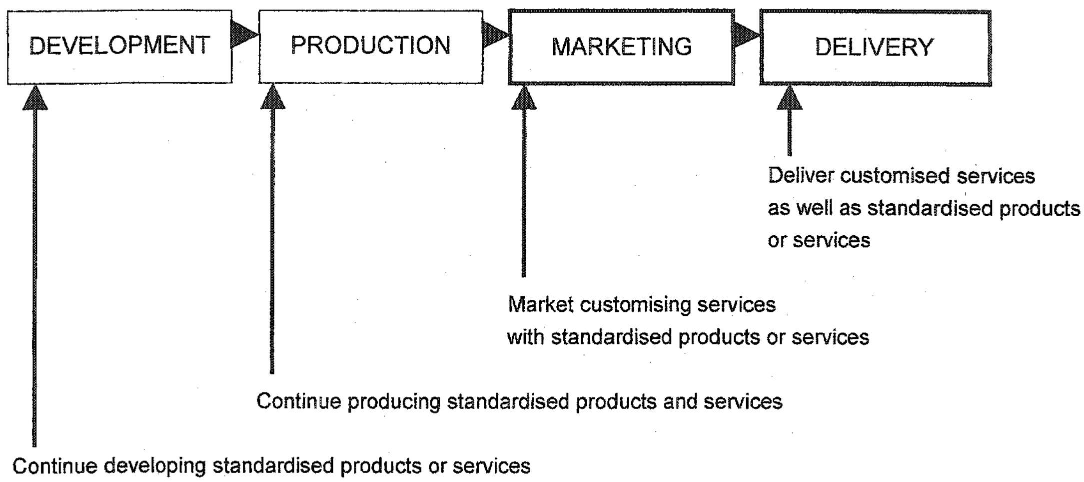

Figure 4.6: Changes in value chain to customise services around standardised products or services (After Pine II 1993)

The fast-food restaurant industry has already been successful in applying this method to mass customising their end products. McDonald's, for example, first symbolised the application of mass production techniques to the fast-food industry—its menu, recipes, uniforms and buildings. However, McDonald's today is considered one of the most well-known, leading service industries, which are undergoing a paradigm shift from Mass Production to Mass Customisation (Pine II 1993:41). McDonald's first appeared in Des Plains, Illinois (a Chicago suburb) on April 15, 1955, after Raymond Albert Kroc's 1954 deal with the McDonald brothers of San Bernardino, California to franchise a chain of restaurants (Fig. 4.7).

Figure 4.7: McDonald's opening-day advertisement in the local newspaper

(Source: Jackle and Sculle 1999)

Originally, the heart of McDonald's success was its chief food item, a 1.6-ounce hamburger, 3.9 inches in diameter, on a 3.5-inch bun with 0.25 ounces of onion sold for 15 cents—i.e. "a standardized product of high quality but also low price" (Jackle and Sculle 1999:141). The firm opened the two-hundredth McDonald's in 1960, while attracting talented specialists to work under Kroc's aegis. In the 1960s, McDonald's emerged as the paradigm, epitomising not only the hamburger chains, but also *fast food*.[4] McDonald's initially grew with one simple product (i.e. a standardised hamburger) from earnings of $37,000,000 in 1960 to $226,000,000 in 1967. Its recent growth in sales and profits is shown in Table 4.3.

[4] The term *fast food* has risen to an accepted word in the American vocabulary and it has been attributed to McDonald's own rise in notoriety (Jackle and Sculle 1999:141).

YEAR	SALES (Millions)	INCOME (Millions)
1985	$11,011	$433
1986	12,432	480
1987	14,330	549
1988	16,064	646
1989	17,333	727
1990	18,759	802
1991	19,928	860
1992	21,885	959
1993	23,587	1,083
1994	25,987	1,224
1995	29,914	1,427

Table 4.4: Growth in sales and income, 1985-1995

(Source: Hartley 1998)

In the 1980s, McDonald's began proliferating the number of menu items —e.g. McDonald's Pizza, chicken fajitas, breakfast burritos, submarine sandwiches, spaghetti and meatballs, bone-in chicken, a grilled chicken sandwich, carrot and celery sticks, fresh-ground coffee, and even bottled mineral water. These menu items are only some of more than 150 new standard items that have been added or are being test-marketed (Pine II 1993:41). However, this type of *product proliferation* only helped increase variety—not *product customisation*. Whilst McDonald's today has broadened its ***product mix*** of existing items in order to tailor any order to whatever a customer demands it still remains uniquely ***undiversified*** (Hartley 1998:271). In other words, McDonald's today has succeeded in mass customising their end products by allowing user choices (i.e. customising services) of existing menu (standard) items, which are mass-produced through a standardised production process—which makes possible the use of local unskilled labourers. As a result, McDonald's management system extolled the power of the brand even overseas (Table 4.5).

COUNTRY	NO. OF RESTAURENTS
Japan	1,482
Canada	902
Germany	649
England	577
Australia	530
France	429
Brazil	243
Mexico	132
Netherlands	128
Taiwan	111

Table 4.5: Top ten foreign markets in number of units at year end, 1995

(Source: Hartley 1998)

As stated earlier, McDonald's applied mass production techniques to the fast-food industry, and standardised its menu, recipe, uniform and building design. A standard menu facilitates a customer's choice of standard items; a standard recipe helps unskilled workers learn how to produce the menu items; a standard uniform helps maintain a certain level of cleanliness required; and a standardised building form provides a functional space to serve their customers, as well as smoothing the flow of production in response to customers' orders. Surprisingly, Japanese housing manufacturers have also applied similar techniques to mass customise homes. For example, the menu used in the fast-food industry can be seen to parallel a catalogue that contains housing components, which homebuyers can directly select in customising their new home. As for the environmental factors (equivalent to McDonald's standardised building), the manufacturers provide housing exhibitions, such as "housing parks" and "housing information centres", which function not only as product exhibitions, but also as design consultation bases, where the clients can choose the catalogue items of standard housing components (Noguchi and Friedman 2002a). Furthermore, the provision of a manual (i.e. a recipe in the case of the fast-food industry) that helps train skilled and unskilled labourers to achieve the standard level of production and marketing operations might be of great importance in proliferating a systematic approach to the delivery of mass custom homes.

Thus, this first method (i.e. customising services to combine standard products or services) can be considered to be a 'service' system of mass customisation, which allows the user to choose standard components to customise an end product.

4.3.2.2. MASS-PRODUCING CUSTOMISABLE END PRODUCTS

This approach can be applied for the production of customisable products or services. It is especially useful where the needs of customers change over time. This tactic is to allow an end product to be customised by customers themselves, even after they purchase it. Accordingly, the components of an end product are essentially mass-produced and each end product is no different from the next as far as the production and delivery *processes* are concerned (Fig. 4.8). However, the end products themselves are "*customisable* to, and often by, each customer" (Pine 1993:180). Thus, this approach necessitates the development of customisable commodities—either products or services.

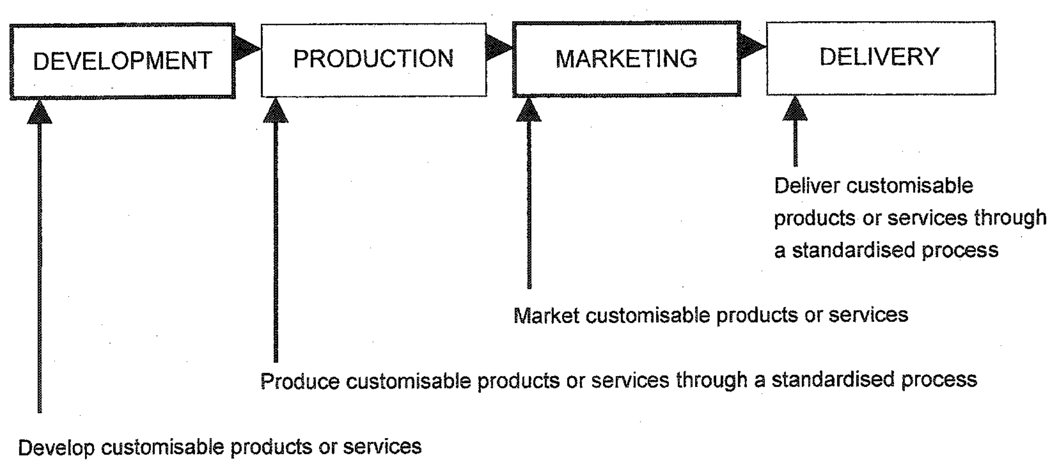

Figure 4.8: Changes in value chain to create customisable products or services
(After Pine II 1993)

Office furniture makers are focusing on customisability (Pine II 1993:181). For example, Herman Miller Inc., founded in 1923 by D. J. DePree, can be considered one of the leading providers of office furniture. In particular, Herman Miller's seating products demonstrate its leadership in ergonomic, customisable design. In 1976, the company produced the "Ergon" chair and modern ergonomic design was introduced to office seating. As well, another office chair product, called the "Equa" chair (first produced in 1984), set new standards for comfort and ergonomic support (Herman Miller 2002a). In 1994, the company also introduced the "Aeron" chair, which was lauded for its innovative design and indeed was designated a "Design of the Decade" Gold Winner in the 1990s by *Business Week* magazine and the Industrial Designers Society of America. These chairs are fully customisable (or adjustable), in terms of the seat height, armrest height and angle, backrest height, seat length, multi-position lock, forward seat angle, and tilt tension. Thus, the chairs fit a broad range of people and their needs. In addition, Steelcase Inc. also produces a variety of customisable work chairs, and their custom features extend to a number of options that the user can select, when buying a chair. These options include mechanical or pneumatic height adjustments; upholstered, plastic, or soft armcaps; armless; foot ring, foot plates, hard casters, soft casters, or glides.

This mass customisation approach applied by these companies focuses mainly on customising mass-produced end products, when they are in use. Thus, it is important to note that this presupposes that the end products themselves are *able* to be mass-produced. However, the rate of production actually determines the level of mass customisation, and some industries (including the housing industry) may be facing a situation where end products can be customised during occupancy, but the production itself does not reach the level of mass-production that yields the economies of scale, which, in turn, reduce production costs, as described in the preceding sections. Besides this point, the *customisation* approach (after occupancy) is already found in the housing industry, when put in another word—e.g. *interior flexibility*.

According to Friedman and Niessen (1991:21), the term “interior flexibility” refers to floor planning, whose objective is to maximise the potential range of limited interior space by presenting an “open floor plan”. This floor planning allows homeowners to define the division of space, based on their needs, which may change over the time. As well, the introduction of movable partitions (such as according walls and drapery) rather than permanent walls enable an open space to be converted into individual rooms. In addition, “vertical expansion” is a common method of providing extra space, which can be modified into a habitable extra room, in response to user needs or demands during occupancy. For example, the provision of an unfinished attic, as well as a basement, which can serve later as extra bedrooms. As well, garages can be converted to enlarge living rooms or additional bedroom. This method is defined as “horizontal expansion” of an occupied house (Friedman and Niessen 1991:20). In fact, these approaches to customising the interior space of a house (an end product) after occupancy are already evident in designs of American homes built in the post-war period between 1945 and 1959 (Fig. 4.9). Post-war homes were built to be compact and efficient, dealing with “two underlying realities: 1. Building a house could no longer be done using traditional methods and design because of high cost. 2. Savings in small house construction came not from major items but from meticulous attention to innumerable details” (Friedman and Niessen 1991:8).

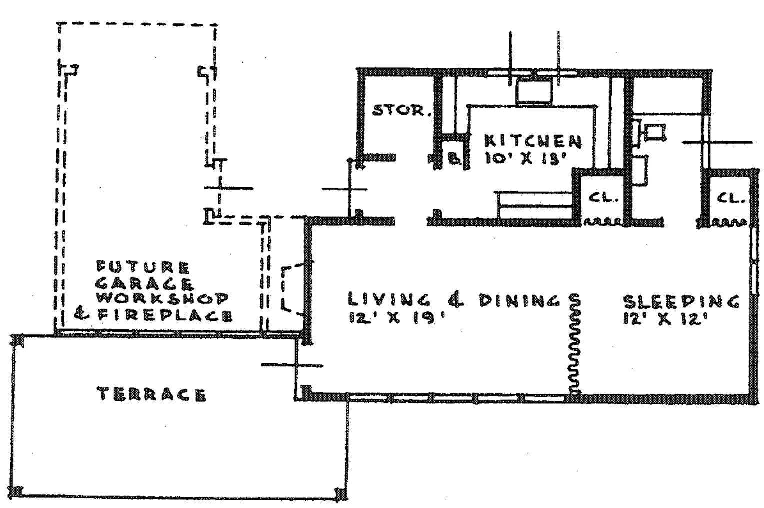

Figure 4.9: Flexible interior for a small house designed by Royal Barry Wills in 1945

(Source: Wills 1945)

In general, this second way of mass-customising products and services suggests the necessity of mass-producing customisable end products, when the product life span is taken fully into account—that is, *customisation* of an end product takes place not during the marketing stage, but during use or occupancy. Accordingly, this method requires a company to develop customisable products or services, before they are actually produced in an organisation's value chain, as described in the preceding section. Thus, it greatly affects the way of designing the components of an end product, if it needs to be customisable during occupancy.

4.3.2.3. PROVIDING POINT-OF-DELIVERY CUSTOMISATION

There is only one way to know exactly what customers want, and also to provide exactly what they want instantly and that is by providing point-of-delivery customisation. In the past decade or so, a number of companies have adopted this technique for the complete manufacture of customised end products, shifting from centralised batch production to localised (one-at-a-time) point-of-sale production (Pine II 1993:185). Accordingly, customisable portions of an end product will be produced at the delivery stage, and this temporary production phase will be added into the organisation's value chain (Fig. 4.10).

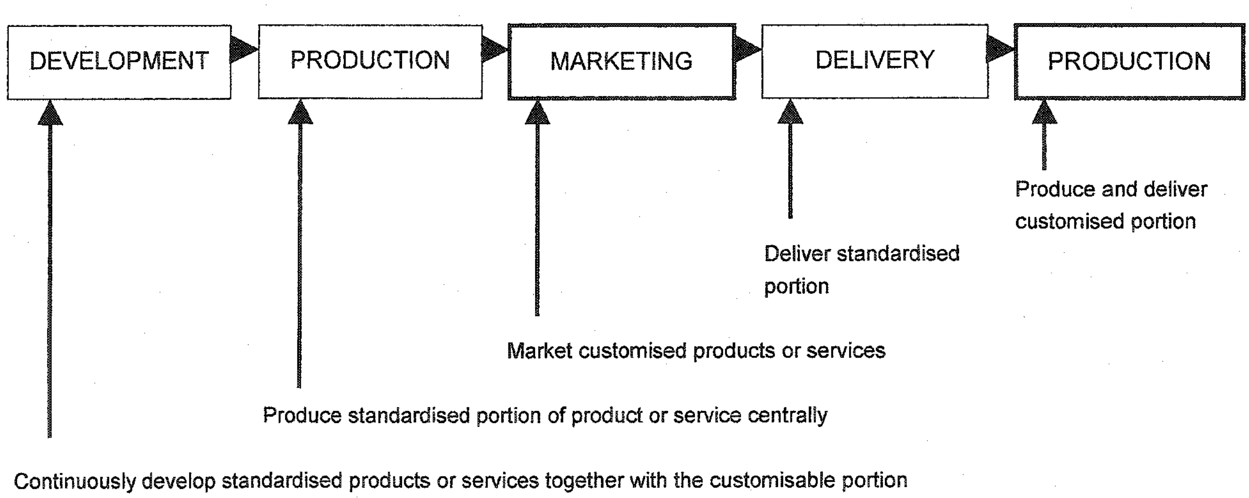

Figure 4.10: Changes in value chain to create customisable products or services

(After Pine II 1993)

Point-of-a-sale customisation is a particular favourite of sporting goods manufacturers: e.g. bowling balls, tennis rackets and ice skates. These items are basically mass-produced at central factories with an appropriate selection shipped to retail outlets. After customers decide which of these selections meets their needs, a trained expert in the shop will perform the final manufacturing step that customises the product for them. The final step includes the following touch-ups: drilling holes in the bowling ball to match the customer's hand, stringing the customer's personal choice of material on a tennis racket to exact tension specifications, adding the choice of blade to ice skates and sharpening them according to the customer's wishes.

In the broadest sense, this technique is already applied to mass housing development of today—i.e. modification of a ready-built home. For example, in the Bois Franc project, as described in Chapter 3, a variety of housing is already mass-produced in a conventional way. When buying a home, buyers can select a specific housing type with some options on room arrangements. As well, they request the builder to modify the existing house: changing the location of outlets, finishing the basement, and providing a mezzanine according to the buyers' requirements (see Chapter 3).

Essentially, this point-of-sale customisation approach limits the level of user participation in product design. Also, the flow of large-scale production is hampered, when higher levels of product customisation are required. However, this technique allows the user to directly select some options (e.g. choices of colours and materials) which help customise the end product and this may result in increasing customer satisfaction.

4.3.2.4. MODULARISING COMPONENTS TO CUSTOMISE END PRODUCTS

This last principle of mass customisation can be considered as an effective means to mass-produce individually customised products and services. Pine II (1993:196) also admitted the potential of this approach by saying that:

"The best method for achieving mass-customization—minimizing costs while maximizing individual customization—is by creating modular components that can be configured into a wide variety of end products and services. Economies of scale are gained through the components rather than the products; economies of scope are gained by using the modular components over and over in different products; and customization is gained by the myriad of products that can be configured. Essentially, this is taking the interchangeable parts innovation of the American System of Manufacturing to a new level: modular, interchangeable parts *across* products and services."

This approach may, however, require some changes to an organisation's value chain to produce modularised components, in order to mass customise end products that meet the wants and needs of individual customers (Fig. 4.11). The typological progress from simple forms of modularity creates great *variations* without significantly changing the nature of what is being sold—i.e. it allows for product customisation and fundamentally changes the structure of an end product for each customer.

To apply this approach, Pine II (1993:201) proposes six basic types of modularity for mass customisation of products and services: component-sharing modularity, component-swapping modularity, cut-to-fit modularity, mix modularity, bus modularity and sectional modularity (Fig. 4.12).

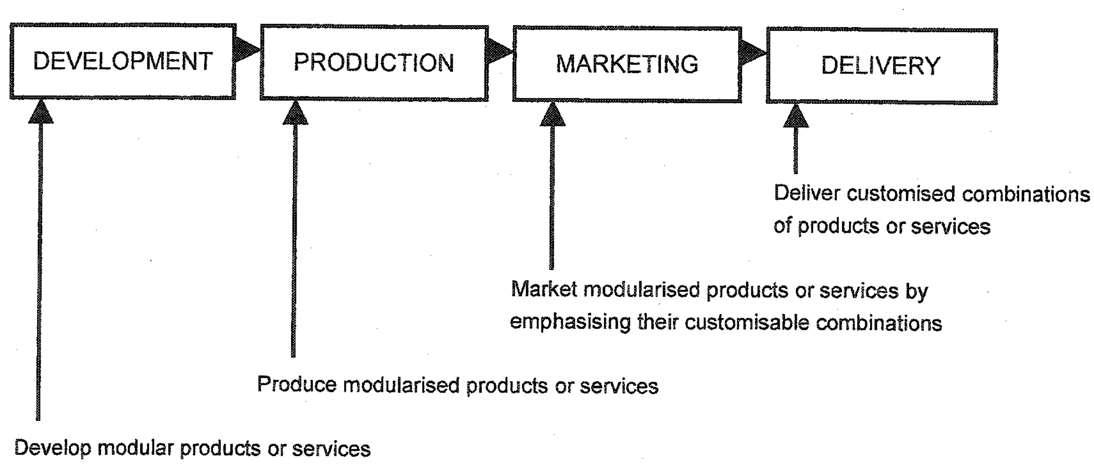

Figure 4.11: Changes in the value chain to modularised components
(After Pine II 1993)

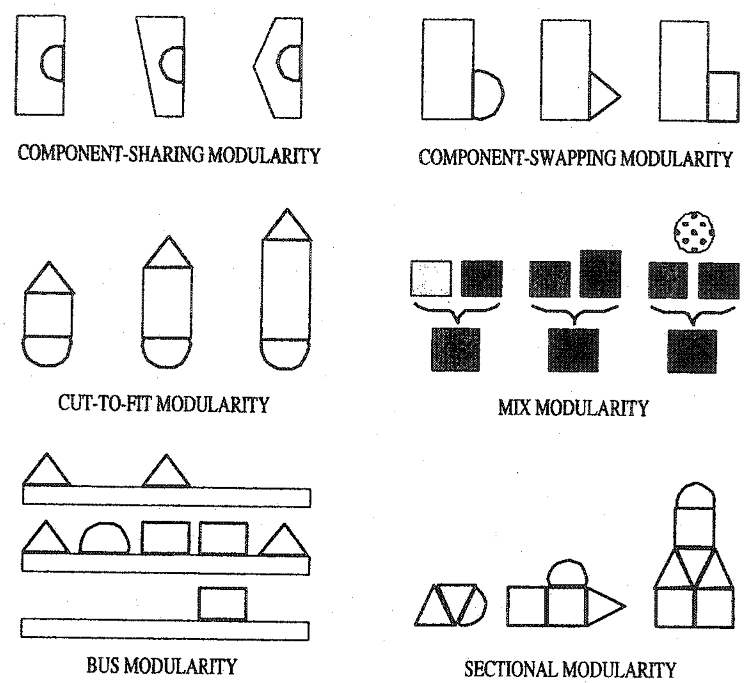

Figure 4.12: Six types of modularity for the mass customisation of products and services (Source: Karl Ulrich and Karen Tung 1991)

Component-sharing modularity: This form of modularity allows some components to be used across multiple products to yield economies of scope, and it helps put the "mass" back into a proliferating product line, whose costs are rising as fast as the number of products. However, this kind of modularity is limited in variety and it may never result in true individual customisation, until it is combined with other types of modularity. Thus, component-sharing modularity is best used to reduce the number of parts on a production line that already has high variety. This form of modularity may be useful for mass customising homes, when, for example, the interior components (such as a kitchen, bathroom, powder room, storage spaces, windows, doors, and staircase) can be shared.

Component-swapping modularity: This method is similar to the former type of modularity and the distinction between component swapping and component sharing is a matter of degree. Thus, true individual customisation may come, when there are a large number of standard components to be swapped. Pine II (1993:202) suggests that, in order to achieve the greatest effectiveness, "the component should have three characteristics: (1) it should provide high value to the customer; (2) once separated, it should be easily and seamlessly reintegrated; and (3) it should have great variety to meet different customer needs and wants." As well, this form of modularity can be applied to mass customisation of housing; for example, the exterior components of housing for the roof, wall, entrance and balcony can be customised, when swapped to the main body, in response to the homebuyers' individual requirements for housing.

Cut-to-fit modularity: This method is also similar to the previous two types, except that, in cut-to-fit modularity, one or more of the components is continually variable or needs some adjustment. Accordingly, it can be considered to be most useful for products, whose customer value rests primarily on a component that can be continually varied to match individual wants and needs. This technique may be utilised during a production stage of housing components—not for the house itself.

Mix modularity: This type of modularity simply mixes the components together, so that they themselves become something different. For example, colours of paints are mixed together; however, the components are no longer visible in the end product. To achieve mass customisation requires an operational change "from processing a recipe according to a predetermined plan to a process-to-order operation" (Pine II 1993:205). This technique can be applied to the production of some housing components—i.e. standard materials, textures, colours and functions are selected by homebuyers and these parts are mixed together to form a specific component of a house.

Bus modularity: This form of modularity uses a standard structure to which a number of different standard components can be attached in order to customise end products. The automobile could benefit from the concept of bus modularity—the basic platform chassis and wiring harness that connects all of the electronics can provide the bus structure, which everything else can plug into. Housing frames, composed of walls, floors and roofs can be considered bus structure, and all other interior and exterior components are installed to customise the home itself. Broadly speaking, this concept is relatively similar to a "support/infill approach" that John Habraken (2002:16) advocated for many years.[5] The bus structure can be considered the 'support' of a house, while other components are the 'infill' that helps customise the interior of a house. However, it is important to note that users are not allowed to customise the bus structure itself, which is usually mass-produced before reaching the market. If this is true, homebuyers, for example, cannot arrange the volume components that support the weight of housing, when purchasing a home. Thus, they are only allowed to arrange the location and nature of the infill components. This implies that total customisation (which includes not only the exterior and interior components, but also the volume or 'support' components that determine the total floor area of the house) is hardly achieved, when the bus structure is mass-produced, before the houses are actually on the market.

Sectional modularity: The final form of modularity provides the greatest degree of variety and customisation. The classical example of the sectional modularity is Lego® building blocks with interlocking-cylinder interfaces that help build a variety of objects. Unlike bus modularity, with sectional modularity, the structure of the end product can be also customised, and therefore, it provides tremendous possibilities for variety. This technique is fully applicable to modular homes—each space within a house (e.g. a kitchen, living room, dining room, bathrooms, storage, and staircase) can be considered volume components that compose a house itself. Thus, the combination of these volume components, which can be mass-produced, helps customise the bus structure, which other interior and exterior components will be added to, in order to customise the home completely. However, today's modular housing manufacturers in North America still standardise a house itself, factory producing the boxy sections, in which they merely cut a ready-designed house into some pieces. In contrast, modular manufacturers in Japan usually offer volume components that clients can directly select in customising the size and location of each room—like Lego® building blocks (Noguchi and Friedman 2002a).

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[5] The 'support' implies the components that support the load of a building, while the 'infill' is non-load-bearing parts of the building; thus, the location of the infill components can be flexibly arranged to meet the users' individual requirements for the interior space (Habraken 2002:16).

In summary, mass customisation can be achieved, based on standardisation and customisation techniques applied for products and services. In particular, four methods to mass customise end products were introduced: customising services around standard products and services, mass-producing customisable end products, providing point-of-delivery customisation, and modularising components to customise end products. However, **none of these methods are mutually exclusive**. Thus, to mass customise homes, as well as housing developments, these mass customisation techniques need to be re-integrated into a "system" for future application. Such a mass customisation system approach will be proposed in the following sections.

4.4. THE APPLICATION OF MASS CUSTOMISATION TO THE HOMEBUILDING PROCESS

The housing industry is no exception to the need for a systems approach to considering products and services. To design, build and market a home requires consideration of these two aspects. A house consists of many components, which can be referred to as 'products', while design, construction and marketing are usually considered 'services'. To generate a mass housing development, these two aspects are again involved with housing materials and systems as the products, and the design and construction of these homes as the services. In short, mass customisation, when it is considered as a "system" for designing, producing and selling a product, is impossible, if either customisable *products* or communication *services* are absent. In other words, a "**mass customisation system**" that concerns products and services can be formulated simply by using a conceptual, analogue model as follows:

$$\mathbf{MC = f\ (PS)}$$

In this model, "MC" denotes a mass customisation system itself, while "P" includes the products that can be *mass-produced*, and "S" the services that involve the interaction with users (or buyers) in order to help *customise* an end product (Noguchi and Friedman 2002b). Furthermore, this model emphasises the interrelationship between products and services and implies that these elements are not mutually exclusive, especially when applied to the designs of mass custom homes (or units), or to the organisation of a mass housing development.

Accordingly, the following section will focus mainly on *how* to apply the proposed mass customisation system to the 'unit' design. The application of the system to the 'organisation' design for housing development will be further discussed in Part II, in which the concept of mass customisation will be considered as a theoretical foundation for the development of a homebuilder's "choice" model applicable to mass housing projects.

4.4.1. MASS CUSTOM DESIGN

Today's housing manufacturers in Quebec claim that they can customise a home to the same extent as conventional homebuilders (Kirouac 2000, Julien 2000). However, their design process for the creation of custom homes does not reflect the advantages of the industrialisation of housing, in which mass production of housing components helps reduce design and construction costs, while in-factory production ensures a steady supply of quality products. Moreover, industrialisation of housing helps eliminate damage or loss of building materials from bad weather, vandalism and theft at the building site. The computer-cutting of materials also reduces the total amount of wastage—these advantages of in-factory production encourage, to some extent, sustainable housing development.

This section focuses on *how* to mass customise homes, based mainly on the author's survey of Japanese housing manufacturers who have already been successful in mass customising their industrialised housing—"their effort began in the 1960s and has become sophisticated since then" (Davis 1987:158). The author surveyed the mass customisation techniques of five manufacturers by visiting their manufacturing plants and analysing their design and production capability (Table 4.6). He found that, in order to bring the concept of mass customisation into full play, the manufacturers have been practising a 'total co-ordination' approach to design, marketing and production, which distinguishes the manufacturers from conventional homebuilders in Japan, who normally produce conventionally-built homes with little or no client participation during the design stage (Noguchi and Friedman 2002a:28).

COMPANY NAME	PLANT LOCATION	PRODUCTION
Daiwa House Industry Co., Ltd.	Nara	Steel hybrid housing (post and beam + panel)
National House Industrial Co. Ltd.	Shizuoka	Steel hybrid housing (post and beam + panel)
Resco House Co., Ltd.	Ibaragi	Concrete panelised housing
Sekisui Chemical Co., Ltd.	Saitama	Wood and steel modular housing
Toyota Motor Co.	Yamanashi	Steel modular housing

Table 4.6: Company profile

One of the most effective methods of mass customisation is to create modular components (see section 4.3.2.4) that are mass-produced, but can be configured into a wide variety of end products. This method minimises costs, while maximising individual customisation (Pine II 1993). For this reason, Japanese housing manufacturers produce a number of modular components, while developing communication tools that effectively adapt the user choices to housing. As a result, the manufacturers have succeeded in mass customising their new homes (Noguchi 2003:362). They have earned a good reputation for their industrialised housing, which the public had perceived as inferior until the mid-70s because the manufacturers had focused only on mass-producing their products with little thought to the design quality. In other words, their industrialised homes can now be referred to as "mass custom homes", bringing the advantages of mass production into full play, while maximising individual customisation in housing design (Fig. 4.13).

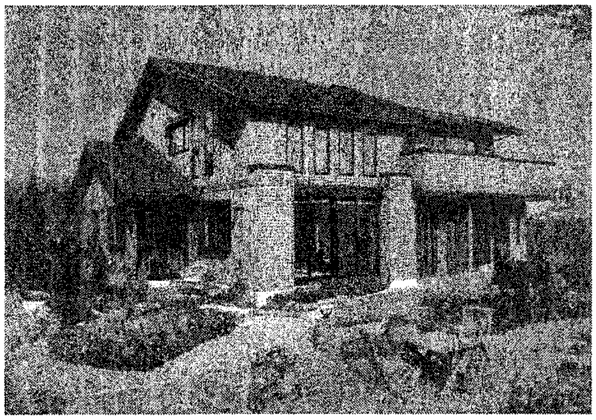 

Figure 4.13: A typical mass custom home in Japan
Left: Exterior appearance
Right: Interior open space arrangements of the living and dining rooms
(Source: Daiwa House Industry Co., Ltd.)

In general, manufacturers focus on a custom design of industrialised dwelling units, while mass-producing a variety of housing components, which users are given the freedom to choose from.[6] Thus, with consideration of the proposed system model of mass customisation, i.e. MC = f (PS), the manufacturers' standard, mass-produced housing components can be categorised into the 'product' sub-system, while the manufacturer's standard custom design process, which encourages homebuyers to select the components, can be considered the 'service' sub-system.

Broadly speaking, the service sub-system concerns communication techniques that lead users to directly participate in customising their new home, while the product sub-system covers production techniques to encourage housing suppliers to mass-produce housing components. Both sub-systems can be considered as indispensable functions of mass customising homes. In general, mass production of housing components is regarded as an effective method of reducing production costs (Sekisui Chemical 1998a:17). Moreover, the higher the in-factory completion of housing components,

[6] Although custom design helps upgrade housing quality, it, in fact, leads to an increase in design costs, while the market still demands affordable homes. However, by using a mass customisation approach, Japanese manufacturers have already succeeded in avoiding a conflict between the demands of customisation and the increase of design costs (Pine II 1993:220).

the better product quality can be maintained under optimum conditions inside the factory, where materials are not exposed to adverse outside climate (Hutchings 1996:4). In addition, the elapsed time for production, which influences the product's costs, is fully controlled. In comparison to the design approaches (such as speculative, semi-custom, and custom) that today's homebuilders, as well as housing manufacturers in Quebec apply (as described in Chapter 2), the "mass custom design" approach may have greater potential to produce quality affordable homes (or mass custom homes). The approach may increase the in-factory completion of housing components, while allowing users to participate in customising their new home.

The following sections describe each of the sub-systems in detail, in order to establish a complete set of examples of the new "mass custom design" approach that today's homebuilders and housing manufacturers in Quebec could apply to housing development.

4.4.1.1. THE SERVICE SUB-SYSTEM

In customising products, 'user participation' is considered important, and therefore, Japanese manufacturers offer design support communication services to their clients. To do this, manufacturers need as a minimum to provide a location with design-consulting staff, and to use appropriate communication tools to facilitate user choice of standard components in customising an end product. Accordingly, these fundamental 'design-service' factors can be integrated into an analogue model that explains the phenomena, as follows:

$$\mathbf{S = f\,(l, p, t)}$$

In this model, the service sub-system is denoted by "S", and is supported by the existence of the location (l), personnel (p), and tool (t) factors. Even though these elements are not necessarily interrelated (e.g. the use of Internet may eliminate the location factor), most homebuilders, or housing manufacturers, in Quebec have already been applying these during the design stage. For example, the company's sales staff explain to clients the characteristics of their new custom home and show them drawings at their office, so that they may understand how their new home looks. In this regard, the distinction between production, semi-custom and custom builders and mass custom builders can be a matter of degree.

Location factors: During the design stage, Japanese manufacturers encourage their clients to participate in customising their new home, and the design consulting service normally takes place in the company's display house located in the Housing Park or in the salon of the Housing Information Centre.

A housing park, which offers a collection of display homes built by a variety of housing companies, also functions as a unique way of advertising and marketing homes (Fig.4.14). In general, such home exhibitions are located in commercial centres readily accessible by transit or train, where model homes are installed temporarily. The size and scale of these housing parks varies, depending on the location; however, 20 to 40 housing companies commonly build their own model homes in the park to encourage potential homebuyers to become familiar with their products. Housing parks are maintained by the companies who rent a vacant site and operate the show homes. Housing manufacturers pay operation fees including land and management fees to these companies. In 1985, McKellar estimated such a fee to be approximately $19,000 per month in the case of a housing park in Sendai, which Asahi Broadcasting Company, the largest of such operators, had maintained.

Housing parks play an important role in local and regional advertising, generating remarkable sales levels. For instance, Sekisui Chemical, Japan's third largest prefabricator—with sales of 17,990 detached housing units in 1998—possesses 711 model homes that are exhibited throughout the country (Nagatomo 1999). Thus, each model house has generated 25 units of sales for Sekisui Chemical. National, another major company, sold 9,720 detached housing units from April 1998 to March 1999, while displaying 380 model homes throughout the country. The company achieved a sales ratio of 27 units per model home (Kojima 1999). Resco House, one of seven prefabricators that produce only concrete panelised homes in Japan, displays 17 model houses nation-wide, and sold 387 detached houses in 1998 (Hayashi 1999). In spite of its relatively small size, Resco House had a sales ratio of 23 units per model house that year. According to these results, housing parks play a significant role in advertising products, and model houses generally translate into home purchases with a rate of roughly 23-27 units per model home in a year.

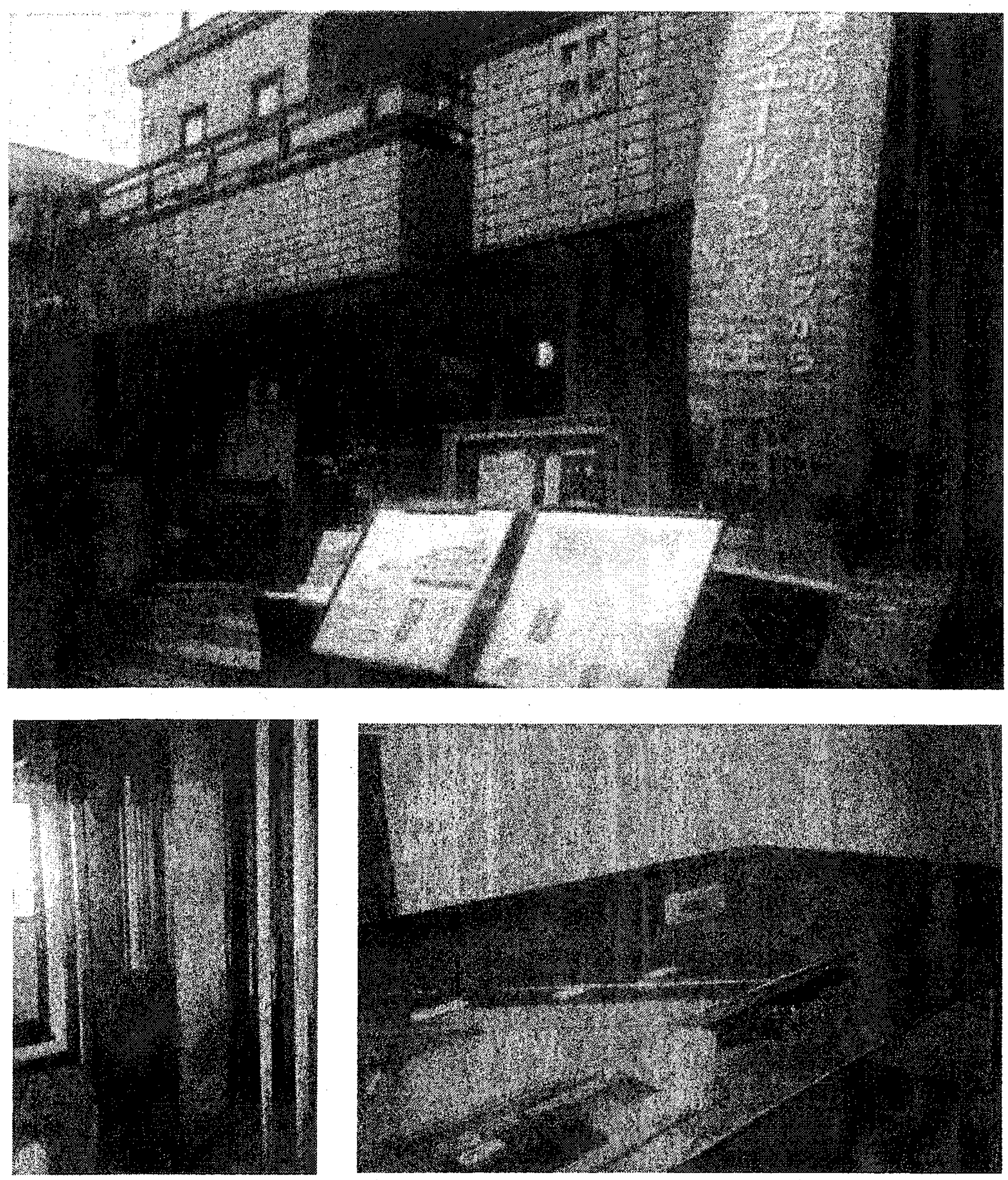

Figure 4.14. A typical display home in a housing park

Top: A display home built in the Nish-magome housing park in Tokyo

Bottom left: Interior door samples

Bottom right: A floor section displaying soundproofing techniques

Many manufacturers set up housing information centres in various parts of the country, offering technical information about housing materials, construction methods, and amenities that people can try out (Fig. 4.15).

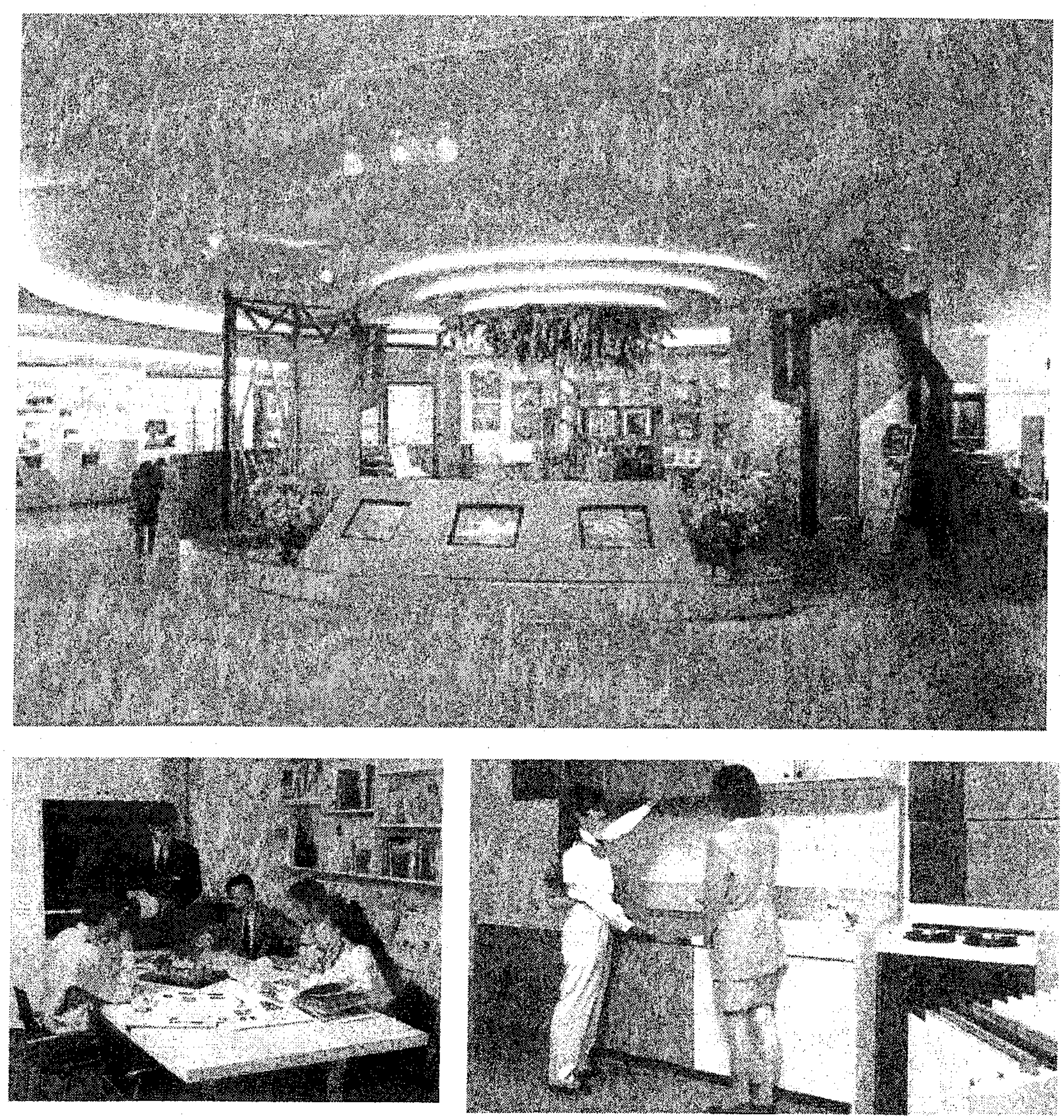

Figure 4.15. A typical housing information centre

Top: The entrance of a housing information centre located in Osaka

Bottom left: Salespersons and their clients discussing the design of a new home

Bottom right: A salesperson demonstrating kitchen utilities to her client

(Source: National House Industrial Co., Ltd. 1999 & Daiwa House Industry Co., Ltd. 1999)

The centre also functions as an exhibition and consultation base, where experienced staff make specific proposals concerning the external appearance and floor plans of a customised home by making use of advanced computer technology. Clients may see and touch the samples to confirm the superior qualities of the company's products; moreover, they learn more about the company's suggestions regarding housing facilities. As a consequence, such visual information, visits, and individual consultations with housing experts may increase the clients' faith in the reliability of the company and its products, and thus increase the likelihood that the client will select the company, when purchasing a home.

Personnel factors: In order to alleviate consumers' anxiety caused by the combination of high risk and limited experience in purchasing a home, manufacturers have been strengthening the national network of housing business by locating sales staff across the country.[7] These salespeople directly contact clients, in order to market, as well as design their products (Noguchi and Friedman 2002a:26). In the model home, for example, the salesman will not only explain the distinguishing characteristics of the company's product, but also address the client's own requirements with rough sketches of the housing layout (Mishima 2000:117). Sales staff are the company's greatest assets in reaching clients, and they are trained to assist clients in designing their custom homes by making use of various communication tools (e.g. catalogues and digital communication tools) that contain various options of standard housing components.

In addition, the user-manufacturer communication process used by manufacturers is highly standardised. Such a standard process may enable the housing makers to maintain quality services by deploying appropriate sales staff (or manual labourers). As well, it helps achieve the higher level of 'efficiency' during the design and marketing stages.

[7] Sekisui Chemical Co., for example, has 54 sales offices, that include its subsidiaries' offices, nation-wide, and is pursuing a customer-satisfaction-oriented business strategy by offering houses of demonstratively high quality and good customer service (Sekisui Chemical 1998:6).

Communication tool factors: Client needs are often difficult to conceptualise and articulate; however, interaction with possible prototypes can help identify these needs (NRC 1994:181). Japanese manufacturers use various types of housing catalogues showing possible prototypes. This enhances client involvement, offering the client a great choice of housing types and components (Fig. 4.16). The catalogues play a variety of roles in advertising and educating clients. In terms of client participation at the design stage, the catalogues mainly function as design tools for the manufacturers and the client. Through consultation with housing experts, clients can choose the housing type and components from the catalogues to design a custom home that meets their needs. Clearly, catalogues can be regarded as synthesised information sources that integrate and simplify extensive data through an inductive process.

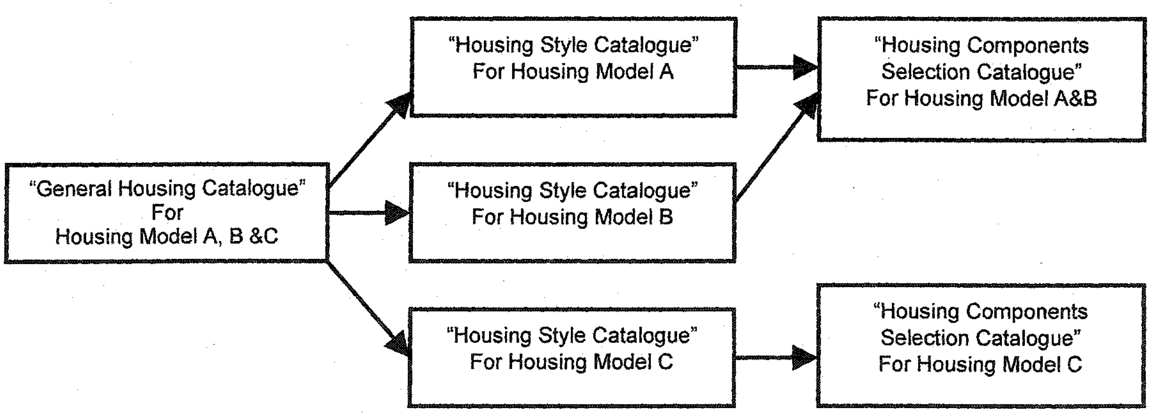

Figure 4.16: Types of catalogues and their compatibility

(Source: Noguchi 2000)

The manufacturers use two kinds of housing catalogues to help the client choose the housing type: a general housing catalogue and a housing style catalogue. The former contains information on all of the company's products in order to communicate general information about the company, while the latter offers more detailed information about specific types of products. Such housing style catalogues explain the characteristics of each commodity in terms of the design concept and technology.

Housing component selection catalogues correspond to the housing types, helping the client to select the various standard housing components for exterior and interior arrangements (Toyota 1998, Sekisui Chemical 1999). The catalogue elaborates in detail on each component in terms of material, size, colour, texture, and functions. Such catalogues do not contain the price of each component, so that the client will choose an item according to its use—not its cost. However, a cost estimate will be offered by making parallel use of a computer with these catalogues under consultation. The selection catalogues are visually integrated in order to compare the components for the client's design decision.

The use of a computer-aided design (CAD) system is important in the creation, modification, analysis, or optimisation of a design, allowing consumers to customise their choice in housing. Most housing manufacturers use a CAD system as a digital communication tool to offer flexibility in design (Mishima 2000:121). The benefits derived from applying a CAD system in the design stage include the short time elapsed between the receipt of a consumer order and the delivery of the proposal, the accuracy of material and cost estimates, and the standardisation of drafting and documentation. Ease of visualisation of a drawing boosts the client's comprehension of the layout of their new home. The interactive CAD system basically contributes to the creation of line drawings; however, advanced geometric modelling, such as solid modelling in three dimensions with shade and colour, helps to display more information on the graphic screen. Another advantage of a CAD system is data communication.[8] The purpose of data communication is to transfer data between a computer and its peripherals that can be defined as any input or output device (Sekisui Chemical 1998b:20).

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[8] Sekisui claims that their house is composed of over 10,000 parts and components. Each of Sekisui's factory has some 11,000 kinds of parts and components, and these need to be well controlled. Accordingly, in 1983, Sekisui developed a computerised control system, called SHIPS, which ensures an efficient supply of parts and components to assembly lines whilst minimising inventory.

In short, Japanese housing manufacturers apply the first principle of mass customisation; that is, they help users customise the design of their new house by integrating the standard products and services on offer (see section 4.3.2.1). Standard services include the design consulting venue, staff, and the tools—those that facilitate user selection of standard housing components, which are the main elements of the 'product' sub-system. These will be discussed in the following section.

4.4.1.2. THE PRODUCT SUB-SYSTEM

In this study, five major manufacturers were surveyed. Since their communication approaches during the design stage were quite similar, the trends within two of the manufacturers (Sekisui Chemical and Toyota) will be examined in this section in order to identify the type of standard housing components that users can directly select to customise their new home.

An important part of mass customisation is that the user directly determines the configuration of their home from choices given as client input during the design stage. This could be hardly achieved without the standardisation of housing components for the structural, exterior and interior arrangements. The concept of component standardisation can be illustrated with the fourth principle of mass customisation (i.e. *modularising components to customise end products*), or put simply, Lego® building blocks. A number of simple, modularised blocks can be connected in a variety of ways, because of their interlocking tabs and holes. Similarly, Japanese manufacturers offer a variety of housing components to their clients and then encourage them to participate in combining the components to design their new home (Noguchi 2000:37). These are arranged in a visually attractive way in a component selection catalogue to enable clients to easily choose from the many options. Housing components can be divided into three categories: volume, exterior and interior. Thus, these can be considered the main elements of the 'product' sub-system (P), which can be explained simply by using the following analogue model:

$$\mathbf{P = f (v, e, i, o)}$$

The volume (v) components are used to construct the structure of housing that determines the number and size of each room, while the interior (i) and exterior (e) components serve to co-ordinate both the decorative and the functional elements that customise a home. In addition, "o" denotes other optional equipment that enhances housing amenities. This may include air conditioning, floor heating system, automatic shutters, home security system, emergency call buttons, hand rails, home elevator, dishwashers and other electrical appliances.

Volume components: This category often applies to modular homes, because a panelised housing system does not define spatial limitations of the size and volume of interior space. However, most prefabricators, who produce panelised components, still adopt a conventional modular system for the room layout of their products, based on the size of a "tatami" mat (3' x 6'). The number of tatami mats determines the size of each room. Tatami mats, made mainly of straw, are Japanese traditional flooring mats of a standardised size, used to describe the size of a room. Manufacturers, who produce unit components, precisely standardise the size and volume of each structural unit component that is simply a box-shaped frame made of either steel or wood. Spatial variation of housing can be achieved by the combination of standard units.

Sekisui Chemical, for instance, produces modular components, standardising nine basic units (Fig. 4.17). Toyota also manufactures unit components, providing three basic units. The length of the units ranges from 224.58" (5,700 mm) to 189.12" (4,800 mm), and 253.66" (3,900 mm), while the depth is basically 94.56" (2,400 mm); however, half-sized units are also available for each. In addition to these units, Toyota offers two extensions to further increase the variation of housing forms.

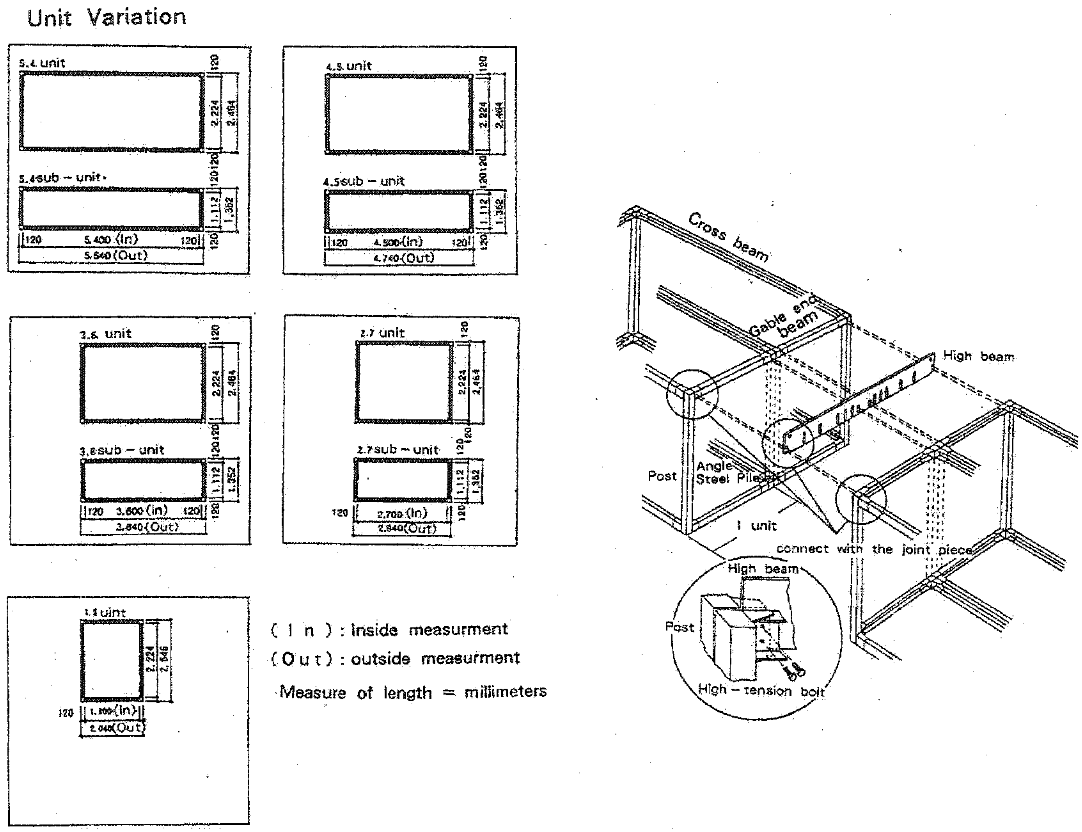

Figure 4.17: Structural unit variation

(Source: Sekisui Chemical Co. 1998b)

Manufacturers expand the variation of spatial arrangements from a limited number of structural unit components for which the size and volume of each are standardised. According to Toyota and Sekisui Chemical, there are roughly 8-10 standard unit components in use that include half-sized units and additional modules. By combining these standard unit components, manufacturers can produce a great number of individualised housing forms to meet clients' spatial requirements.

Exterior components: The exterior of a house is vital to first impressions and its personalisation also serves to enhance the sense of ownership. A house's identity is defined by its external design features, such as roofs, walls, openings, verandas, balconies, and entrances. To facilitate customisation of their homes, Japanese manufacturers offer a variety of external components to satisfy clients' preferences. This section covering exterior components primarily reviews Toyota's component selection catalogue covering four types of their housing models (Toyota 1998).

Roofs. Two types of roofs are commonly offered: a pitched roof and a flat roof. The former is a more conventional roof shape, and has a classic appeal. The latter is also becoming popular, because efficient land use is essential, and a flat roof is usable as a multifunctional space, for example, as a garden. In order to increase roof variation, the manufacturers provide several types of roofs with different shapes, colours, and textures. Toyota, for instance, produces two types of pitched roofs (gable and hipped) with an overhang of 17.73" (450mm), 23.64" (600mm), or 35.46" (900mm). In addition, they also offer five different covering materials.

Walls. Walls vary mainly in colour and texture. Many manufacturers apply walls made of ceramic-based materials that can be moulded into types of walls, which then look as if the house is built of brick or stone (Fig. 4.18). The wall surface is usually coated with weather-resistant acrylic resin that increases the durability of walls against weathering. Toyota offers six colours for brick-type walls, eight colours for sandstone-type and Oya tuff stone-type walls, six colours for Teppeiseki stone-type walls, and five colours for general masonry-type walls.

Windows. Windows not only create a sense of identity on house facades, but also allow each room to gain access to natural light and ventilation. The larger the window, the larger the room looks, because one focuses on the outside; however, the larger the window, the higher the rate of heat loss. In order to improve the heat insulation property of windows, insulating glass and sash are preferred by most manufacturers. Toyota's catalogue categorises windows into five types: large-sized bay windows, bay windows, patio windows, waist-height windows, and small windows. Also, Toyota provides additional windows to fit specific locations such as kitchens and bathrooms.

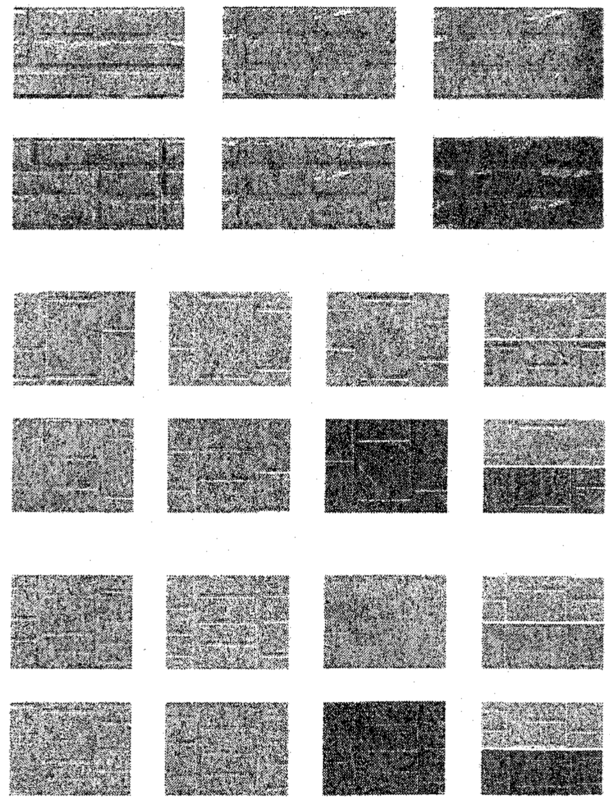

Figure 4.18: Wall variation

(Source: Toyota Motor Co. 1998)

Balconies. Verandas and balconies are prominent features of any home's exterior, and can function as gardens, hobby spaces or laundry spaces. The Japanese generally prefer to dry their laundry outside in the sunshine rather than use dryers; thus, the location of verandas and balconies is important. In the case of Toyota, the size of the veranda is determined by the combination of structural units, and the overhang of balconies is standardised at 35.46" (900 mm) from the surface of the external wall. The appearance of verandas and balconies is harmonised with the wall materials selected by the user. In addition, each housing type has its own style of balusters and balustrades (Fig. 4.19).

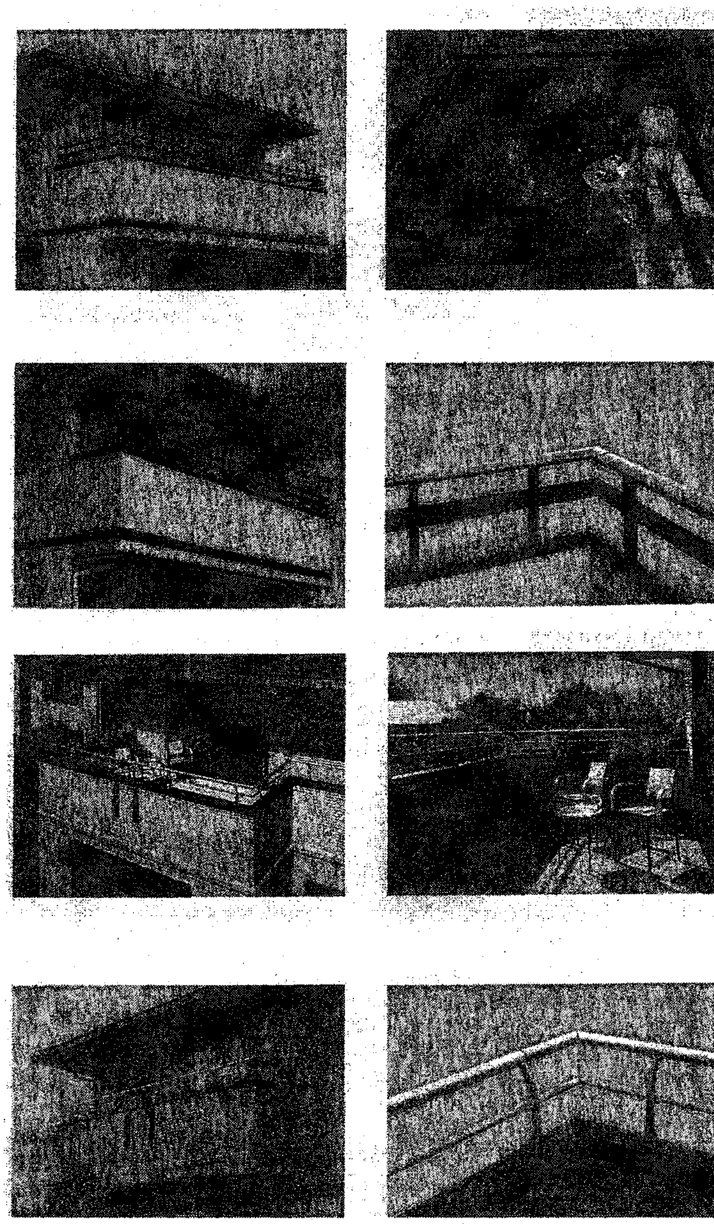

Figure 4.19: Veranda and balcony variation

(Source: Toyota Motor Co. 1998)

Entrance doors. The entrance is another important decorative feature of a house. Toyota provides two types of entrance doors, aluminium and heat-isolating steel, which are used in three types of their products. The aluminium door comes in five types: single-swinging lattice doors, double lattice doors, double decorated doors, double-slit doors, and double quasi-fire-preventive doors. There are also three types of heat-isolating steel doors: double doors, single-walled doors, and double-walled doors. As an additional option, some of these doors can be equipped with a remote control key system.

Front Entrance. The Japanese usually take their shoes off at the entrance, when entering a home, so that the entrance must have sufficient space for removing and storing shoes. The inside floor is normally built a few steps higher than the entrance floor level. Toyota provides two types of front entrance configurations: flat and alcove. In order to decorate entrance façades, a variety of frames is used. The location and size of the entrance also influence the design. To enhance the façade variation of the entrance, Toyota offers entrances with roof-shaped pediments, or located under the overhanging balcony and under the veranda with pediments.

Interior Components: Interior components are more diversified and are designed to co-ordinate the living environment for each client. The main interior components are kitchens, sanitary facilities, storage, interior finishes and amenities. In this section, the variety of interior components will be reviewed, based on the Sekisui component selection catalogue for their products known as 'Two-U home'. To meet the varied client requirements, Sekisui Chemical allows freedom in interior design and, at the design stage, introduces a complete selection catalogue that enables clients to customise interior components (Sekisui Chemical 1999).

Kitchens. The kitchen layout must be carefully designed in order to provide a convenient place for cooking, serving, storing, and cleaning. Sekisui, for example, provides two kitchen types: I-shaped and L-shaped (Fig. 4.20). The former is the simpler shape, where the sink is central and counter space extends horizontally on either side. The space is large enough for two people to use at the same time. The L-shaped kitchen is also designed to allow the user ease of movement, while cooking, and offers a shorter distance from the sink to the refrigerator and stove. As for kitchen variation, Sekisui provides eleven styles for the I-shaped and nine styles for the L-shaped. Such variation is mainly achieved by using a variety of partitions to separate the kitchen from the dining room. These partitions come in four styles: open, open hatch, hatch, and separation. Sekisui Chemical also offers fifteen different colours for kitchen furniture. In addition, many other options are available for the sink, oven, dishwasher, and storage.

Sanitary facilities. Sanitary facilities include bathrooms, washrooms and toilets, and are essential for everyday life. In Japan, these facilities are usually separated by permanent partitions, and are designed for people of all ages to use comfortably and safely. Most prefabricators use barrier-free design strategies for sanitary facilities, especially for the elderly. For instance, Sekisui equips bathrooms and toilets with handrails.

Figure 4.20: I-shaped and L-shaped kitchen variation
(Source: Sekisui Chemical Co. 1999)

Bathrooms. A bathroom consists of many components: a floor, ceiling, shower, bathtub, counter, storage, walls, doors, windows, lights, fans, and metal work. The variation in the bathroom is mainly in the size, colour, texture, and additional equipment. Sekisui Chemical produces three types of bathrooms: Ageless, New Wide and New Custom. They also offer clients a choice of 14 colours of bathtub and counter. In order to improve users' choice, Sekisui Chemical increases bathroom variation with optional equipment such as emergency call buttons, wide handrails, and shower-sliding hooks.

Washrooms. In Japan, a washroom does not usually have a toilet—the area is normally used only for hand washing. It consists of a washstand, racks and mirrors. The racks are arranged according to the size of the bathroom and the choice of door colour allows for a sense of variation. Sekisui Chemical produces three types of washrooms—one of the washrooms has a modern appearance, while the other two types are more traditional, and have laminated wood doors. In order to enrich the variation of the closets, the user can choose from a wide variety of colours and sizes (Fig. 4.21). The size variation is essentially created by means of horizontal extension of the closets, mirrors, and counter.

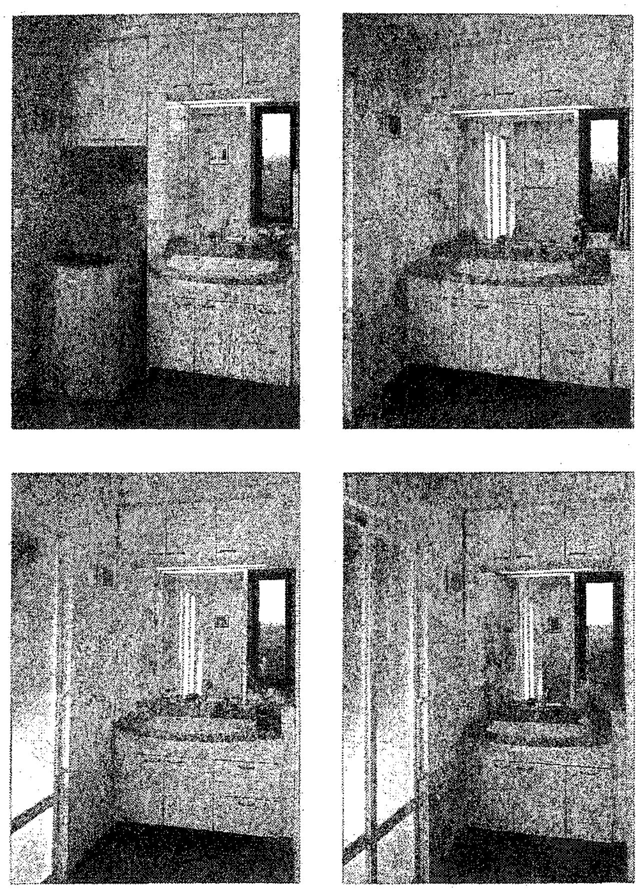

Figure 4.21: Washroom variation

(Source: Sekisui Chemical Co. 1999)

Toilets. In Japanese homes, the toilet is usually separated from the bathroom and is similar to the North American 'powder room'. It is a small space with a toilet, washstand, and mirror. Using barrier-free design techniques, the prefabricators ensure toilets are comfortable, safe, and equipped with handrails to help the user's vertical movements. In addition, they provide electric toilets with functions such as heating, cleansing, drying and deodorising. Some electric toilets are equipped with a moveable seat that helps the user to sit down and stand up. Sekisui Chemical's toilet rooms come in two sizes, standard and wide. They also provide, as standard equipment, a spot heater that is strong enough to instantly warm up the small toilet room when needed.

Storage systems. A house is required to have enough storage space for users to store their family's belongings. Usually, 10 to 20% of the floor area is used as storage space for clothes, cookware, bedclothes, books, foods, cookware, and household utensils. Sekisui Chemical illustrates the usability of storage, dividing the uses into two types: concentration and diversion. The former concerns belongings that are used seasonally and then stored away. The latter involves those items that are frequently used, and therefore, each room needs such storage spaces to allow for easy access. Once clients understand their spatial needs for storage space under the manufacturer's guidance, they will select the shelving systems as well as the entrance- and laundry-storage systems from a catalogue. In addition, storage is often placed under the staircase and in the attic in order to use indoor space more efficiently.

Closets are designed to fit every room and function as both concentration and diversion storage spaces. The location of these shelves is determined according to the client's spatial arrangements and needs. Closet variation is based on the volume that determines the capacity for storing, the shelf combination, and the door variation. Sekisui Chemical carefully categorises their closet systems into 11 types, and, with some exceptions, most types can extend to a certain size based on modules. For the horizontal extension, Sekisui Chemical standardised the width of closets at intervals of 35.46" (900mm), 39.40-47.28" (1,000-1,200 mm), 51.22" (1,300 mm), 70.92" (1,800 mm) and 86.68" (2,200 mm), while the depth is also fixed by 15.76 (400 mm), 23.64" (600 mm) and 35.46" (900 mm) modules (Fig. 4.22). In total, Sekisui Chemical offers 81 configurations and 48 door arrangements to satisfy clients' tastes and storage requirements.

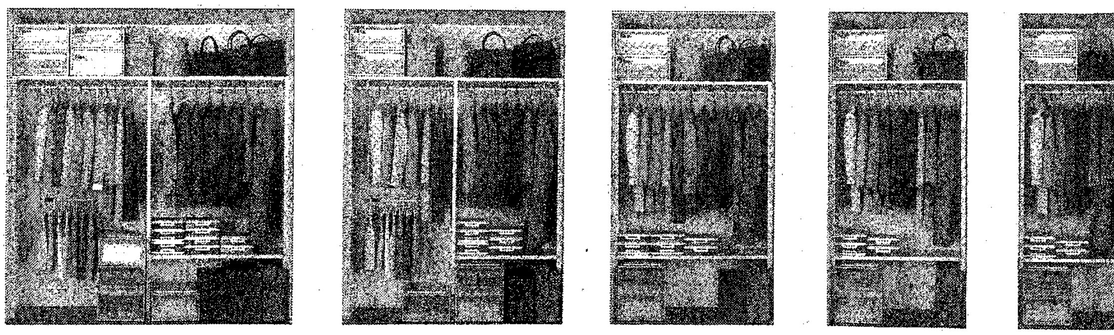

Figure 4.22: Closet system variation
(Source: Sekisui Chemical Co. 1999)

As is the Japanese tradition, people usually keep all shoes on shelves located in the entrance. Even though entrance space is limited, entrance storage should have sufficient space for all forms of outerwear. Sekisui Chemical offers several types of entrance storage spaces: a waist-height shelf with a counter on the top, a counter shelf with storage space below and above the counter, and a tall closet without a counter. Configurations and door colours increase the variety of options. Sekisui Chemical produces two basic shelf units of 17.34" (440 mm) and 29.94" (760 mm) in width. In combination with the two units, the widths of the shelves can be extended to 47.28" (1,200 mm), 59.88" (1,520mm), and 77.22" (1,960 mm). In addition to these, Sekisui Chemical provides 16 colours for doors and 4 colours for full-length mirrors to help customise the entrance storage.

Laundry space should be large enough to enable the user to launder clothes and store all the necessary laundry cleaning materials. As a result, a laundry space is usually filled with shelves for detergents and other small articles, as well as a washer, a dryer, and a washstand. However, these items are optional, because each household differs from the other in terms of the user's needs and spatial limitations. Sekisui Chemical divides their laundry space into five storage arrangements. Normally, they put one or two shelves above the washer space, and selectively, one high-level closet can be placed on either side of the upper shelf. As for the closet doors, clients can choose from 11 colours.

Interior Finishes. Sekisui Chemical has been practicing their own design approach, and the company gives clients the opportunity to co-ordinate the interior space of their new home. They provide two styles of rooms, "Decorator" and "Modern", with four colors (ecru, medium, dark and light) for flooring and moulding materials. The Decorator style is designed to represent the elegance of Western classic ambience, while the Modern style is simplified and modern. In addition to these two styles of rooms, Sekisui Chemical also produces a Japanese-style room. Most clients like to have at least one room in their house designed in this traditional way.

Flooring. Flooring helps decorate the interior of a house, and flooring materials, such as wood, carpet, and tatami mats, are preferred in Japan. Flooring varies mainly in colour and texture (Fig. 4.23). With wood flooring, the combination of wood boards that differ in size also helps increase flooring variation that the user can select. In addition, Sekisui Chemical provides more selections in wood flooring, with eight decorated floors in four basic colours, and, in total, they offer 32 types of wood flooring to their clients.

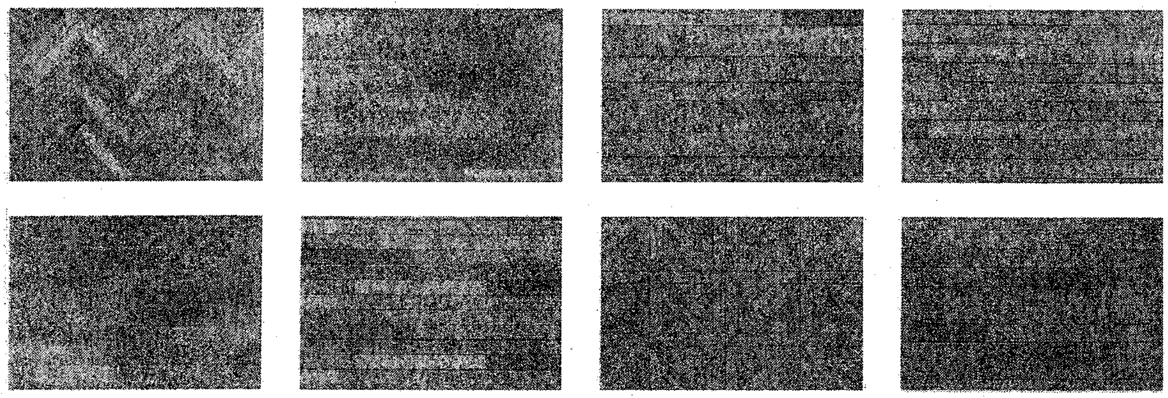

Figure 4.23: Flooring variation

(Source: Sekisui Chemical Co. 1999)

Interior doors. Interior doors not only provide visual and acoustical privacy when closed, but also allow for natural ventilation when opened. Two types of doors are normally used: swinging and sliding. Swinging doors suit most rooms and are relatively easy to install; however, they require a certain amount of space for opening and closing. In order to use the limited space efficiently, sliding doors are more effective. The parallel sliding system for the opening and closing of sliding doors does not require much space. In terms of the variation of interior doors, Sekisui Chemical provides, in total, 24 types of interior doors that are applicable to the two types of their interior arrangements (Decorator and Modern). Most of the door variants are the swinging doors, but the manufacturer also offers one sliding door. These doors vary in size and decorative pattern, some of which have transparent windowpanes that provide a visual link to adjoining rooms. In addition, Sekisui Chemical offers four colours for the laminated wood doors. Therefore, in total, 96 interior door styles are offered.

Staircases. A staircase serves as a link between levels, and is designed with consideration for safety in terms of the shape, length, and pitch of the stairs, which are determined by the height of risers and the depth of treads. Also, staircases must be safe enough to be used by people of all ages. Handrails are often put in place to prevent users, especially the elderly, from falling, and to help them climb up the stairs. As well, the treads must be non-skid. Japanese prefabricators offer a variety of staircase designs: I-shape, J-shape and U-shape. Each manufacturer differs as to the length and pitch of the stairs; in particular, such manufacturers as Toyota and Sekisui Chemical that produce modular homes standardise staircase units to fit their specific housing types. Sekisui Chemical, for instance, produces 18 different staircase units that correspond with one specific housing type (Fig. 4.24). The location of the staircase is not predetermined. Instead, during the design stage, clients choose a staircase type from a catalogue and then decide on its location.

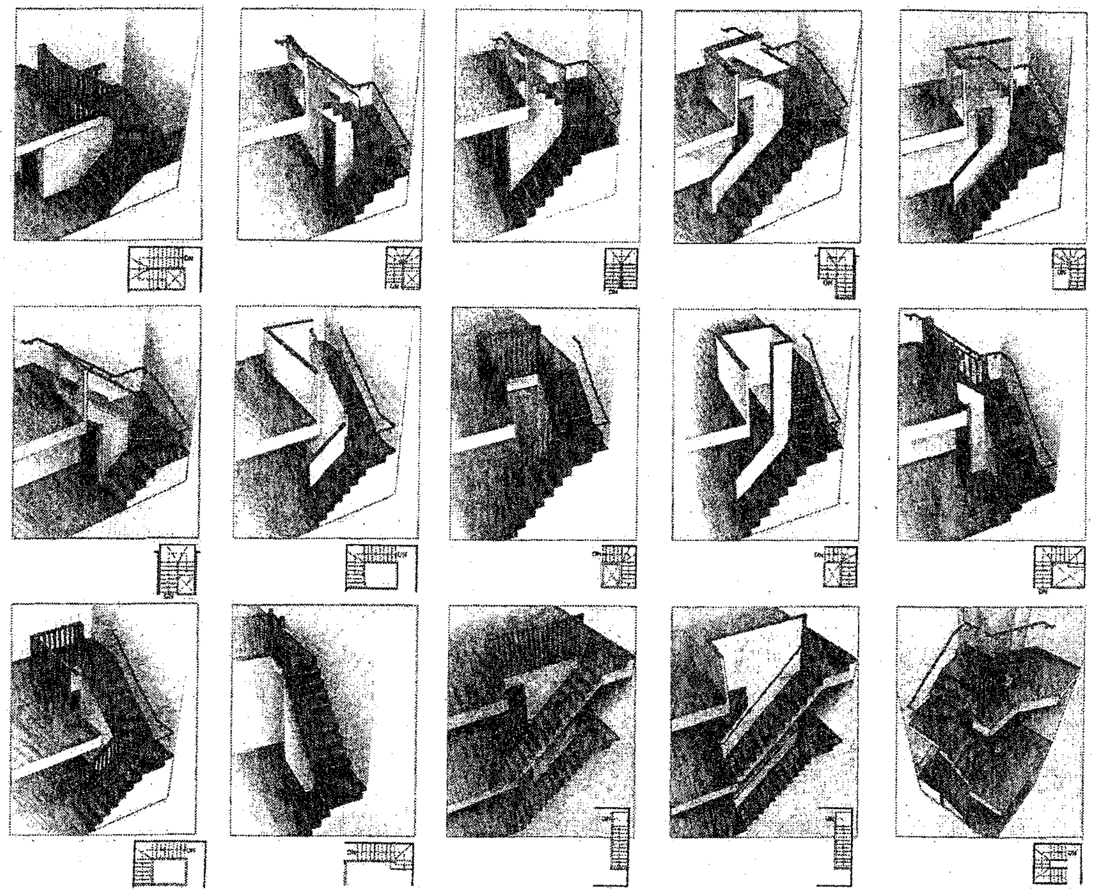

Figure 4.24: Staircase variation

(Source: Sekisui Chemical Co. 1999)

In practice, the design approach, which Japanese housing manufacturers have developed and practised since the 1960s, cannot really be categorised into the design approaches described here—i.e. speculative, semi-custom, and custom design. Rather, with consideration of the concept of mass customisation, their approach can be termed "**mass custom design**", which is a result of the combinations of three basic sets of design elements of housing: the volume, exterior and interior (Noguchi 2001). In addition, manufacturers usually provide optional equipment, in order to improve the amenity of housing. In principle, these housing components are mass-produced, but the home itself is customised by the user's direct choices of such standard components. The exterior and interior designs include sub-categories such as the roof, walls, doors, windows, balconies, and front entrance arrangements for the exterior, as well as the kitchens, sanitary facilities, bathrooms, washrooms, toilets, storage, and finishing arrangements for the interior. In addition, the variety of sizes, materials, colours, and textures available for each component, as well as the variety of amenities offered, help expand the number of housing variations. Consequently, in order to meet clients' individual requirements, the manufacturers are able to provide a broad range of housing variations for their clients without producing a number of standard model homes that are usually designed on a speculative basis. The application of the mass custom design approach may have potential to reduce production costs by achieving the *economies of scope*, which also help customise homes.

4.5. SUMMARY AND CONCLUSIONS

"Mass Customisation" is a relatively new concept, invented by Stan Davis in 1987, who re-examined the paradox of the simultaneity of opposites—particularly "of the whole and its parts." In 1993, Joseph Pine II proposed the general methods of mass customisation by referring to a variety of industries. In this chapter, based on the state-of-the-art reviews of standardisation, as well as customisation techniques, the author integrated the principles of mass customisation into a new "system" applicable specifically to the homebuilding industry.

Considering the homebuilding process that Japanese housing manufacturers use (which, in 1987, were recognised by Davis for their design and production capability of mass customisation), a mass customisation (MC) system has been proposed, composed of service (S) and product (P) sub-systems, none of which are mutually exclusive. Accordingly, the system was formulated by using a conceptual model, as follows: MC = f (SP). This model represents that, in fact, to design, build and market a home somehow requires both products and services. Regarding the service sub-system, it includes the location (l), personnel (p) and tool (t) factors that support users' participation in *customising* their new homes; this subsystem is formulated as follows: S = f (l, p, t). Even though these elements are not necessarily interrelated, today's homebuilders usually use all of the three communication factors during the design stage. Similarly, the product sub-system includes the volume (v), exterior (e) and interior (i) components, as well as other optional (o) equipment that can be *mass-produced*, formulated as follows: P = f (v, e, i, o). Again, these factors can be considered to be mutually exclusive, and some may be eliminated, according to the housing supplier's production capability.

As a result of surveying Japanese housing manufacturers, the author concluds with the fact that the manufacturers do mass customise industrialised housing—i.e. they mass-produce a variety of standard housing components (or *products*), while adopting user selection of these to customise a home using standard processes (or *services*). Accordingly, this attests to the fact that the system model proposed—i.e. MC = f (PS)—represents the principles of mass customisation, which are applied by the manufacturers, and it helps define their design approach as a "**Mass Custom Design**" method of producing a "**Mass Custom Home**" (Noguchi 2003).

However, there is an argument (while has not yet been raised in this chapter) that when clients are offered too many choices of standard components their decision-making capacity may become paralysed. Even though Japanese manufacturers have successfully integrated their design support service sub-system (using catalogues and CAD at a model house), users may still have some difficulties in selecting from the components offered, because they may not understand the true value of each. Accordingly, value analysis techniques, which *visualise* the value of each component, may facilitate user choices of *appropriate* components in customising their new home.

This issue, related to the buying decision-making process, needs to be further discussed. In addition, the value analysis techniques, which facilitate user choices, will be reviewed in Part II, in which the proposed system of mass customisation will be applied to the 'organisation design' level, in order to mass customise the design and construction systems for the supply of quality affordable homes.

PART II:

THE CHOICE MODEL
FOR MASS CUSTOMISATION

5.1. INTRODUCTION

Chapter 1 emphasised the advantages of industrialised building systems, while Chapter 4 introduced a new 'mass custom design' approach to the delivery of *quality affordable homes* that relates closely to today's market demands for housing, as discussed in Chapter 2. However, in reality, homebuilders tend to follow *routines* in their way of doing business and to be reluctant to apply (or *buy*) innovative design and construction systems to their mass housing developments, as described in Chapters 1 and 3. Their buying behaviour towards the adoption of a new product or service was surveyed by reviewing *organisational (or industrial) buying behaviour.* In consequence, the author found that organisational buying decisions are complicated and influenced considerably by the buyer's *task*- and *non task*-related concerns, and are described in this chapter. The task-related variables reflect both initial and operating costs, while the non task-related variables are those that have no direct bearing on the specific problem to be solved by the buying task—such as buyers' emotional concerns. Furthermore, the organisational buyers tend to cut down the information search for **non-programmed** decisions to determine whether or not to buy an unfamiliar product or service.

In the light of the organisational buying behaviour models reviewed, the author developed a "choice" model that attempts to help homebuilders understand the true *value* of innovative design and construction systems applicable to their housing development in conjunction with the concept of *mass customisation*, as described in Chapter 4. The model was thus termed the "choice model *for mass customisation*" and an outline of it is described in this chapter.

5.2. THE STATE-OF-THE-ART REVIEWS OF 'ORGANISATIONAL BUYING BEHAVIOUR'

To some extent, housing development involves the purchase of "products" and "services" in order to carry out a housing project. Thus, homebuilders can be considered as the industrial buying decision-makers who determine whether or not to subcontract out to familiar or unfamiliar sub-contractors (i.e. *suppliers*) who actually execute the housing projects initiated by the builders. The homebuilder's buying decision-making process is seemingly complex; thus, this section aims to identify the major *unclear* factors that considerably influence their buying decisions, based on the state-of-the-art reviews of *organisational buying behaviour*.

Webster and Wind (1972:2) defined *organisational buying behaviour* as:

> "the decision-making process by which formal organizations establish the need for purchased products and services, and identify, evaluate, and choose among alternative brands and suppliers."

The term "decision-making" used in this definition includes information acquisition and processing activities, as well as the development of goals and other *multiple* criteria to be used in choosing among the alternatives.

Moriarty and Galper (1978:1) emphasise that the organisational buying decisions differ from consumer (or *individual*) buying decisions. First, the number of people typically involved in the buying decision is greater due to the differing needs and objectives of participants and the operating functions, which they represent. Second, the major technical complexities related to the product or service being purchased. Third, the length of time involved is typically longer than consumer buying decisions due to the technical complexity of industrial buying decisions, which require more information and longer evaluations, as well as involving more *uncertainty* about product performance. Fourth, such information, proposals and purchase contracts in the organisational buying process add a formal dimension, which is rarely found in consumer buying. Fifth, the personal and organisational *risks* generated are much greater, because a larger amount of money is often involved. In addition, the organisational members, who participate in the buying function, are neither purely "economic men" nor purely emotional or irrational men; rather, they are *human beings*, whose buying decisions and behaviour are influenced by both *task*- and *non task*-related variables (Webster and Wind 1972:7).

As stated above, the organisational buying process is complex and decisions are influenced essentially by task- and non task-related variables; thus, the organisational buying behaviour models can be also classified into task- or non task-oriented models. "Task-oriented" models include those that emphasise task-related variables (such as *price*), while "non task-oriented" models are those that attempt to explain organisational buying behaviour based on a set of variables (such as emotional factors) which have no direct bearing on the specific problem to be solved by the buying task. The following sections aim to identify the task- and non task-oriented models, as well as to examine other models that successfully integrate both types of variables into an organisational buying decision-making process, in order to develop a new 'choice' model that homebuilders can practically apply for the selection of design and construction systems.

5.2.1. TASK-ORIENTED MODELS

The task-oriented models may be most useful for investment justification; however, these models may suffer the disadvantages of incompleteness, due to the absence of "non task" variables, which are also considered as important determinants of organisational buying behaviour. The *minimum price* and *lowest total cost* models may well exemplify the task-oriented models with regard to monetary considerations, while the *constrained choice* model stresses the existence of habitual behaviour that many organisations may engage in while making an industrial buying decision.

The minimum price model: A firm is often forced to obtain all factors of production at the lowest possible price and to achieve the most efficient methods of operation since a firm is usually motivated to maximise its *profit* (Webster and Wind 1972:13). The minimum price model can be considered the simplest organisational buying behaviour model.

The lowest total cost model: The lowest total cost model is essentially an elaboration that attempts to achieve the *minimum* of initial costs (like the minimum price model), as well as of additional operating costs, which are recognised as significant. In other words, the model aims to adjust the initial purchase and reflect the additional costs of product-in-use, while considering the "opportunity" costs associated with *profit* opportunities.

The constrained choice model: The constrained choice model focuses on the fact that the buyer's decisions often involve choosing from a limited set of potential suppliers. Webster and Wind (1972:15) indicate that the potential suppliers in this set are regarded as "in", while all other potential suppliers are "out". In addition, Moriarty and Galper (1978:22) emphasise that the buyer usually views the selection of an "in" supplier for its product or service to be purchased as "low risk" since the "routine purchase" reinforces the buyer's perception. Thus, any member of the buying organisation may impose constraints on the list of possible suppliers, in order to reduce the risk perceived by the buyer in the purchasing decision.

5.2.2. NON TASK-ORIENTED MODEL

Non task-oriented models generally concern the *emotional* factors influencing organisational buying behaviour, thus disregarding the rational (or *economic*) factors as aforesaid. Accordingly, this section focuses mainly on examining the *perceived risk* model, which reflects the *uncertainty* associated with the purchasing process.

The perceived risk model: *Perceived risk* is defined as "*the uncertainty that consumers face when they cannot foresee the consequences of their purchase decisions*" (Schiffman and Kanuk 1999:153). The perceived risk model was originally proposed by Bauer and is regarded as a useful framework within which to consider organisational buying behaviour from the viewpoint of the *individual* (Webster and Wind 1972:100). Furthermore, Webster and Wind (1972:101) explain perceived risk as follows:

> "Perceived risk is a function of uncertainty which an individual has about the outcome of a given course of action and the consequences associated with alternative outcomes. The individual may be uncertain either about the goals that are relevant in the buying situation or about the extent to which a particular course of buying action will meet those goals."

Furthermore, they also defined the two types of consequences ("*goal identification uncertainty*" and "*goal/purchase matching uncertainty*") regarding them as important determinants of the amount of risk perceived by the organisational buyer in a given buying situation.

In general, the major types of risk that buyers somehow perceive when making a buying decision include *performance risk, financial risk*, *psychosocial risk*, and *time risk* (Schiffman and Kanuk 2000:153; Webster and Wind 1972:101). The 'performance risk' can be considered as the risk that the product will not perform as expected or the risk to self or others that the product may be harmful. The 'financial risk' is the risk that the product will not be worth its cost. The 'psychosocial risk' represents the risk that a poor product choice may result in social embarrassment or damage to the consumer's ego or self-esteem. The 'time risk' is the risk that the time spent in product search may be wasted if the product does not perform as expected.

Webster and Wind (1972:17) indicate that organisational buyers may adopt several strategies for reducing the amount of perceived risk. First, the buyers may simply avoid a decision. Second, they may remain loyal to "in" suppliers to maintain their *routine* purchase. Third, they may extensively gather and evaluate additional information in the search of new products or services. Fourth, they may do business with well-known, reputable, established suppliers—this also reflects *brand loyalty.*[1]

In addition, they also introduced a unique approach to avoiding uncertainty in the course of the

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[1] *Brand loyalty* is a term used to describe consumers' consistent preference and/or purchase of the same brand in a specific product or service category (Schiffman and Kanuk 2000).

organisational buying action—i.e. **"split orders"**. They said "Another strategy used by organisational buyers to reduce risk is to split orders between two or more vendors, although single sourcing (especially from well-known suppliers) was found to be more common practice…" (Webster and Wind 1972:72). This approach may help buying organisations venture to apply more innovative products that meet their demand, while they can reduce risk by splitting the orders between two or more suppliers. In this case, buyers may be able to choose "in" and "out" suppliers not only for conventional products, but also for innovative products. The weight given to each of the suppliers for their products or services that will be purchased may vary according to the buying organisations' needs and demands for them.

The amount of uncertainty surrounding the purchase of a new product may be reduced through a series of "problem-solving" activities.[2] However, the type of problem solving adopted depends on the task at hand. It is classified into two buying situations: *programmed* and *non-programmed* (Fig. 5.1).

A '**programmed**' decision reflects a habitual (or *routine*) purchase, and it may lead almost immediately to a purchase, while a '**non-programmed**' decision may require more time (which can be also considered as a cost relating to the search) for the acquisition and processing of information on a product to be purchased (Blythe 1997:122). Information search usually comes from an *internal* search from memory and an *external* search from outside sources (Blythe 1997:120). The extent of the external search for information depends on a range of factors that are connected with the buyer's situation, the value and availability of the information, the nature of the decision being contemplated, and the nature of the individual (Fig. 5.2).

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[2] The term "problem solving" used in the field of consumer behaviour implies a general approach to understanding consumer decision making and it focuses on consumers' cognitive representation of the decision as a problem. Important aspects of the problem representation include consumers' end goals, sub-goals and relevant knowledge. Consumers construct a decision plan by integrating their knowledge within the constraints of problem representation (Peter and Olson 1996:717).

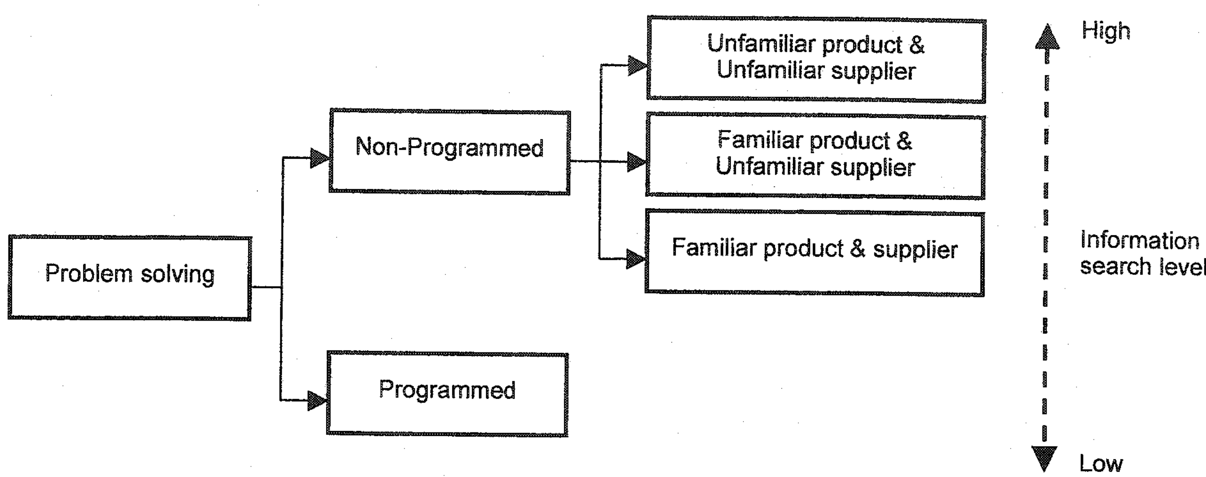

Figure 5.1: Classification of problem solving

(After Onkvisit and Shaw 1994)

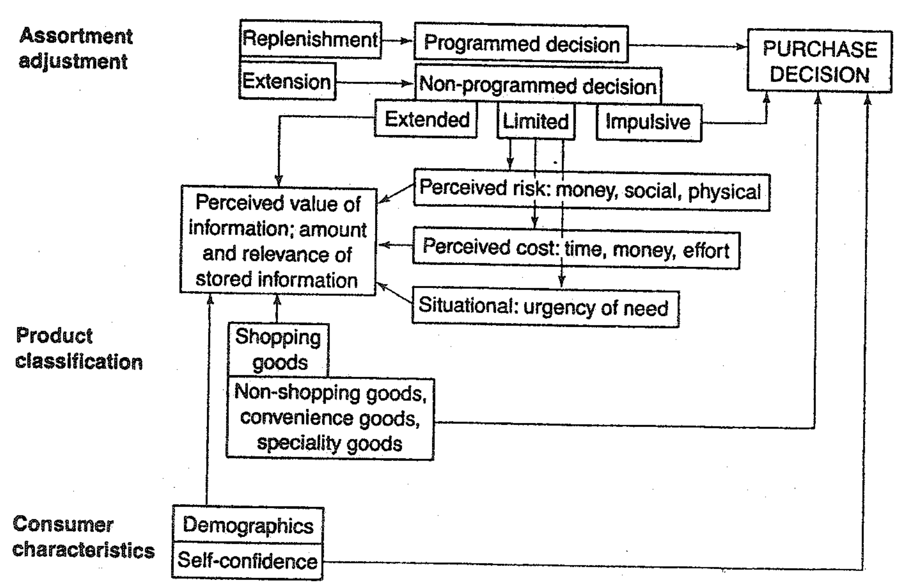

Figure 5.2: Factors affecting external search

(Source: Blythe 1997)

5.2.3. THE INTEGRATED MODELS

Webster and Wind (1972:8) admit that a model of organisational buying behaviour which deals with task and non task variables, generally takes one of two forms: a "stimulus-response" type model or a "stimulus-respondent-response" type model. The former model relates inputs (i.e. *market stimuli*) to output (i.e. *buying response*), while the latter model consists of a set of propositions (e.g. advertisement and market trends) about how the buyer responds to marketing stimuli and these propositions may provide some answers about how inputs lead to outputs. In part, these models reflect a model of a classical behavioural learning theory that indicates what goes on inside the buyer's head is a "black box" in which a given market stimulus will prompt a particular response (Fig. 5.3). However, none of these models helps clarify the way of identifying "what is happening inside the black box" (Blythe 1997:60).

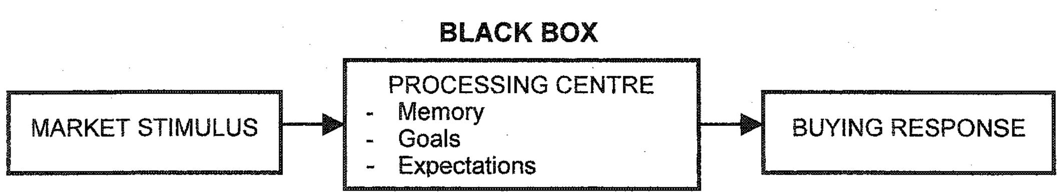

Figure 5.3: A simplified model of buying response
(After Blythe 1997)

In general, the organisational buying decision-making process is considered a *complex* process that takes a relatively long time to reach the final buying decision and involves several members of the given organisation and relationships with other organisations, based on contractual arrangements. Webster (1991:28) emphasises that:

> "Buying decisions do not just happen. They represent a complex set of activities engaged in by many members of the buying organization and result in a commitment to purchase goods and services from a vendor.

Buying is not an event. It is an organizational decision-making result of which is a contractual obligation."

In 1965, Webster published an article entitled "Modeling the Industrial Buying Process." In his article, he confined his model strictly to the process of industrial buying and outlined the following four stages:

1. Problem recognition
2. Assignment of buying authority and responsibility
3. Search process for identifying product offerings and for establishing selection criteria
4. Choice process for evaluating and selecting among alternatives

Moriarty and Galper (1978:4) recognised that this four-phase model was "a major breakthrough in understanding and documenting the *process of buying*." Furthermore, in 1967, Robinson, Faris, and Wind expanded this four-phase model into an eight-phase model:

1. Need recognition
2. Definition of the characteristics and quantity of items needed
3. Development of the specifications to guide the procurement process
4. Search for and qualification of potential sources
5. Acquisition and analysis of proposals
6. Evaluation of proposals and selection of suppliers
7. Selection of an order routine
8. Performance feedback and evaluation

Both of these approaches have successfully conceptualised the organisational buying process. Webster (1991:29) also admits that this particular description of the organisational buying decision process "is based upon field research where these [eight] activities were observed as distinct phases in the purchasing process."

It is important to note that the aforementioned models represent the outline of organisational buying processes which do not *yet* identify the complex interactions of 'task' and 'non task' variables, as well as of the individual, interpersonal (or group), organisational and environmental factors in determining buying responses to market stimuli. These elements that affect organisational buying decisions are called "buying determinants" (Fig. 5.4.)

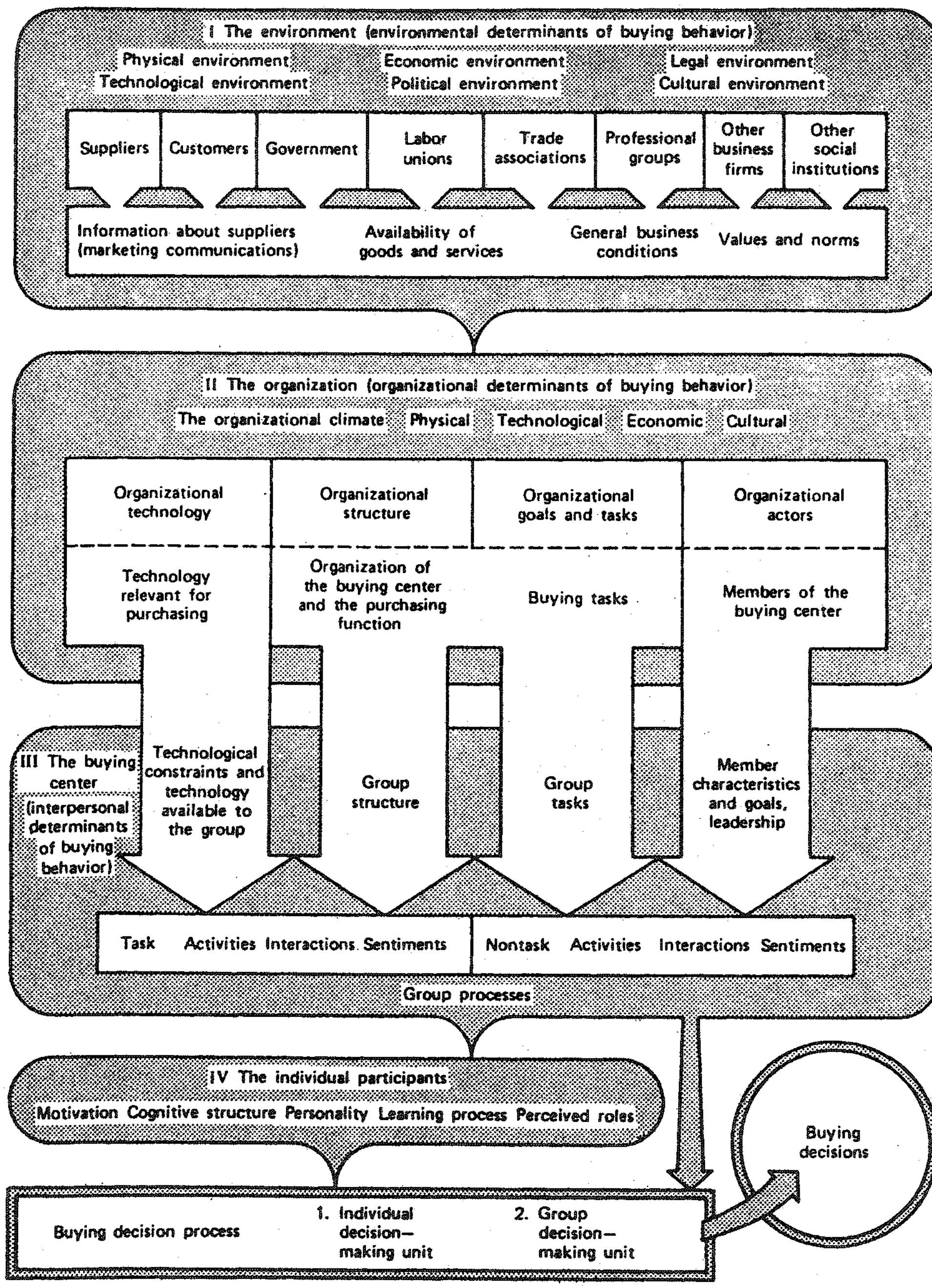

Figure 5.4: A general model of organisational buying behaviour

(Source: Webster 1991)

In 1972, Webster and Wind integrated these *multiple* influences on the buying decision into a conceptual model as follows:

$$B = f(I, G, O, E)$$

In this model, "B" denotes the buying behaviour itself, which is a function of individual characteristics: (I), group factors (G), organisational factors (O) and environmental factors (E). Furthermore, in order to distinguish between the task and non task elements of the individual, group, organisational, and environmental variables that affect the buying decisions, they expanded the model as follows:

$$B = f(I_T, I_{NT}, G_T, G_{NT}, O_T, O_{NT}, E_T, E_{NT})$$

In this model, "T" stands for task variables, while NT stands for non task variables. Task variables are those that directly relate to the organisational "buying problem", which is defined by the organisation's objectives. Non task variables are those that do not directly relate to the buying problem.

Environmental factors: Task-related environmental influences are not limited. However, the complex nature of environmental influences may reflect the interrelation of physical, technological, economical, political, and legal factors, while the non task-related environmental factors include both the influences of other organisations (e.g. the government, banks, transportation companies) and the social and cultural environment (Fig. 5.5). The values of any given society exert significant influence on the organisational buying process.

In addition, as part of the environmental factors, a growing awareness of the impact of economic activity on the physical environment (i.e. sustainable development) also needs to be taken into consideration. Webster and Wind (1972:43) emphasised that "This new concern for the physical environment will undoubtedly change the constraints within which organizational buying decisions must be made."

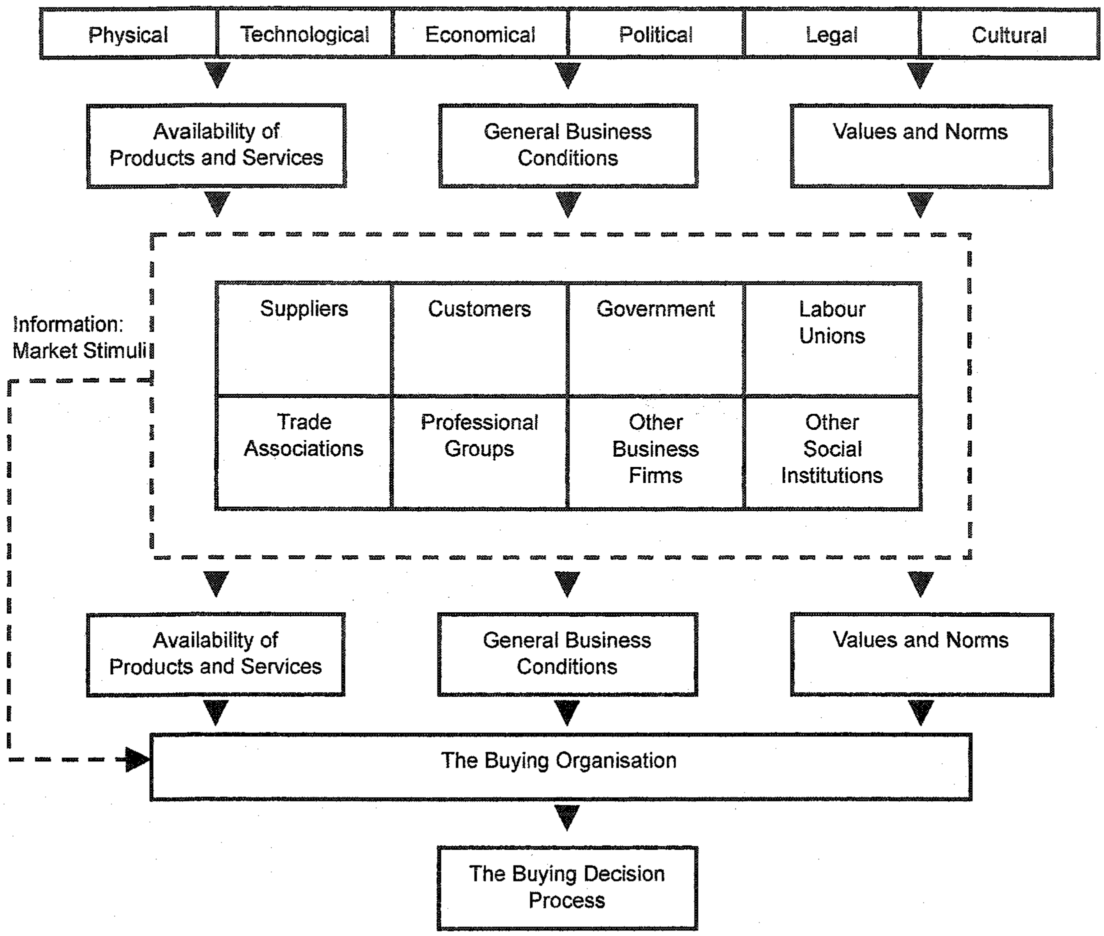

Figure 5.5: A model of environmental effects on the organisational buying process (After Webster and Wind 1972)

Organisational factors: The task-related organisational factors mainly include the organisation's policies which provide the criteria as to the kind of materials to be purchased, as well as product quality specifications (Webster and Wind 1972:34). On the other hand, organisational policies, which relate to buying activities, can be also formulated based on non task factors, such as the favouring of local businesses and preferences for dealing with "in" suppliers.

Interpersonal (group) factors: Interpersonal influence is defined simply as the influence of one person on another. Such interaction between individuals yields a shared set of objectives, values (norms) and expectations (Webster and Wind 1972:75). Furthermore, Webster and Wind (1972:76) summarise a number of key factors related to interpersonal behaviour: "(1) the multiplicity of and interdependency among the factors affecting group processes and outcomes; (2) the fact that the essence of a group process can be described as the mutual relationships among activities, interactions and sentiments; (3) the relevance of both task and non task activities, interactions and sentiments; and (4) the nature of the output (consequences) of the group process, which includes not only the accomplishment of the task but also the satisfaction and growth of both the group and the individual" (Fig. 5.6).

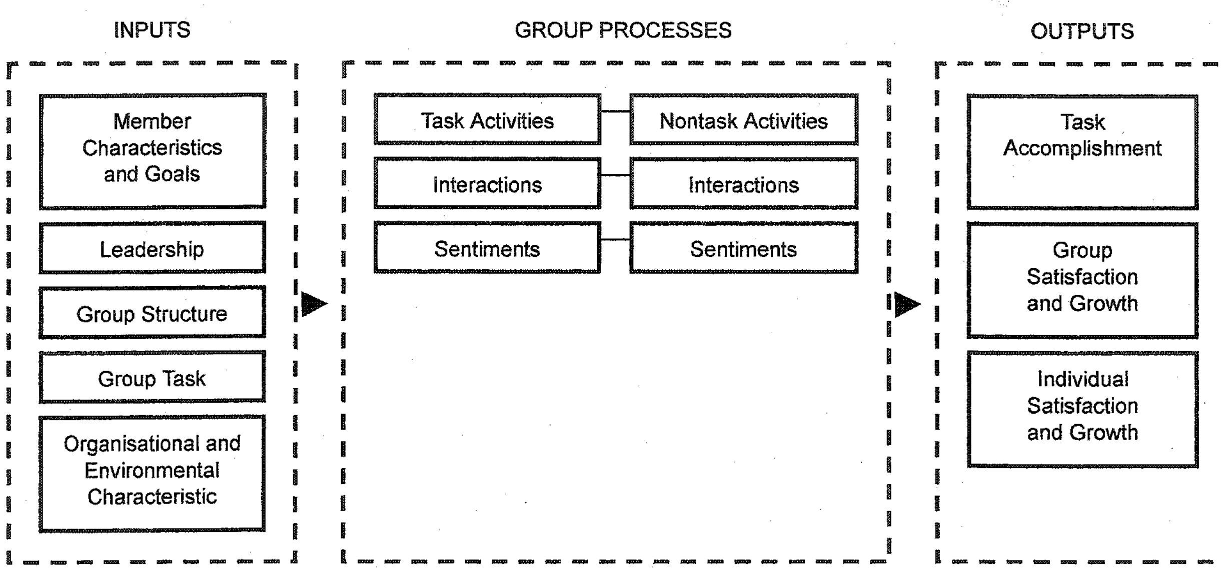

Figure 5.6: A simplified model of interpersonal determinants of buying behaviour

(After Webster and Wind 1972)

Individual factors: Only the person can think, feel and act, even though each aspect of individual behaviour may be affected by the people, tasks, structure and technology of the organisation which the individual belongs to. Webster and Wind (1972:89) point out that "individual behaviour is a function of three factors: (1) the person's personality, motivation, cognitive structure, and learning (habit and attitude formation) process; (2) his interaction with the environment situation; and (3) his preference structure and decision model." Furthermore, they also indicate that individual factors in organisational buying include the person's age, income, education and professional experience. In reality, some of these factors may generate non task variables that affect buying decisions.

In short, industrial buying decisions are influenced by task and non task variables. Task-oriented models focus solely on the "economic" choice, while non task-oriented models generally concern the "emotional" factors—thus, this study examined a perceived risk model. Both sets of factors must be taken into consideration when organisational buying decisions are in question. Accordingly, this study also examined an integrated model of organisational buying behaviour developed by Webster and Wind in 1972. Their model is valuable for identifying a number of task- and non task-related "buying determinants" at the environmental, organisational, interpersonal, and individual levels.

The industrial buying behaviour models reviewed are useful in organising a decision-making *process* for the selection of design and construction systems with consideration of the presence of *multiple* evaluation criteria that are coupled with the risk and uncertainties associated with estimating future outcomes. However, the organisational buying behaviour models do not explain any analytical evaluation *techniques* for the selection of alternatives. Thus, as stated in Chapter 1, "value analysis" techniques, which take account of both task and non task variables in order to help decision-makers find the most optimal alternative, merit being integrated into the choice model that will be outlined in the following section.

5.3. STRUCTURING A CHOICE MODEL *FOR MASS CUSTOMISATION*

As reviewed in the preceding sections, an organisational *buying response* is assumed to be the result of a *market stimulus*. In fact, homebuilders (seen as formal *organisational buyers*) need to take the responsibility for the selection (or *purchase*) of sub-contractors (or *suppliers*) who actually carry out the housing projects that the builders initiate. In other words, homebuilders make some buying decisions for the 'design' and 'construction' systems to be applied, in order to design and build homes that must meet the market demands for housing (Figs. 5.7).

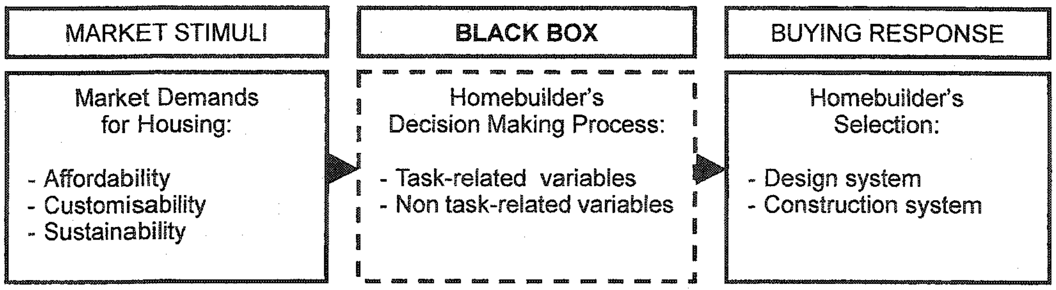

Figure 5.7: A model of the homebuilder's buying response

However, it is questionable whether homebuilders respond simply to the market demands for housing when selecting the design and construction systems for their housing development.

As described in Chapter 2, in today's housing market, *quality affordable homes* are still in great demand. Housing affordability reflects the selling price, which is affected by direct and indirect costs. The former represent material and labour costs that to some extent relate to construction time, while the latter include the external costs, such as financing, tax, land cost, overheads and profit. The notion of housing quality may concern a wide range of 'design' and 'product' features, as described in Chapter 2. Thus, the 'product quality' of housing represents the physical quality that the expected work of a house being purchased must perform, while the 'design quality' of housing reflects, to some extent, the homebuyer's individual needs, desire and expectations in design—i.e. *customisability*. In addition to these aspects, *sustainability* is also a matter of concern in today's homebuilding industry. Except for product quality (i.e. insulating properties and air-tightness), the housing type (i.e. attached, semidetached or detached housing) can be considered as one of the most influential factors in producing energy-efficient homes, as discussed in Chapter 2.

In order to produce quality affordable homes, homebuilders may wish to apply industrialised building systems as the industrialisation of housing has the potential to eliminate building site inconveniences, such as bad weather, vandalism and theft, all of which generally affect construction time, quality and cost, as described in Chapter 1. In addition, the computer-cut of building materials may also help reduce the amount of wastage and contributes to sustainable development. In reality, builders rarely use innovative building technologies and tend to build homes in a *conventional* way, in which the productivity is somewhat considered to be inefficient and the construction cost is greatly affected by economic fluctuations—i.e. *inflation*. In general, inflation contributes towards increasing labour and material costs that, in turn, increase to some degree the selling price of housing, as discussed in Chapters 1 and 3.

Accordingly, in order to produce *quality affordable homes* that reflect today's housing market demands, industrialised building systems should ideally be incorporated with the builder's mass housing development that yields *economies of large-volume work*. However, this is impossible if homebuilders, who generate and supervise the project, do not fully appreciate the advantage (or *value*) of innovative construction technologies over that of traditional site-built construction.

The major barriers that hinder today's homebuilders from adopting and implementing new design and construction approaches to their homebuilding activities can be enumerated as follows:

1. The small size of a homebuilding firm keeps staff extremely busy—pressures of multi-tasking and time-constraints
2. Homebuilders tend to follow a *routine* that maintains great efficiency for their activities
3. Homebuilders are not risk-takers; rather, the way of doing business is incentive-oriented, based on an *economic* choice

Homebuilders tend to be reluctant to adopt new construction technologies to their mass housing development, because a departure from their routine activities may impact considerably on their administrative burdens. The homebuilding industry, like other industries, remains unwilling to pay for *information*, even though it is considered "the integrator of the resource system" (Charney et al. 1971:168). Thus, builders may cut down the information search for '**non-programmed**' decisions on the purchase of unfamiliar design or building systems simply because searching for information takes too much time, money, and effort. In order to help homebuilders understand the true *value* of other possible alternatives applicable to mass housing development, their buying decision-making process needs to be well '**programmed**'. Furthermore, two types of the non-programme decision's consequences (i.e. "goal identification uncertainty" and "goal/purchase matching uncertainty") which generate the greatest amount of *risk* perceived by organisational buyers must be eliminated.

Accordingly, the main purpose of the choice model to be proposed is to systematise a decision-making *process* for the selection of alternatives that helps *mass customising* an end product, such as a housing unit or development. In this context, the term "buyer" represents a "homebuilder" who needs to *make* or *buy* certain products and services (i.e. design and construction systems) in order to carry out a housing project (Fig. 5.8).

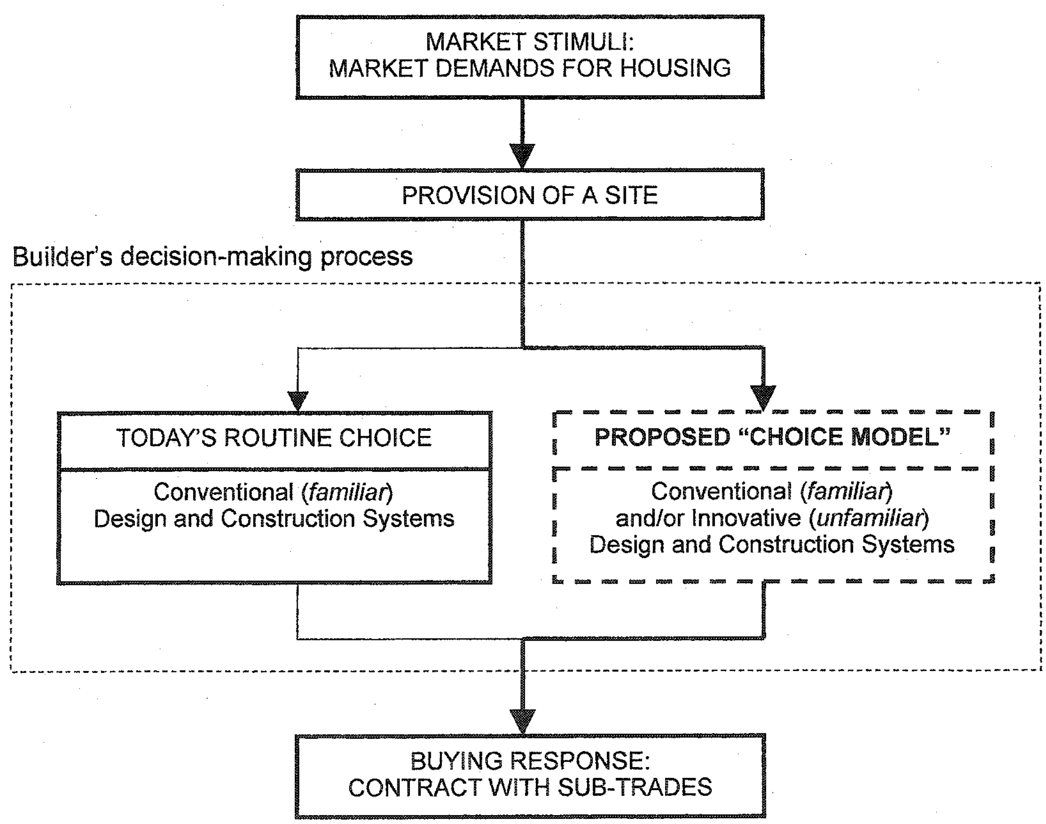

Figure 5.8: A model of the homebuilder's decision-making process for the selection of design and construction

systems

However, the choice model will also be designed to help a "homebuyer" select certain alternatives (i.e. the standardised housing components) in order to mass customise homes, as described in Chapter 4.

In addition, the major objectives of the choice model are to form some alternatives that help mass customise an end product, according to the market stimuli, as well as to evaluate the *value* of the given alternatives. The model attempts to help *buyers* select optimal alternatives in accordance with the objectives and specifications established during the decision-making process within the choice model that accommodates their *task*- and *non task*-related choices. Hereafter, it will be termed the "choice model *for mass customisation*" that will focus mainly on:

1. Identifying the need for buying or making actions
2. Formulating the objectives and specifications for making optimal choices
3. Generating the alternatives for mass customising an end product
4. Evaluating the given alternatives
5. Selecting the preferred alternatives

In order to mass-customise an end product, these five stages within the choice model may need to be followed cyclically. As well, the specific nature, importance of, and interrelationships among these stages may vary slightly across users of the model. However, the choice model may provide a 'general' starting point for integrating the homebuilder's non-programmed decision-making process when choosing the design and construction systems for mass housing development.

Identification of need: Homebuilders build homes that *need* to meet the market demands for housing. These external demands function as *market stimuli* that prompt them to generate housing projects. Thus, there is no clear-cut distinction between the two—i.e. producers' *need* and buyers' *demand*. In reality, market demands for housing (which can be considered to be the homebuilders' need to produce marketable homes) must be identified when the project is initiated. In addition, housing development involves a wide variety of products and services; thus, homebuilders make a decision whether or not to produce the product and service internally or purchase them from outside suppliers. Homebuilders perceive a problem that can be solved via the buying or making actions. Thus, this stage aims to identify the 'local' market demands for housing which, in turn, help homebuilders understand mainly *why* and *what* they 'need' to buy or make (e.g. certain products and services) in order to carry out their housing project that must meet the external demands. In other words, this stage is to eliminate the "goal identification uncertainty."

Formulation of objectives and specifications: The need for the buy-or-make decisions is defined with sufficient clarity to permit the drawing up of *specifications* for the buying or making actions. Specifications grow directly out of the definitions of the need, which help identify certain *objectives* that the buy-or-make decisions must meet. In other words, this stage is to identify the homebuilder's *task*- and *non task*-related concerns that will be taken into consideration for their future buying or making actions. As well, it serves to establish the *multiple* evaluation criteria including both concerns for the *value analysis* of the given alternatives, in order to eliminate the "goal/purchase matching uncertainty."

Generation of alternatives: After the multiple evaluation criteria are established, a set of alternatives, which contribute towards mass customising an end product that corresponds to market stimuli, will be generated. In the context of the choice model *for mass customisation*, alternatives are the products (and services) readily available on today's market or those that homebuilders can obtain information relating to the evaluation criteria developed in the preceding stage. According to the concept of mass customisation, a new combination of existing or standardised elements helps make the end product mass-customised, based on the buyer's direct "choices" that correspond with their objectives and specifications for the buying or making actions.

Evaluation of alternatives: The *value* of the alternatives formed in the preceding stage will be analysed in terms of the task and non task variables that influence the buyer's decision making. Task variables basically reflect the characteristics of the given alternatives with regard to the cost, quality, and time factors that correspond to the *specifications* formulated in the second stage, while the buyer's *objectives* include the non task variables. It is important to note that the choice model *for mass customisation* focuses on analysing the *value* that represents not only the cost of the products or services in question, but also the buyer's needs, desires and expectations.

Selection of alternatives: The main purpose of this stage is to help the buyer understand the value of the given alternatives by *visualising* it in a simple form. The 'value visualisation' of the given alternatives may, to a considerable extent, facilitate the buyer's final decision for the selection of the preferred alternatives, in response to market stimuli.

Furthermore, based on the specific tasks assigned to each of these five stages in the choice model *for mass customisation*, these can be classified widely into two phases: *mass customisation* and *value analysis* (Fig. 5.9). The 'mass customisation' phase includes the first three stages of the proposed choice model—i.e. identification of need, formulation of objectives and specifications, and development of alternatives. In the broad sense, this first phase plays an important role in developing a set of alternatives that contribute towards mass customising an end product. On the other hand, the 'value analysis' phase covers the last two stages—i.e. evaluation and selection of alternatives. Thus, this phase actually helps evaluate the value of the given alternatives, visualising the value in order to facilitate a buyer's final decision for the selection of the preferred alternatives.

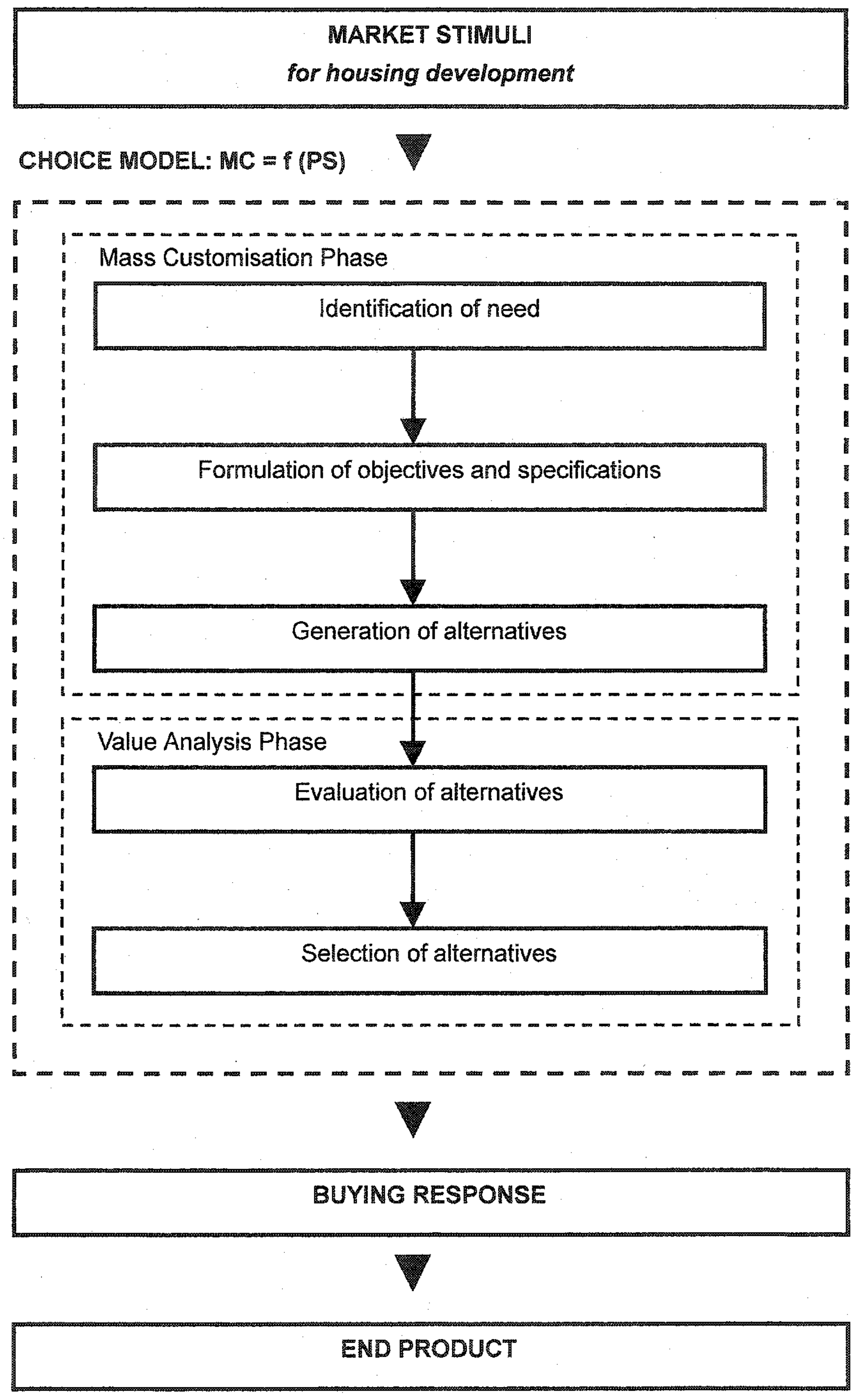

Figure 5.9: The outline of the choice model *for mass customisation*

5.4. SUMMARY AND CONCLUSIONS

Housing development involves the purchasing *actions* for products and services. Thus, a homebuilder, who can be regarded as a formal organisation consisting of a number of employees, needs to make buying *decisions*. Accordingly, the models of ***organisational buying behaviour***, which relate to an industrial buying decision-making process, were reviewed. These indicated that **task**- and **non task**-related factors have a significant influence on the buying decision-making process. The task-oriented models reviewed reflect an organisation's "economic" choices, while the non task-oriented model of *perceived risk* indicates that the large amount of risk and uncertainties associated with the purchase of a new product or service often functions as a hindrance that discourages an organisation from adopting it. In order to reduce the amount of **risk** perceived by buying organisations due to the **non-programmed** decisions, the industrial buying decision-making process needs to be well **programmed**.

In fact, today's homebuilders rarely adopt (or *buy*) new construction approaches which to some degree interrupt their production-consumption cycle, which can be defined as *routine*, even though innovative building technologies have the potential to produce *quality affordable homes* that correspond to today's market demands for housing. With consideration of organisational buying behaviour, homebuilders seem to be unwilling to pay for *information* and to restrict their information search to the programmed decisions, since the search for information needed for the 'non-programmed' decisions of whether or not to purchase unfamiliar design and construction systems takes too much time, money and effort. Thus, **the homebuilders' buying decision-making process needs to be well 'programmed'** in order to bridge the communication (or marketing) gap extant in today's homebuilding industry.

In this chapter, the conceptual framework (or decision-making *process*) of a choice model was developed based on the organisational buying behaviour models reviewed. The choice model attempts to help homebuilders understand the true *value* of possible alternatives (i.e. innovative design and/or construction systems) that contribute towards *mass customisation* of the end product (i.e. a housing unit or development), in response to today's market demands for housing. Thus, it was termed the "**choice model *for mass customisation***" consisting of five consecutive stages: identification of need, formulation of objectives and specifications, generation of alternatives, evaluation of alternatives and selection of alternatives. Furthermore, according to the tasks assigned to each stage, these steps can be classified broadly into two phases: *mass customisation* and *value analysis*. The former emphasises the process that helps develop possible alternatives that help to mass customise an end product, while the latter serves to evaluate and visualise the value of each of the given alternatives, in order to facilitate the buyer's *choices*.

The organisational buying behaviour models were helpful in developing the decision-making **process** of the choice model *for mass customisation*; however, they do not involve any analytical *techniques* that answer the *how* of each event that deals with the buyer's task and non task variables occurring in the process. Accordingly, some state-of-the-art decision-making tools (i.e. *value analysis* techniques) will be integrated into the choice model. Each stage of the model will be detailed in Chapter 6 and 7.

6.1. INTRODUCTION

Chapter 5 outlined the choice model *for mass customisation*, which was developed within the framework of organisational buying behaviour. However, although the decision-making *process* of the choice model was defined, none of analytical *techniques* that actually deal with the buyer's task- and non task-related variables occurring within the process were identified. Thus, this chapter introduces selected analytical techniques applicable to the initial phase of the choice model, i.e. the 'mass customisation' phase, which contains the first three stages of the proposed choice model:

1. **Identification of need**
2. **Formulation of objectives and specifications**
3. **Generation of alternatives**
4. Evaluation of alternatives
5. Selection of alternatives

The main purpose of this phase is to assist homebuilders in generating *alternatives* (i.e. products and/or services) that contribute towards the mass customisation of an end product (i.e. a housing unit or development). The techniques applied to this phase include those that help **visualise** a chain of events that attempt to identify not only the buyer's task- and non task-related *objectives* to be accomplished, but also the *objects* to be purchased in order to achieve these objectives. This visualisation of the chain of events may have the potential to eliminate the "goal identification uncertainty" and "goal/purchase matching uncertainty" associated with buying decisions. In addition, within the framework of set theory as well as of mass customisation, the author developed a mathematical formula that rationalises (or *quantifies*) the relationship between the levels of standardisation and customisation (as discussed in Chapter 4). This will be also discussed in this chapter.

6.2. IDENTIFICATION OF NEED

Assuming that homebuilders do not wish to spend an extensive amount of time and money on further data gathering and analysis, it is essential to determine how much *market research* should be undertaken in order to identify perceived market stimuli. In other words, the problem is in deciding how much is *enough* and this needs to be further discussed.

Greer and Farrell (1988:74) indicate that benefits from market research are not objectively measurable; however, there is a point at which research and analysis must be carried out and a "go or no-go" decision made by the investor (Fig. 6.1).

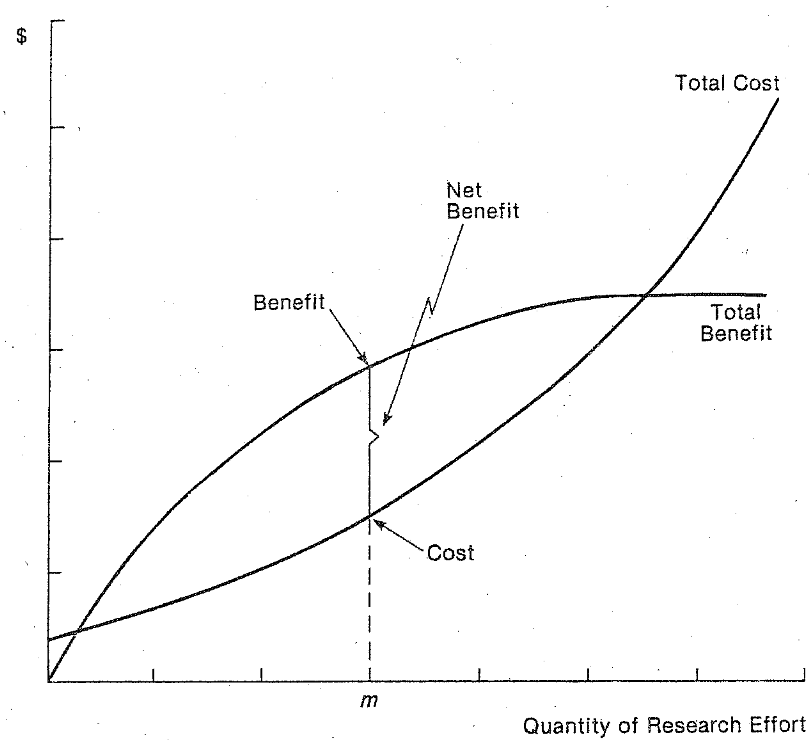

Figure 6.1: Cost, benefit and optimum level of research effort

(Source: Greer and Farrell 1988)

As shown in Figure 6.1, expected research costs and benefits are both measured on the vertical axis. The vertical distance between the cost and benefit functions represents the net benefit, which will be derived from the research undertaken. Maximum net benefit results from the amount of research and analysis represented by point *m* on the horizontal axis. This indicates that additional increments of research and analysis activities beyond this point (*m*) cost *more* than the incremental benefit; thus, the net benefit from such activities will be reduced.

The following sections aim to enumerate some general *market indicators* in order to help homebuilders collect information on 'local' housing market trends, as well as the restrictions imposed on their housing development. The use of prescribed indicators that homebuilders can select for further information gathering may to some extent facilitate their market research activities. As well, it may optimise their research activities to gain proper net benefit, but the activities are confined to the minimum.

6.2.1. MARKET INDICATORS

Dasso and Ring (1989:332) proposed '**indicators**' that can be applied to housing market research and that cover market information on *demand*, *supply-demand interaction*, and *financing*. Basically, the 'demand' indicators concern population, employment, unemployment, and family income. In general, increases in population yield the need for housing, while high levels of employment indicate economic growth, which may to some extent result in additional immigration and population. Family income may represent purchasing power for housing or influence affordability. The indicators related to 'supply-demand interaction' include price levels, vacancy rates, and rent levels. Price-level information may help homebuilders estimate the possible selling price of a new house, while vacancy rates and rent levels may help them understand what portion of the existing supply of space is not being used. As well, an increasing vacancy rate may foretell a weakening in prices, while a declining rate suggests that selling prices are likely to increase (Dasso and Ring 1989:333). Finally, their ‘finance’ indicators mainly concern the availability of local lenders and local mortgage interest rates as these also affect housing affordability, as described in Chapter 2.

In addition, the Appraisal Institute (1994:101) identified other market indicators at international, national, regional, municipal, community and neighbourhood levels. In comparison to those stated above, the institute’s indicators which cover the wider area of housing market research may be more useful in understanding today’s market conditions (Table 6.1).

After selecting a certain number of the market indicators that appear in the list, homebuilders carry out information gathering and analysis in order to identify the ‘local’ market demand for housing. However, the number of indicators as well as the amount of research required, may increase as the market becomes more defined. For example, the category of *local population* that appears in Table 6.1 represents all gender and ethic origin groups and it changes as a result of natural growth or decline and movement into or out of an area. Furthermore, migratory patterns can be studied internationally, nationally, and within specific communities. In addition, the category of *household formation* contains all traditional and non-traditional households whereas the emergence of new household types, which has a significant impact on housing design, may require the establishment of further subcategories in this area.

6.2.2. DATA COLLECTION AND INTERPRETATION

After selecting indicators for market research, homebuilders need to turn their attention to data collection. In general, such information can be obtained by using either *primary* or *secondary* sources (Greer and Farrell 1988:76). Basically, primary data are statistics that are gathered by the information seekers themselves (e.g. homebuilders) specifically for the problem in hand, while secondary data are those that are previously gathered for other purposes.

International Level
- Comparatively low or high land prices - Comparative stability or instability of governments - Energy costs - Balance of foreign trade - Rate of foreign exchange - Foreign interest rates - Commodity price levels, industrial production levels and volume of retail sales
National level
- Gross national product (GNP) and national income - Balance of payments to other countries - Fiscal policy - Domestic interest rates
Regional level
- Regional price level indexes - Interest rates - Aggregate employment and unemployment statistics - Housing starts, building permits issued, and dollar volume of construction - Provincial laws governing environmental protection, and low- and moderate-income housing development
Community level
- Local population - Long-term and seasonal employment - Income and wage rates - Diversity of employment - Interest rates - Household formulation - Household income - Availability of mortgage money - Competitiveness with other communities - Adequacy of utilities and transportation systems - Zoning, subdivision regulations, and building codes
Neighbourhood level
- Age of occupants - Rates of construction - Rates of vacancy - Property use before and after sale - Presence of neighbourhood facilities - Maintenance standards - Exterior attribution or appearance

Table 6.1: Typical housing market indicators at different levels

(After Appraisal institute 1994)

Primary data may be gathered either by *communication* or by *observation*, unless statistical techniques that require a high level of mathematical skills are applied. Communication involves questioning respondents. Questions may be oral or written and may elicit responses in either form. In addition, questions may be short or involve in-depth interviews. Observation implies checking and recording relevant facts or behaviour. Communication is a more versatile means of gathering data than observation as it is "more amenable to the collection of a variety of factual data" (Greer and Farrell 1988:79). However, data collected by communication is sometimes tainted by a lack of objectivity and responses are influenced by *how* questions are structured and by the vary nature of the "interview situation". On the other hand, data collected by observation are more likely to be factual although the data analysis may, again, tend to be somewhat subjective in nature.

Secondary data are almost certain to be less costly and less time-consuming to gather than primary data as statistical information is readily available free of charge in libraries or on the Internet. For example, Statistics Canada publishes Census data on the Internet. This information is generally of high quality and available in a variety of formats. Secondary data can also be obtained at modest cost from government agencies, universities, and private firms that specialise in generating such data. For example, Canada Mortgage and Housing Corporation (CMHC) can be regarded as one of the largest data-gathering government agencies in Canada offering up-to-date housing market information, while real estate appraisers, brokers and counsellors, market research firms, and accounting firms generate the data. However, secondary data have some disadvantages; for example, the information is rarely available in the desired form; units of measure are sometimes inappropriate for the intended purpose; and class definitions seldom fit exactly with those of the information seeker (Greer and Farrell 1988:77). Information on the provincial laws governing environmental protection and low- and moderate-income housing development, as well as the municipal regulations governing zoning and subdivision development can be obtained from the government offices at each level. Legal documents and references, published by National Building

Code of Canada and Canadian Standard Association, may be also useful for the data gathering of building regulations.

Data analysis may involve the editing, coding and tabulation of data. Editing is the process by which the data collection forms are reviewed to assure that they are complete and consistent. Coding is the assignment of numerals to the observations so that the data can be more readily analysed. Tabulation is the classification that results from counting the values of the observations.

All data are gathered and interpreted in order to transform the market stimuli that a homebuilder might perceive into the actual 'local' market demands for housing, as well as to understand the building regulations that are imposed on a given construction site. Buyers' housing *demand* identified in this stage can paradoxically be considered builders' housing *need* to satisfy their clients. Thus, the identification of the buyer's need may help eliminate the "goal identification uncertainty" associated with the builder's buying or making decisions about products and services involved in their housing development.

Based on the results of market analysis, the builders' objectives and specifications for further buying versus making decisions will be formulated by using appropriate analytical techniques on a step-by-step basis, and they will be discussed in the following sections.

6.3. FORMULATION OF OBJECTIVES AND SPECIFICATIONS

As discussed in Chapter 1, homebuilders to some degree need to balance *cost*, *quality* and *time* trade-offs, in order to achieve the specific objectives and goals ascribed to a given housing project. Accordingly, the cost-quality-time factors can be considered major influences on their buy or make decisions involved in the homebuilding process. In addition, the design and construction of a home must comply with building regulations that correspond with local climates. Thus, *location* factors must also be taken into account in order to produce homes that at least meet the *minimum* of housing quality as defined by the local building codes, as well as the local market demands for housing—e.g. housing materials and styles prevailing in the area. Generally speaking, the degree of housing quality affects construction cost and time; thus, none of these four factors (i.e. **location**, **cost**, **quality**, and **time**) can be neglected in the homebuilding process. These major factors may considerably affect builders' buy-or-make decisions especially during the project conception stage that aims to specify, in part, building materials, systems and styles—those that affect housing design, which must correspond with the market demand identified in the preceding stage (Fig. 6.2).

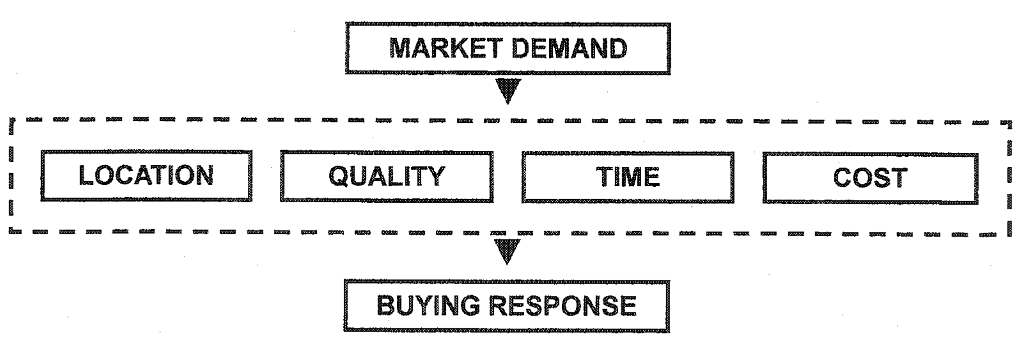

Figure 6.2: Major factors that affect homebuilders' buy-or-make actions

It is important to note that homebuilders can work on the reduction of construction cost and time, as well as the improvement of housing quality during the design and construction stages that are typically carried out after the building site is identified or obtained. As well, this choice model *for mass customisation* is aimed mainly at *programming* homebuyers' selections for the design and construction systems applied to their mass housing development. Thus, in this model, the location factors will be regarded as **restrictive factors** that impose some limitations on the formulation of builders' objectives and specifications related to the cost-quality-time factors (Fig. 6.3).

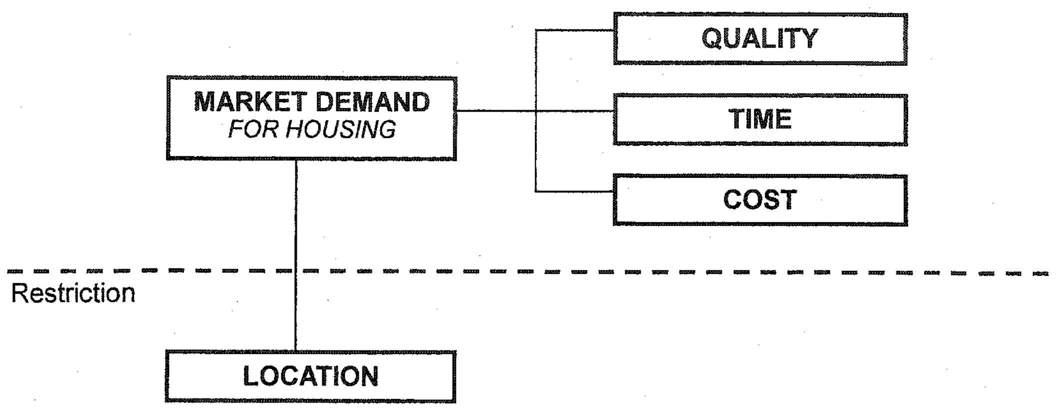

Figure 6.3: Interrelationship of four major factors in response to market demand for housing

In the following sections, a *function analysis* approach that helps to clarify the interrelationship of the cost-quality-time-location factors will be introduced in order to formulate the homebuilder's project objectives that include their task- and non task-related concerns, as well as specifications that facilitate their buy-or-make decisions about products (or services) involved in housing development.

6.3.1. FORMULATING THE PROJECT OBJECTIVES VIA 'FUNCTION ANALYSIS'

"Function analysis" can be referred to as the study of design performance and is considered as "the heart of value methodology" (Dell'Isola 1997:73). According to Miles (1961:12), *function* consists basically of two parts—"that which causes the product to perform and that which causes it to sell." In other words, the *use* values involve **task-related functions** that cause the product to perform and the *esteem* values require **non task-related functions** that cause the product to sell.

Furthermore, Dell'Isola (1997:73) modified the classical classifications of functions, including "required secondary functions" that cover restrictive factors. Thus, in this choice model, functions will be classified into three fundamental categories: basic, secondary and restrictive functions.

- **Basic functions** are those which are essential to accomplish the ultimate goal of the product or which describe the primary utilitarian feature of a product or design to fulfil its user (i.e. homebuyer) requirement.
- **Secondary functions** are those which support the accomplishment of the basic functions or that may be required by a technical need of the producer, but which can be ignored by the user.
- **Restrictive functions (or required secondary functions)** are those which must be achieved in order to meet codes, standards, safety requirements or other mandatory requirements.

Miles (1961:14) indicates that functions are defined by using a *verb* and a *noun* and exist at various levels. For example, the preceding sections specified the four major factors (i.e. cost, quality, time and location) that concern any construction project and these factors can be also translated into functions—i.e. develop land; reduce cost; improve quality; and shorten time. According to the classifications of function, as stated above, location factors partly fall into the category of restrictive functions that concern climatic and geographical conditions, as well as building regulations affecting homebuilder's design and construction approaches. As well, market needs and demands for housing, identified in the preceding stage, differ from one place to another and are determined by the given location. Thus, such location factors considerably affect the level of housing quality, the delivery time (and availability) of materials, and housing prices. When quality housing is in great demand in a certain market, the quality factors are of prime importance and may be considered as basic functions. On the other hand, cost and time factors are subordinate factors that depend somewhat on the quantitative level of housing quality required; thus, they may be classified into secondary functions. However, it is important to note that there are actually no clear definitions that prioritise the cost-quality-time factors, because the classifications of function depend entirely on the 'local' market demands for housing identified by the homebuilder.

Parrot (2002:54) proposes six comprehensive function analysis approaches to identifying functions that concern any given project:

1. Intuitive research
2. Environmental analysis
3. Sequential analysis
4. Movements and efforts analysis
5. Reference product analysis
6. Standards and regulations analysis.

Intuitive research is an approach in which participants (or project team members) freely express the functions to the project, based on their 'intuition'. This approach to identifying functions is neither systematic nor rational; however, it functions as a good "ice breaker" for further detailed function analysis (Parrot 2002:57). As well, this approach may help homebuilders bring in non task-related factors that they perceive as important in carrying out their housing development—e.g. "use well-known products." **Environmental analysis** is aimed at identifying the elements of the environment which interact with the product to be produced; defining the features of the environment related to the product; clarifying the relationship between the environment and the product and identifying the possible links between the environment and the product. **Sequential analysis** serves to predict the sequence of activities to be accomplished (e.g. by product users), when the product is in use, as well as to identify the functions related to them. **Movements and efforts analysis** is used to identify interrelationships between the physical forces (e.g. wind, earthquake, soil movement, rain and snow) applied to the product and its resistance, as well as to translate the potential outcomes into functions. **Reference product analysis** identifies the reference product selected, decomposes the reference product into various elements, and clarifies the functions of each element. **Standards and regulations analysis** is used to identify constraints imposed on the product and verify its legality.

By using these approaches, a homebuilder first lists all task- and non task-related functions with consideration of the cost-quality-time-location factors, as stated above. Next, the interrelationship of the functions enumerated by a homebuilder will be analysed by using the Function Analysis System Technique that will be revealed in the following section. This system technique helps homebuilders not only to understand the interrelationship of functions themselves, but also to increase or reduce the number of functions in response to the 'local' market demand for housing identified in the first stage.

6.3.1.1. FUNCTION ANALYSIS SYSTEM TECHNIQUE: FAST

For the purpose of this study, 'functions' in verb-noun form will be treated equally as 'objectives' when accomplishing an ultimate project goal namely to reduce construction cost and time and improve quality of housing. These objectives (or *purposes*) are established to eventually produce quality affordable homes.

'FAST' is an abbreviation of the well-known 'Function Analysis System Technique' which is considered to be an evolution of the *value analysis* process. This was introduced by Charles W. Bytheway in 1964, who presented as a paper to the Society of American Value Engineers conference in 1965 (Crow 2003). Functions usually form some 'dependency' links with other functions (Figs. 6.4 & 6.5). Thus, FAST is applicable to displaying the interdependence of functions in the form of a diagram—the so-called "FAST Diagram" (Fig. 6.6).

As shown in Figure 6.6, the first function on the left side of the diagram is called "**order function**" which represents the project's ultimate goal—i.e. market demand for housing identified in the first stage of the choice model. The next column indicates the classifications of function (or **group functions**) in which **restrictive functions** are gathered at the bottom of the column. In the choice model, those functions that appear in the column are likely to work on the cost-quality-time-location factors, as shown in Figure 6.3, in order to accomplish the order function that reflects the market demand identified by the builder. Following the group functions, **sequential functions** that help accomplish the preceding functions, which appear on the left or to the top, will be identified. Finally, the **'solution' box** that appears on the right side of the diagram mainly contains the multiple evaluation criteria (and *alternatives*) that directly correspond with the last functions, which cannot be subdivided further.

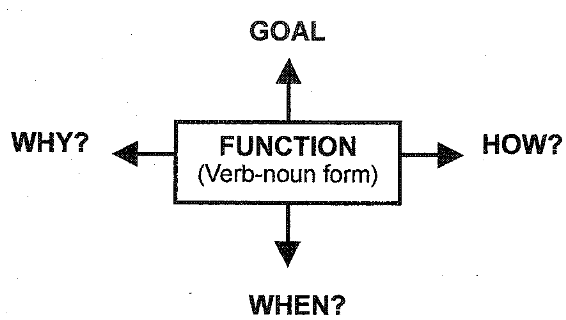

Figure 6.4: Function tree unit cell

(After Parrot 2002)

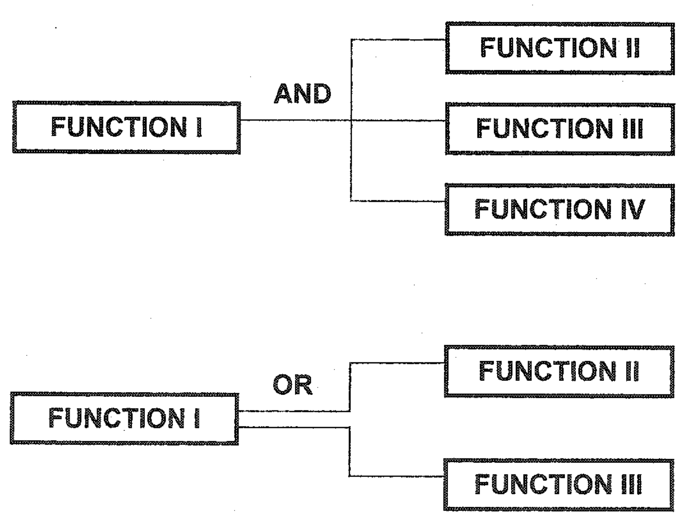

Figure 6.5: Function tree logical relations

(After Parrot 2002)

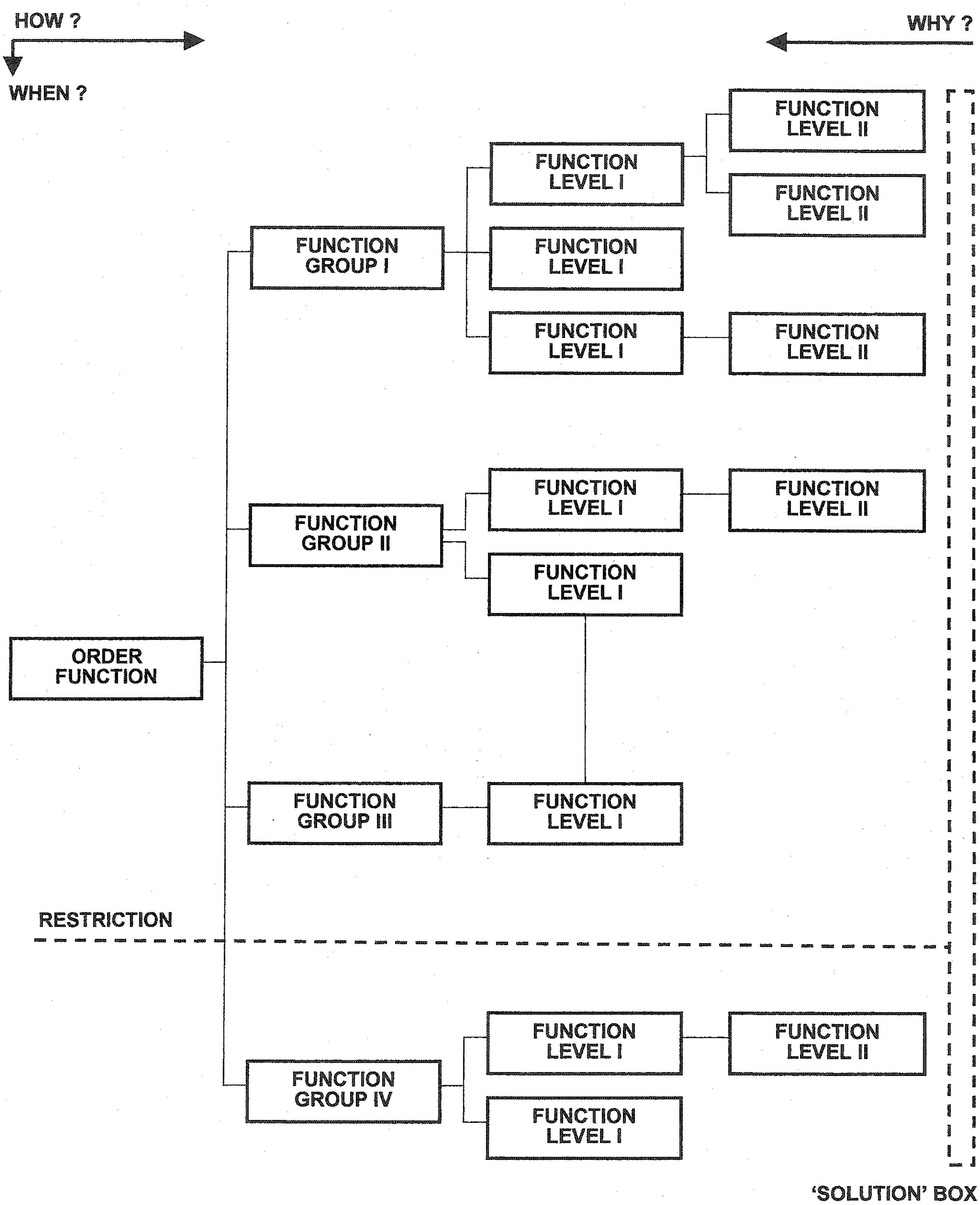

Figure 6.6: A simplified structure of FAST Diagram

(After Parrot 2002)

The FAST Diagram is useful in grouping and prioritising functions according to the classifications (i.e. basic, secondary and restrictive functions) and validating them through their links, in order to bring out the project initiator's goals, objectives and aspirations (Parrot 2002:75). In addition, Dell'Isola (1997:74) summarises the benefits of the use of the FAST Diagram at the conception stage in a construction project:

- "It allows a quick function challenge to validate or question the proposed conceptual design decisions."
- "It provides a valuable "mind setting" and "mind tuning" about the project in a short period of time."
- "It facilitates presentation and discussion of the project's overall goals with the designer and owner for better communication."

After the project *objectives* are identified logically by using FAST, multiple evaluation criteria including both task- and non task-related concerns will be specified and weighted by the buyer. In other words, the next sections aim to formulate the project *specifications* that are applied to further value analysis of alternatives that will be identified in the next stage of this choice model. Accordingly, selected analytical techniques that help homebuilders describe evaluation criteria, as well as give weight to each of them, will be introduced in the following sections.

6.3.2. FORMULATING THE PROJECT SPECIFICATIONS

In this stage, a homebuilder is asked to *specify* multiple **evaluation criteria** in accordance with the project objectives clarified by using FAST. In addition, the builder may need to prepare some conceptual drawings (e.g. plans and elevations) of a typical house and its design specifications, when comparing the features of a conventional building system applied to housing developments completed in the past with those of other innovative systems.[1]

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[1] The drawings and specifications of typical housing prepared in this stage function as 'guidelines' of the *minimum* housing requirements that will be taken into account for further value analysis of alternatives.

According to the project objectives identified, the evaluation criteria described in this stage may include both task- and non task-related factors. Although today's homebuilders tend to focus on measuring all benefits in economic terms, it is likely that some 'intangible' factors (or attributes), such as improved housing quality, reduced construction time and improved customer service, cannot be reduced to dollars. Some of these may fall into task-related factors measured in economic terms, while the others fall into non task-related factors. However, both factors are regarded as influences on homebuilders' buy-or-make decisions about certain products and services involved in their housing development; thus, they must be taken into account when developing the *multiple* evaluation criteria for further value analysis of alternatives.

6.3.2.1. DEVELOPMENT OF EVALUATION CRITERIA VIA 'BRAINSTORMING' TECHNIQUE

"Brainstorming" is said to be one of the techniques applied for speculating and generating ideas—it "is most often used for the creative step" (Dell'Isola 1997:102). Thus, the brainstorming approach will be applied to identifying multiple evaluation criteria (especially 'non task-related' factors) in this stage, based on the builder's subjective needs, desires and expectations concerning buy-or-make decisions. A typical brainstorming session takes place when a certain number of people sit around a table and spontaneously generate ideas designed to solve a specific problem. In this stage, the problems to be solved directly relate to specific areas of project objectives described in the preceding stage. However, during this session, no attempt is made to judge or evaluate ideas suggested by the participants, because evaluation will take place when the brainstorming session is complete (Fig. 6.7). The elimination of adverse judgement from the idea-generating stage allows for maximum accumulation of ideas, preventing the "premature death of a potentially good idea" (Dell'Isola 1997:102). Consideration of all ideas encourages every participant to explore new areas; thus, this may result in enhancing the individuals' involvement in the idea generation session.

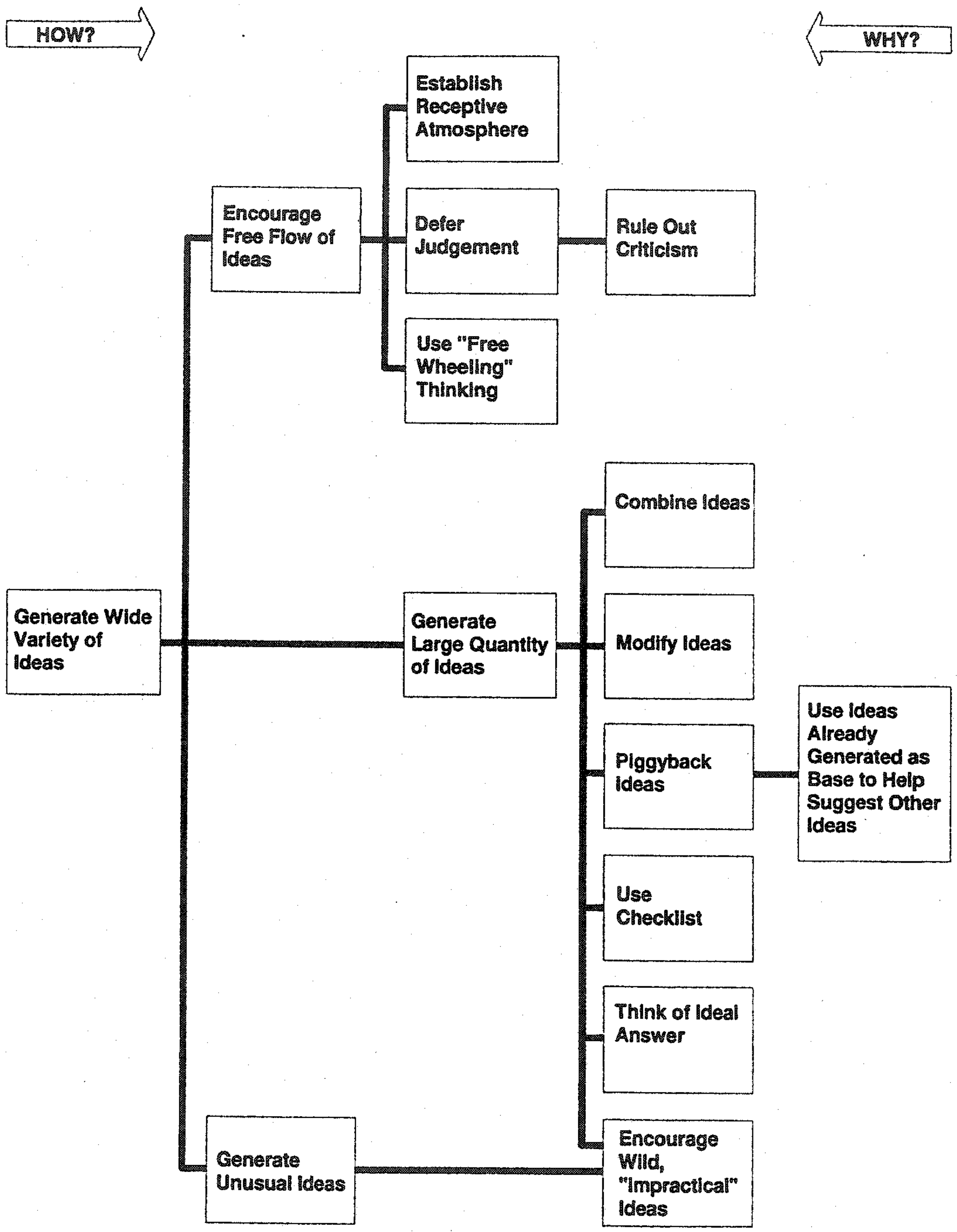


Figure 6.7: Rules of brainstorming

(Source: Dell'Isola 1997)

Dell'Isola (1997:102) sums up the guidelines of a group brainstorming session:

1. "Rule out criticism. Withhold adverse judgement of ideas until later. If nothing good can be said about an idea, nothing should be said."
2. "Generate a large number of possible solutions; set a goal of multiplying the number of ideas produced in the first rush of thinking by five or ten."
3. "Seek a wide variety of solutions that represent a broad spectrum of attacks on the problem."
4. "Watch for opportunities to combine or improve ideas."
5. "Before closing the session on possible solutions, allocate time for a subconscious operation on the problem while consciously performing other tasks."

Finally, he also indicates that "The technique and philosophy of brainstorming may also be used by individuals to generate solutions to problems. However, this is not usually as productive as group brainstorming. Brainstorming does not always yield a final solution, but it does at least generate leads towards the final solution" (Dell'Isola 1997:104).

In addition, in order to develop 'task-related' evaluation criteria, referential reviews of common codes and standards related to building materials and systems may be useful. Many governmental and non-governmental agencies affect the codes and standards and the list of the names and addresses of the agencies is included in Appendix C. In fact, these codes and standards are readily available for the development of evaluation criteria in this stage. For example, in order to describe the criteria concerning noise control, Standard Classification for Determination of Sound Transmission Class (ASTM E413), Standard Test Method for Measurement of Airborne Sound Insulation in Building (ASTEM E336), and Standard Method of Laboratory Measurement of Impact Sound Transmission through Floor-Ceiling Assemblies using the Tapping Machine (ASTM E492) can be applied. As well, the fire resistance rating of materials used for the roofs, exterior and interior walls, firewalls, ceilings, floors, doors and windows may need to be taken into account, while R-Value is often applied for the thermal resistance of the materials used. Naturally, the task-related evaluation criteria also include cost factors.

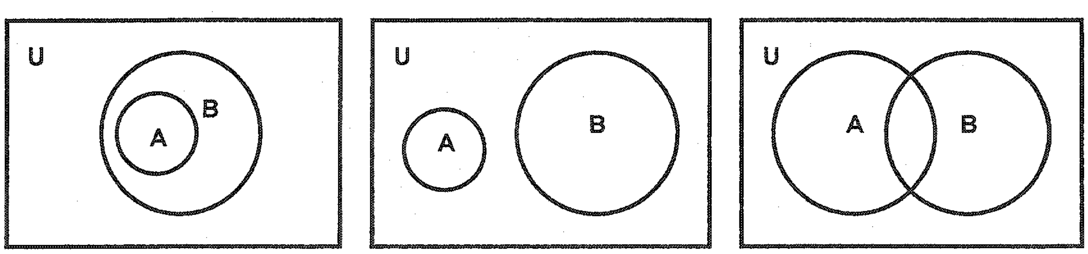
In short, the second stage of the choice model focused on formulating project objectives and specifications for further value analysis of alternatives by using the function analysis techniques (including FAST and the Diagram), as well as the brainstorming technique. The buyer's objectives and specifications will function as guidelines for further development of alternatives—i.e. products and/or services involved in housing development that must meet the 'market demand' identified in the preceding stage. In other words, this stage was to eliminate the "goal/purchase matching uncertainty" associated with organisational buying behaviour, as described in Chapter 5. Accordingly, in the following stage, the alternatives that help mass customise an end product will be generated based on the homebuilder's *needs* and *demands* for housing development, which were identified in the preceding stages.

6.4. GENERATION OF ALTERNATIVES

This third stage of the choice model is aimed at generating alternatives (i.e. products and/or services) that *should* meet the project objectives identified in the preceding stage, based on the concept of mass customisation: **MASS CUSTOMISATION = ACHIEVING MASS + CUSTOMISATION**.

As described in Chapter 4, this formula reflects the fact that standardisation encourages mass production of components, and the combinations of standard components help *create* a customised product or service. In this context, the definition of 'creativity' would be the "Innate aptitude of man in creating new combinations starting with existing elements" (Parrot 2002). As discussed in Chapter 4, low cost, short delivery time and uniform quality may be achieved through mass customisation that yields *economies of scope* (Pine II 1993:48). Before identifying a technique for generating alternatives, the basis of "set theory" will be reviewed, in order to transfer our attention from individual objects to collections of objects—i.e. *a whole with its parts.*

Set theory is a branch of mathematics developed by Georg Cantor[2] who defined the term *set* as "any collection of definite, distinguishable objects which can be conceived as a whole" (Pinter 1971:4). The objects that appear in this context are the elements (or *members*) of the whole. Venn diagrams are invariably used for a pictorial representation of sets (Fig. 6.8).



(a) Proper subset (b) Disjoint set (c) Union/intersection

Figure 6.8: Venn diagrams showing typical patterns of sets

[2] Georg Cantor (1845-1918) investigated problems pertaining to trigonometric series and series of real numbers that led him to recognise the *need* for a means of comparing the magnitude of infinite sets of numbers and finally to build the foundation of set theory (Stoll 1974:1).

As shown in the diagram, the rectangular box represents the universal set, while the other sets appear in circles lying within the box. If $A \subseteq B$, then it is still possible that $A = B$; however, if $A \subseteq B$ (but $A \neq B$), then A is said to be a *proper subset* of B (or B contains A). If A and B have no elements in common the two sets are called *disjoint sets*. *Set operations* are known as methods for generating new sets from existing sets by defining two ways of composing pairs of sets—i.e. the union or intersection of the sets (Stoll 1974:15). The *union* of two sets A and B can be symbolised by $A \cup B$ and is the set of all elements which belong to A or B; Thus,

$$A \cup B = \{x : x \in A \text{ or } x \in B\}$$

For example,

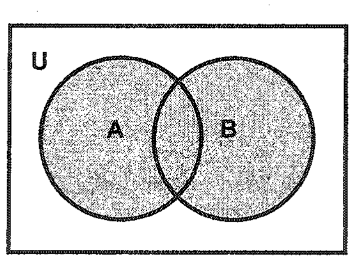
$$\{1, 2, 3\} \cup \{1, 3, 4\} = \{1, 2, 3, 4\}$$

As noted above, "or" that appears in the model is used in the sense of and/or (Fig. 6.9). On the other hand, the *intersection* of two sets A and B can be denoted by $A \cap B$ and is the set of all elements which belong to both A and B; thus,

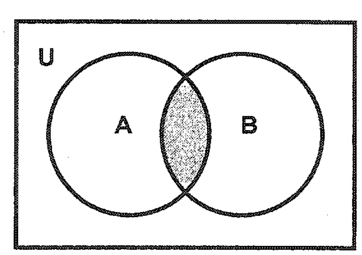
$$A \cap B = \{x : x \in A \text{ and } x \in B\}$$

For example,

$$\{1, 2, 3\} \cap \{1, 3, 4\} = \{1, 3\}$$



(a) $A \cup B$



(c) $A \cap B$

Figure 6.9: Venn diagrams showing the union and intersection of two sets

The basic idea of set theory might help us recognise the fact that a product can be subdivided into several parts (or *elements*); paradoxically, the parts having some *relations* are combined into one product. In mathematics, the word *relation* is used in the sense of relationship, including the following partial sentences (or *predicates*): "is less than", "is included in", "divides", "is a member of", "is congruent to" and "is the mother of". Broadly speaking, these relations consider the existence or non-existence of certain connections between pairs of objects taken in a definite order. Thus, within the framework of set theory, such relations can formally be defined in terms of *ordered pairs*—e.g. ordered pairs (a, b) of elements indicates that "a" is designated as the first element and "b" as the second element; thus,

$$(a, b) = (c, d) \text{ if and only if } a = c \text{ and } b = d$$

In particular, $(a, b) \neq (b, a)$ unless $a = b$. Furthermore, Stoll (1974:26) summarises the aforementioned notion of ordered pairs in a logical manner as follows:

> "As the notion is used in mathematics, one relies on ordered pairs to have two properties: (i) given any two objects, *x* and *y*, there exists an object, which might be denoted by $<x, y>$ and called the ordered pair of *x* and *y*, that is uniquely determined by *x* and *y*; (ii) if $<x, y>$ and $<u, v>$ are two ordered pairs, then $<x, y> = <u, v>$ iff [if and only if] $x = u$ and $y = v$."

The notion of pairing objects helps us understand the relations between the elements that exist in the sets combined—i.e. a *product* of sets. For example, let A and B be two sets. The product set of A and B (written A x B) is the set of all ordered pairs (a, b) such that $a \in A$ and $b \in B$; thus,

$$A \times B = \{(a, b) : a \in A \text{ and } b \in B\}$$

Accordingly, let $A = \{1, 2\}$ and $B = \{a, b, c\}$. Then,

$$A \times B = \{(1, a), (1, b), (1, c), (2, a), (2, b), (2, c)\}$$

$$B \times A = \{(a, 1), (a, 2), (b, 1), (b, 2), (c, 1), (c, 2)\}$$

The results indicate that $A \times B \neq B \times A$. As well, for any finite sets, the total number of possible ordered pairs (or *combinations*) of the given elements can be simply calculated by using the following formula:

$$\boxed{n(A \times B) = n(A) \cdot n(B)}$$

where n = number of elements given to the particular set. Thus, the number of combined elements, as described in the preceding example, can be calculated as follows:

$$n(A \times B) = 2 \cdot 3 = 6$$

Furthermore, the idea of a product of sets can be extended to any finite number of sets. Especially, for any sets $A_1, A_2, \dots A_m$, the set of all m-element lists $(a_1, a_2, \dots a_m)$, where each $a_i \in A_i$, is called the (*Cartesian*) product of sets $A_1, A_2, \dots A_m$ and it is denoted by $A_1 \times A_2 \times \dots \times A_m$.

In the choice model *for mass customisation*, the variations of mass customised products (or services) will be generated within the framework of set theory—i.e. *product sets*. Thus, the alternatives that help mass-customise the end product will be referred to as the *elements* of sets to be paired. For example, the alternatives can be considered as some housing *systems* (e.g. design and construction systems) that to some extent affect a homebuilding process in housing development. As well, they can be also considered as some housing *components* with regard to the volume arrangements, as well as the interior and exterior designs—those that reflect the product sub-system of the 'mass custom design' approach, as described in Chapter 4:

$$P = f\,(v, e, i, o)$$

Thus, the alternatives are defined based on the given project objectives. It is important to note that an end product is regarded as a *product* of sets that is mass customised by the buyer's direct selections for the given alternatives generated in this third stage of the choice model.

The basis of set theory, as reviewed above, emphasises collections of objects (i.e. *parts of a whole*) rather than individual objects, as well as leading to an understanding as to *how* the several sets that contain individual elements combine mathematically into a product. The following section aims to help identify individual elements (or *alternatives*) in the given sets that correspond with the last level of the project objectives (or *functions*) appearing in the FAST Diagram, as described in the second stage of the choice model. Thus, in order to accomplish the project objectives in question, the work breakdown structure that helps to logically identify the potential alternatives will be introduced.

6.4.1. WORK BREAKDOWN STRUCTURE

The work breakdown structure (WBS) acts as a vehicle for breaking the work down into smaller elements; thus, it provides a great probability that every major and minor activity will be considered. A variety of work breakdown structures exist for use in the management of a variety of construction projects. However, Kerzner (1992:609) emphasises that the six-level indentured structure can be considered the most common application (Table 6.2).

LEVEL	DESCRIPTION
1	Total program
2	Project
3	Task
4	Subtask
5	Work package
6	Effort level

Table 6.2: Six-level work breakdown structure

The top three levels of the WBS are considered as managerial levels, while the remaining three levels are technical levels. Level 1 is the total program, composed of a set of projects and each project can be broken down into tasks. The summation of all elements in one level must be the sum of all work in the next lower level. Each element of work should be assigned to one and only one level of effort—e.g. the construction of a house's foundation should be included in one project (or task), not extended over two or more. However, a question with the WBS 'still' arises: "How far down do we have to go? How much detail is enough?" (Devaux 1999:80). Kerzner (1992:617) admits that a tendency to develop guidelines, policies and procedures for project management exists, but *not* for the development of the WBS itself. The tendency is to avoid limiting the way the work breakdown structure is developed because the WBS must have must have some flexibility built into it. At last, Kerzner (1992:617) concluded from the projects which he surveyed, that the top three levels are often used in the same fashion and the differences appear in levels 3, 4, and 5, as shown in Table 6.2. In other words, the top three levels of the WBS can be considered to be "generic" and therefore "applicable" to many different projects.

Furthermore, on simple projects, WBS can be constructed as a "tree diagram" according to the logical flow (Fig. 6.10). The tree diagram can follow the work or even the organisational structure of a project (or company). It helps create a logical flow and clusters certain elements to represent tasks. In the tree diagram, lower-level functional units may be assigned to one and only one work element (Kerzner 1992:617). In addition, coding the WBS may permit efficient communication to take place between external and internal parties involved in the project.

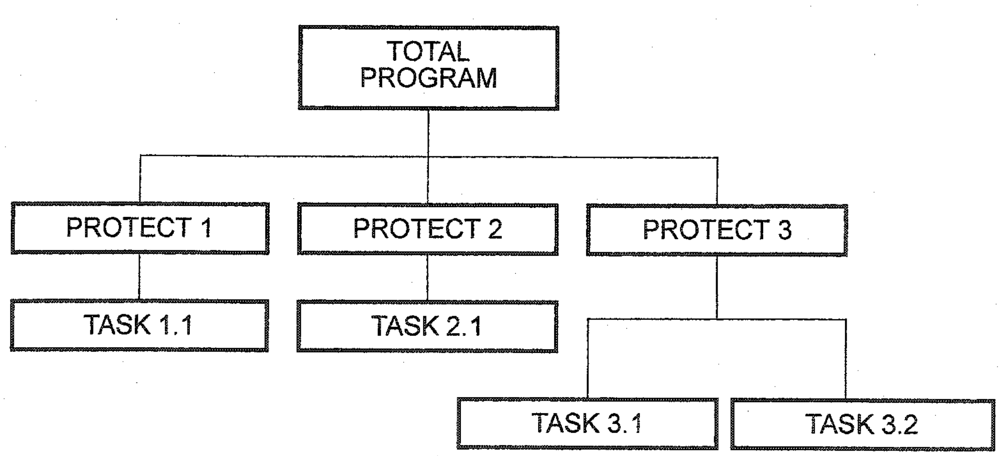


Figure 6.10: WBS tree diagram

In the choice model *for mass customisation*, the first level of the WBS is considered an end product (or *purpose*—i.e. housing design or development) that reflects the 'order function' that appears in the first column of FAST Diagram developed in the preceding stage. According to the definition of an end product, some of the buyer's objectives that appear in the last level of the FAST Diagram will be selected and grouped into several classes assigned to the second level of the WBS (Fig. 6.11). Finally, alternatives that help mass customise the identified end product will be generated based on the higher level of the WBS and will appear in the lowest level (Fig. 6.12).

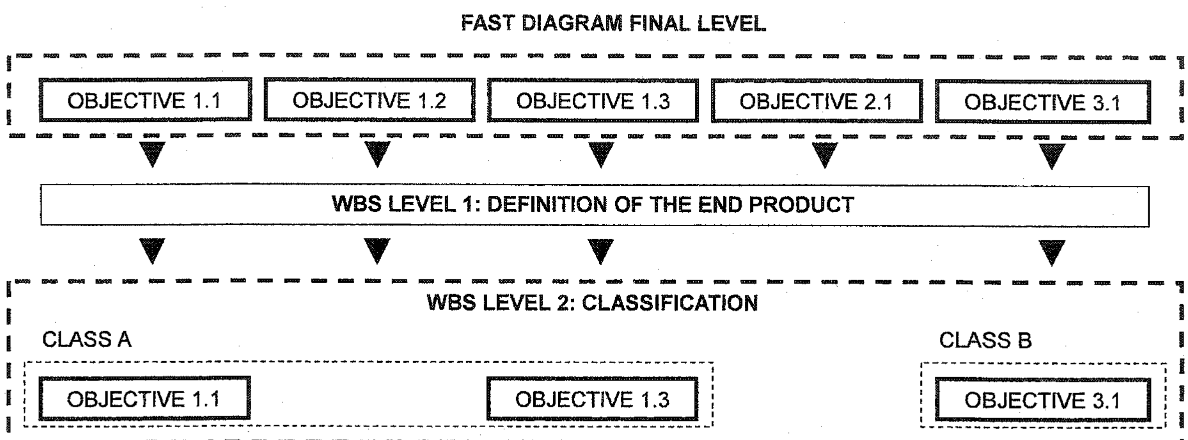


Figure 6.11: Grouping of the project objectives selected

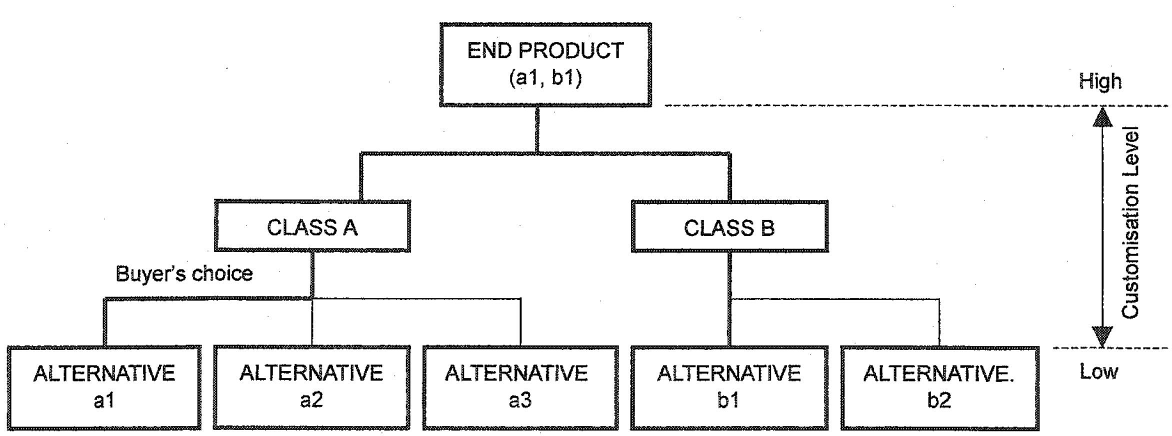


Figure 6.12: WBS tree diagram applied to the choice model *for mass customisation*

The number of product variations can be calculated simply by using the formula, as described in the preceding section related to the notion of *product sets*. As shown in Figure 6.12, Class 1 contains 3 alternatives while Class 2 has 2 alternatives. It is important to note that the alternatives that appear in the lowest level of the WBS are regarded as *standard* components that can be mass-produced (or *re-used* several times). Hereafter, Class A and B will be considered as two sets—A and B, respectively. As well, three alternatives that belong to set A will be called a1, a2, and a3, while two alternatives that belong to set B will be called b1 and b2. Thus, A = {a1, a2, a3} and B = {b1, b2}. Accordingly, the product set of A and B is:

$$A \times B = \{(a1, b1), (a1, b2), (a2, b1), (a2, b2), (a3, b1), (a3, b2)\}$$

In addition,

$$n(A \times B) = 3 \cdot 2 = 6$$

Thus, the product that appears in the top level of the WBS has 6 *potential variations*[3] that can be made by the buyer's choices of a total of 5 given alternatives, in order to accomplish the buyer's own objectives specified previously. Logically, the end product can be considered as a product *mass-customised* by the buyer's *direct* choices of alternatives—i.e. *standard* components that can be mass-produced or re-used. Thus, the higher the number of standard components that are given to a buyer to choose from in designing a product, the higher the number of potential variations of the product—thus, the higher the level of product customisability (Table 6.3).

NUMBER OF STANDARD COMPONENTS GIVEN TO SET A	NUMBER OF STANDARD COMPONENTS GIVEN TO SETB	POTENTIAL PRODUCT VARIATION (Level of customisability)
1	1	1
10	10	100
100	100	10,000
1,000	1,000	1,000,000

Table 6.3: Relationship between the number of standard components and product customisability

[3] For the purpose of this study, the term *potential variation* is used to express the level of customisability of an end product, distinguished from *actual variation* that reflects the number of product models.

In addition, by reflecting the product sub-system of a 'mass custom design' approach, as stated above, the potential variation (Pv) of housing can be formulated in mathematical terms as follows:

$$\boxed{Pv = n(V \times E \times I \times O)}$$

For example, supposing 10 alternatives are given to each set of standard housing components applied for volume (V), exterior (E), and interior (I) arrangements, as well as for other optional (O) equipment, the potential variation (Pv) of this mass custom home will be:

$$\begin{aligned} Pv &= n(V \times E \times I \times O) \\ &= n(V) \cdot n(E) \cdot n(I) \cdot n(O) \\ &= 10 \cdot 10 \cdot 10 \cdot 10 \\ &= 10{,}000 \end{aligned}$$

In contrast, the potential variation of a ready-built home can be estimated at 1, when the volume, exterior and interior components, as well as other necessary equipment are already installed (i.e. V = 1, E = 1, I = 1, and O = 1) at the purchase of the home. Thus, the level of product customisability of ready-built homes can be regarded as much lower than that of mass custom homes, although all housing components (i.e. V, E, I, O) used in both types of housing are completely standardised. To some extent, these results may attest to the provisional analysis concerning the relationship between the levels of standardisation and customisation, compared by housing type, as shown in Table 4.3 and Figure 4.4.

6.5. SUMMARY AND CONCLUSIONS

This 'mass customisation' phase of the proposed choice model contains three decision-making stages (i.e. identification of need, formulation of objectives and specifications, and generation of alternatives) and aims to help identify alternatives (products and/or services to be purchased) that contribute towards mass customising an end product. Thus, this phase can be considered as being **product-oriented** and falls into the product (P) sub-system that in part composes the mass customisation system—i.e. MC = f (PS).

As well, this chapter focused mainly on identifying the analytical techniques (or approaches) applicable to each stage of the choice model that help programme the buyers' decision-making process with consideration of their task- and non task-related concerns, as described in Chapter 5. The techniques used in this phase can be summarised as follows:

Identification of need: A 'descriptive research' approach was used for identification of the 'local' market *demand* for housing, which is also considered the builder's *need* for production of homes that must be marketable.

Formulation of objectives and specifications: In the first part of this stage, 'cost-quality-time-location' factors that affect builders' buy-or-make decisions were identified. As well, the basis of 'Function Analysis System Technique' (FAST) was introduced and the 'FAST Diagram' were applied to the formulation of the buyer's task and nontask-related objectives (i.e. *purposes*). In the last part, the 'brain storming technique' was introduced in order to *specify* the evaluation criteria that directly meet the project objectives identified in the FAST Diagram.

Generation of alternatives: In this stage, 'Work Breakdown Structure' (WBS) was applied for the identification of alternatives, in order to connect the buyer's project objectives to be accomplished with the objects to be purchased for that accomplishment. As well, the concept of 'potential variation' was proposed, while a mathematical 'formula' that aims to calculate the potential variation of an end product was developed within the framework of set theory. Furthermore, this new formula reflecting the product sub-system of a 'mass custom design' approach helped rationalise (or *quantify*) the relationship between the levels of standardisation and customisation, as described provisionally in Chapter 4.

In theory, through this comprehensive systems approach to **visualising** a buyer's decision-making process, the buyer's task- and nontask-related concerns can be integrated into the proposed choice model, while "goal identification uncertainty" and "goal/purchase marching uncertainty" associated with buying decisions can be eliminated. Thus, in order to examine these potentialities, this 'mass customisation' phase will be demonstrated in Chapter 8.

In the following phase, the 'value analysis' of the alternatives identified in this 'mass customisation' phase will be conducted; thus, some additional analytical techniques that lead the buyers to the final selections for the given alternatives will be identified.

7.1. INTRODUCTION

As discussed in Chapter 4, mass customising an end product requires product- and service-oriented sub-systems. Accordingly, the first phase of the choice model *for mass customisation* focused mainly on generating alternatives that contribute toward mass customising an end product, while the buyers' selection process for the given alternatives were less of a consideration. Thus, this chapter concerns the service (or *process*) aspects and aims to introduce selected analytical techniques applicable to the second phase of the choice model, i.e. the 'value analysis' phase, which contains the last two stages of the proposed choice model:

1. Identification of Need
2. Formulation of objectives and specifications
3. Generation of alternatives
4. **Evaluation of alternatives**
5. **Selection of alternatives**

The main purpose of this phase is to assist the buyers (e.g. homebuilders or homebuyers) in making optimal choices amongst given alternatives. Thus, the *value* of alternatives may well need to be analysed and visualised in a comprehensive form, so as to facilitate the buyers' final decision. In order to analyse the value of alternatives, the cost-quality-time factors involved in the execution of a project must be examined; furthermore, the buyers' emotional factors need to be taken into account during the evaluation and selection processes. Thus, the mass customisation approach that helps generate alternatives, as described in the preceding chapter, will be integrated with the value analysis techniques, which are the subject of this chapter.

7.2. EVALUATION OF ALTERNATIVES

The fourth stage of the proposed choice model *for mass customisation* aims to evaluate the given alternatives by examining the potential *value* concerning not only economic considerations (e.g. cost and time issues) but also the performance required for the accomplishment of the project objectives (e.g. quality issues) identified in the proceeding stages. The term *performance* is used here to encompass both the term *function*, often used to represent the specific work that a design or an item must perform, and the term *quality* which encompasses the buyer's needs, desires and expectations, as described in Chapter 1. Furthermore, all elements composing the *value* of a product (or service), as stated above, will be simplified indeed re-interpreted by the following relationship:

VALUE = PERFORMANCE / COST

It is important to note that the *cost* that appears in the value components reflects an economic assessment of competing given alternatives using equivalent costs that concentrate on both present and future costs. In general, present costs represent overall initial costs, while future costs are all the associated costs of executing a project and running the facility, such as energy consumption, maintenance and operating costs, replacements and alternations costs, and staffing costs (Fig. 7.1).

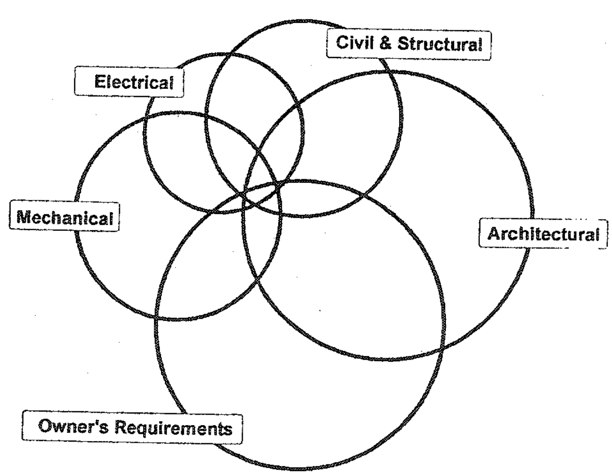


Figure 7.1: Decision maker's impact on total building costs

(Source: Dell'Isola 1997)

Housing development may require a consideration of time factors since the longer the elapsed time for the project execution, the higher the financing costs—"Today's dollar is not equal to tomorrow's dollar" (Dell'Isola 1997:111). White et al. (1998:30) also indicate that "money has a time value" since the value of a given sum of money depends not only on the amount of money, but also when the money is received. For example, letting time be measured in years, if a single sum of money has a present monetary value of "P", its value in "n" years would be equal to:

$$F_n = P + I_n$$

Where:

F_n = the actualised value of P over n years (or future value of P)

I_n = the increase in the value of P over n years (or accumulated interest of P)

Furthermore, for all practical purposes, two approaches are used for calculating the future monetary value of P—i.e. simple interest and compound interest. When "i" denotes an annual interest rate, the simple interest approach can be expressed by the following formula:

$$F_n = P\,(1 + in)$$

On the other hand, the compound interest approach regards "i" as the interest rate of change in the accumulated value of money. Thus, the accumulated interest in borrowing or lending transactions (I_n) can be calculated as follows:

$$I_n = \sum_{t=1}^{n} iF_{t-1}$$

Where "t" increments the years from 1 to n; however, $F_0 = P$. In addition, the future value of P would be equal to:

$$F_n = F_{n-1}\,(1 + i)$$

As shown in this formula, the compound interest approach has the mutual relationship between the principal amount and the compounding of interest over the given time frame (Table 7.1). This approach is more realistic, since all monetary transactions are usually based on compound interest rates rather than simple rates (White et al. 1998:37).

End of Period	(A) Amount Owed	(B) Interest for Next Period	(C) = (A) + (B) Amount Owed for Next Period*	
0	P	Pi	$P + Pi$	$= P(1 + i)$
1	$P(1 + i)$	$P(1 + i)i$	$P(1 + i) + P(1 + i)i$	$= P(1 + i)^2$
2	$P(1 + i)^2$	$P(1 + i)^2 i$	$P(1 + i)^2 + P(1 + i)^2 i$	$= P(1 + i)^3$
3	$P(1 + i)^3$	$P(1 + i)^3 i$	$P(1 + i)^3 + P(1 + i)^3 i$	$= P(1 + i)^4$
⋮	⋮	⋮	⋮	
$n - 1$	$P(1 + i)^{n-1}$	$P(1 + i)^{n-1} i$	$P(1 + i)^{n-1} + P(1 + i)^{n-1} i$	$= P(1 + i)^n$
n	$P(1 + i)^n$			

*Notice, the value in column (C) for the end of period ($n - 1$) provides the value in column (A) for the end of period n.

Table 7.1: An illustration of the effect of compound interest

(Source: White et al. 1998)

Generally speaking, the time required to accomplish a project exerts an influence on the total cost (Fig.7.2). Thus, project time needs to be estimated in advance of the economic analysis, which will be discussed later. Accordingly, the following section aims to identify some analytical techniques for project time estimates.

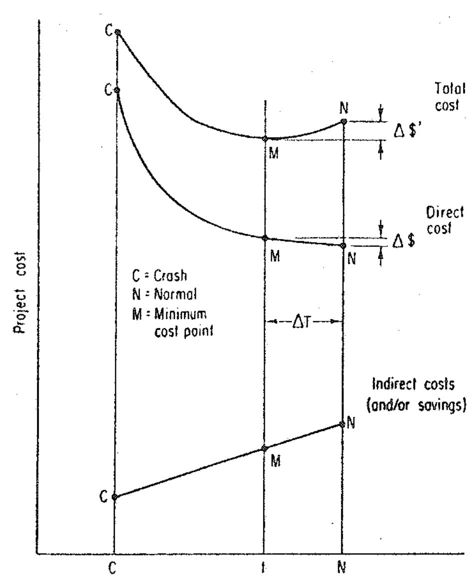


Figure 7.2: The interrelationship between project time and cost

(Source: O'Brien 1984)

7.2.1. PROJECT TIME ESTIMATES

If the project is a familiar one, definition of the activities involved may not be too difficult. For example, CMHC (2001:11) categorises fundamental homebuilding activities into 11 stages, excluding pre-construction activities, such as plans, financing, permits and estimates. In addition, the total construction time of a typical house is estimated at an average of 16 weeks (Table 7.2).

CONSTRUCTION STAGE	
1	Layout of building
2	Excavation and footings
3	Foundations, drainage and backfill
4	Framing (including roofing and flashing)
5	Doors and windows
6	Plumbing, heating and electrical rough-in
7	Exterior finishes
8	Insulation, air and vapour barriers
9	Interior finishes
10	Paint, cabinets and fixtures
11	Landscaping

Table 7.2: General stages of building a typical house
(Source: CMHC 2001)

In addition, Hutchings (1996:95) outlines 37 scheduling phases required for the construction of a typical house, examining the 17 activities selected in order to compare the average elapsed time between site-built homes and modular homes (Tables 7.3 & 7.4). The time is measured in elapsed time from delivery and installation events to the finishing event.

	SCHEDULING PHASE
1	Design plans and engineering calculations
2	Approve design and plans contract
3	Obtain building permits
4	Bid out construction
5	Negotiate contractors' bids
6	Complete any required geotechnical site surveys and soil testing
7	Negotiate project schedule with best bidder
8	Approve and award winning general contractor's bid
9	Obtain contractors' bonds, workers compensation, and liability insurance
10	Begin site work
11	Final inspection of site work
12	First progress payment
13	Begin foundation work
14	Inspect final foundation work
15	Second progress payment
16	Begin framing work
17	Pre-final inspection framing work
18	Third progress payment
19	Begin electrical, plumbing, and HVAC rough-in work
20	Inspect final framing work
21	Fourth progress payment
22	Pre-final inspection electrical, plumbing and HVAC rough-in work
23	Fifth progress payment
24	Begin interior work
25	Pre-finish inspection work
26	Sixth progress payment
27	Final inspection of electrical, plumbing, and HVAC work
28	Seven progress payment
29	Final inspection of exterior and roof
30	Eight progress payment
31	Final total building project inspection
32	Project close out
33	Contract close out
34	Final payment and release of retention
35	Obtain release of liens and file Notice of Completion

Table 7.3: Scheduling phases involved in a homebuilding process

(Source: Hutchings 1996)

ACTIVITY	SITE-BUILT HOME (DAYS)	MODULAR HOME (DAYS)	DAYS SAVED
Clear site	45	10	35
Excavate basement	15	15	0
Rough walls and floors	45	15	30
Exterior siding	35	0	35
Pour basement	30	30	0
Roof	20	1	19
Rough-in plumbing	25	0	25
Rough-in electrical	20	0	20
Finish plumbing	20	10	10
Finish electrical	14	7	7
Interior painting	30	0	30
Drywall, taped & textured	27	3	24
Exterior fixtures	10	3	7
Exterior paint	30	0	30
Finish flooring	25	0	25
Roofing	20	0	20
Landscaping	30	30	0

Table 7.4: Average elapsed time for site-built and modular homes

(Source: Hutchings 1996)

However, in the conception (i.e. problem-setting) phase of a project, the time required to prepare the initial network of activities may be difficult to *quantify*, because there are numbers of uncertainties involved in the time estimates. In the late 1950s, the Program Evaluation and Review Technique (PERT) was developed for use in industry to aid the time estimates of a project (Wiest and Levy 1977:2). It incorporated 'uncertainties' into a model that attempts to compute the '**expected time**' required for completion of each activity within the project. Closely akin to PERT, is the technique known as CPM, an acronym for the Critical Path Method (Wiest and Levy 1977:2). CPM is basically concerned with determining the optimum trade-off of time (or project duration) and total project cost and, unlike PERT, it uses a single time value for each activity of the project (Moder and Phillips 1970:6). Thus, in the conception phase of a project, PERT may be more applicable for the estimates of uncertain time for each activity and will be further discussed in the following section.

7.2.1.1. THE PERT MODEL

PERT takes into account some of the uncertainties inherent in any home building project, allowing for them in each activity duration. For each activity in the project network, not only is an estimate made of the most probable duration that is required to complete the activity, but also some measure of uncertainty is applied to this estimate. All computations of activity time are made prior to the actual performance of the activity; thus, the basis of PERT calculations involves no statistical sampling—rather, it depends mainly on the judgement of the person (or team) in charge of the activity in question (Angus et al. 2003:188). However, the judgement itself must be made based on a sampling of the person's work experiences and knowledge of the requirements of the activity in question. In order to estimate the expected time of an activity, three performance times (i.e. optimistic, pessimistic and most likely times) are identified (Fig. 7.3). Angus et al. (2003:188) describes these three times as follows:

> "The most optimistic performance time (a) might be described as a duration that would occur with a frequency of one in one hundred. The most pessimistic time (b) might also be a time with a duration that would occur one time in one hundred. The most likely time (m) is the estimated time that the task will most often take."

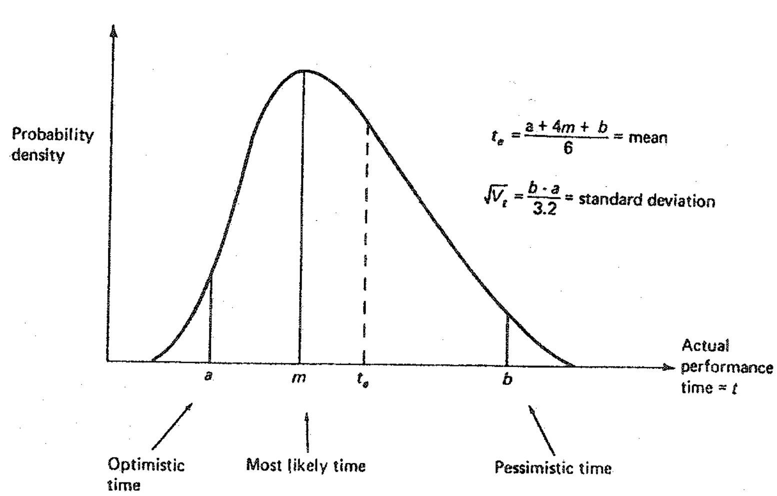


Figure 7.3: The PERT Model of three time estimates

(Source: Moder and Phillips 1970)

Furthermore, Moder and Phillips (1970:284) summarise the key points helpful in obtaining *reliable* values for these time estimates:

1. "The estimator should submit values for a, m, and b which are appropriate if the work is carried out with the initially assumed manpower and facilities, and under the assumed working conditions."
2. "The estimates of a, m, and b should not be influenced by the time available to complete the project..."
3. "To maintain an atmosphere conducive to obtaining unbiased estimates of a, m, and b, it should be made clear that these are estimates and not schedule commitments in the usual sense."
4. "In general, the estimates of a, m, and b should not include allowances for events which occur so infrequently that one does not ordinarily think of them as random variables. The estimates of a, m, and b should not include allowances for acts of nature—fires, floods, hurricanes, etc."
5. "In general, the estimates of a, m, and b should include allowances for events normally classed as random variables. An example here would be the effects of weather.

In order to estimate the expected time (te) of the activity time distribution, a simple formula was developed by the early PERT researchers. It is the simple weighted average of the estimates a, m, and b given by the equation:

$$\boxed{T_e = \frac{(a + 4m + b)}{6}}$$

In addition, another statistical measure that is an indicator of the variability of the estimate made using T_e is the variance (V_t) which can be calculated as follows:

$$Vt = \left(\frac{b - a}{6}\right)^2$$

To some extent, this indicator is helpful in measuring the reliability of the expected time, as determined from the three time estimates. If the time required for an activity is highly variable (or if the range of the estimates is very large), the average value will be less certain. For example, the duration of an activity was estimated by team members as follows: optimistic time = 9 days, pessimistic time = 15 days, and most likely time = 12 days, and then later, the team manager reviewed the same activity. He questioned whether the proposed pessimistic time is too short and tentatively extended it from 15 to 18 days. The expected time (Te) of the first estimates is equal to:

$$\text{Te} = \frac{(9 + 4 \bullet 12 + 15)}{6} = 12 \text{ days}$$

The variance (Vt) can be calculated as:

$$\text{Vt} = \left(\frac{15 - 9}{6}\right)^2 = 1$$

Similarly, the expected time of the manager's estimates can be computed at 12.5 days, while the variance is 2.25. These results indicate that the expected time of 12 days, estimated by the team members, has a much lower value of variance in comparison to the other, even though there is a difference of only a half day in the expected time. Thus, the manager might consider the expected time of 12 days as reliable enough and adopt it for the final estimate of the project duration.

The next step would be to calculate the critical path—i.e. the total duration of the project. However, in advance of finding the critical path of a project, the relationship of each activity needs to be clarified. Thus, the network analysis technique will be first identified in the following section.

7.2.1.2. THE NETWORK ANALYSIS

Angus et al. (2003:182) indicate that the concepts of network analysis and network representation of a project are often explained by using the following definitions:

Activity: "A task or job that forms a component of the project. The representation of network diagrams uses the "activity-on-arrow"—i.e. all activities are shown in arrows."

Nodes (or Events): "The beginning and ending points of activities. A node is shown as a circle with a label."

Merge Node: "A node where more than one activity is complete."

Burst Node: "A node where more than one activity is complete."

Network: "A graphical representation of a project with the activities shown as arrows that terminate at nodes."

Path: "A series of activities joined together to form a distinct route between any two nodes in a network."

Critical Path: "The limiting path(s) through the network that defines the duration of the project. Any reduction of the project duration must begin on the critical path."

Precedence Relationship: "The order in which activities should be performed."

Dummy Activity: "Fictitious activities that carry out a zero time estimate and no cost are used to illustrate precedence requirements in a network diagram."

Time Duration: "The total elapsed time of an activity from start to finish."

In order to identify the beginning and end events for an activity, nodes are placed at the tip and tail of the activity arrow in the activity-on-arrow network representation of a project (Fig. 7.4).

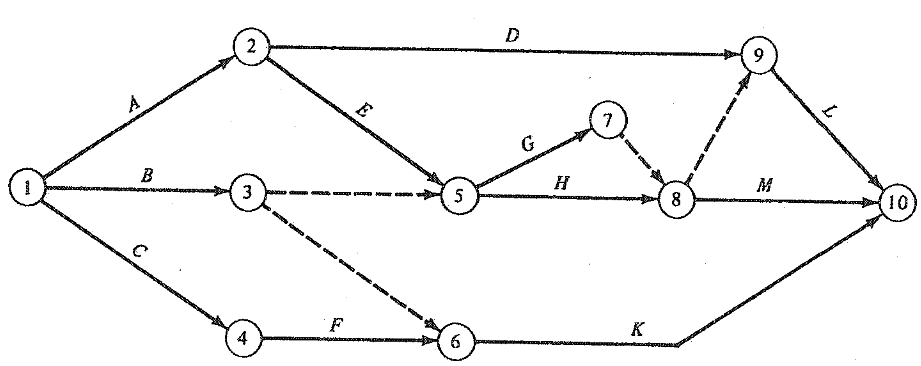


Figure 7.4: Activity-on-arrow network

(Source: Barrie and Paulson 1992)

Angus et al. (2003:184) recommend the use of the Work Breakdown Structure (as described in the preceding chapter) to organise all activities necessary for the accomplishment of the project; furthermore, they summarise the comprehensive steps that lead to the development of a project network diagram:

1. "Make a list of the activities that will drive the master schedule, that is, the activities on the Work Breakdown Structure that form major categories of work."
2. "Label these activities…so that the diagram is easy to read."
3. "Determine or estimate the duration of the activity."
4. "Note all precedence relationships and check that these relationships are correct."
5. "Start with the initial node, label it node 1, and move forward, constructing the project network while continually checking the precedence relationships."

After the project network with associated task time, which is estimated by using the PERT model, is developed, the critical path needs to be identified in order to estimate the total project time. Thus, the next section aims to introduce an algorithm for finding the critical path.

7.2.1.3. THE CPM ALGORITHM

As stated earlier, the critical path is regarded as "continuous chain of activities from the beginning to the end of a network with the [null or] minimum float value" (Barrie and Paulson 1992:288). Thus, it is the longest duration path through the project network. There may be more than one critical path in various parts of the network. In order to identify the critical path, "forward pass" and "backward pass" computations must be performed (Fig. 7.5).

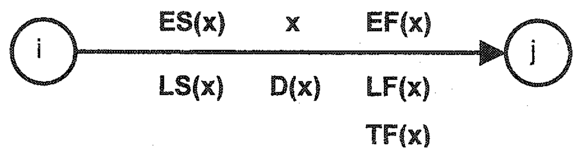


Figure 7.5: Notation for a network diagram of forward and backward pass calculations

The computation procedure called the **forward pass** establishes the earliest expected start and finish times for each activity in the network (Fig. 7.6). The set of rules that defines the procedure for the forward pass (and backward pass) calculations is called "algorithm" (Barrie and Paulson 1992:277).

In order to perform the forward pass calculations, three simple rules must be complied with:

1. The early start (ES) of all activity with no predecessors is equal to the project start time (S).
2. No activity may start until all the preceding activities have been completed; thus, the early start time of any activity other than starting activities is equal to the maximum of the early finish (EF) times of the predecessors.
3. The early finish (EF) of an activity is equal to the early start (ES) plus its duration (D).

In mathematical notation, these rules can be expressed as follows:

S = Project start time
D (x) = Estimate of duration for activity x
ES (x) = S for beginning activities, or
ES (x) = Earliest (expected) start time for activity x
EF (x) = Earliest (excepted) finish time for activity x
= ES(x) + D(x)

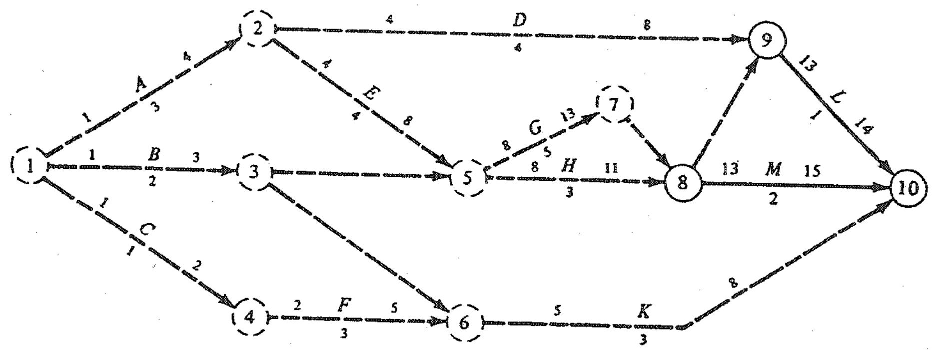


Figure 7.6: Activity-on-arrow network with forward pass calculations

(Source: Barrie and Paulson 1992)

The computation procedure called the **backward pass** establishes the latest allowable start and finish times for each activity that will still permit the overall project to be completed without delaying beyond the planned completion date (Fig. 7.7).

The following rules define the algorithm from the backward pass:

1. The latest allowable finish (LF) of all activities with no followers is equal to the target project completion time (T).
2. The latest allowable finish time (LF) for any other activity is equal to the earliest allowable start times of the successors.
3. The latest allowable start time (LS) for any activity is equal to the latest allowable finish (LF) minus the duration (D).

In mathematical notation, these rules can be expressed as follows:

T = Target project completion time

LF (x) = T for ending activities x, or

LF (x) = Latest allowable finish time for activity x

LS (x) = Latest allowable start time for activity x

= LF(x) – D(x)

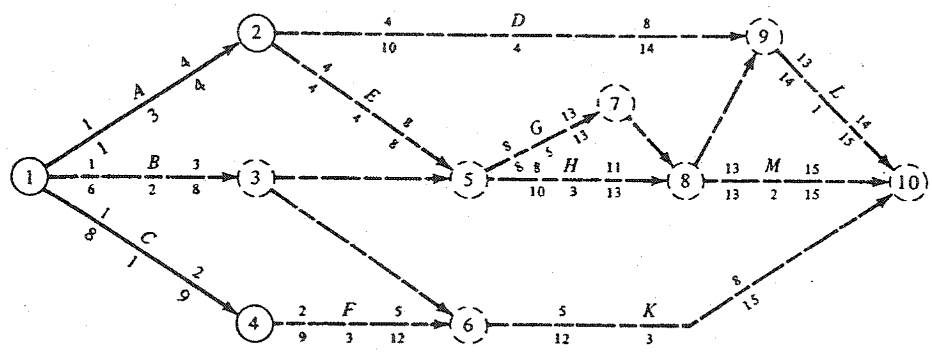


Figure 7.7: Activity-on-arrow network with backward pass calculations

(Source: Barrie and Paulson 1992)

The **total float (or slack)** for an activity is the maximum amount of time that the activity can be delayed without extending the completion time of the overall project (Fig. 7.8). After the forward and backward pass computations are complete, the total float for each activity can be calculated as follows:

TF (x) = Total float for activity x

= LS (x) – ES (x)

= LF (x) – EF (x)

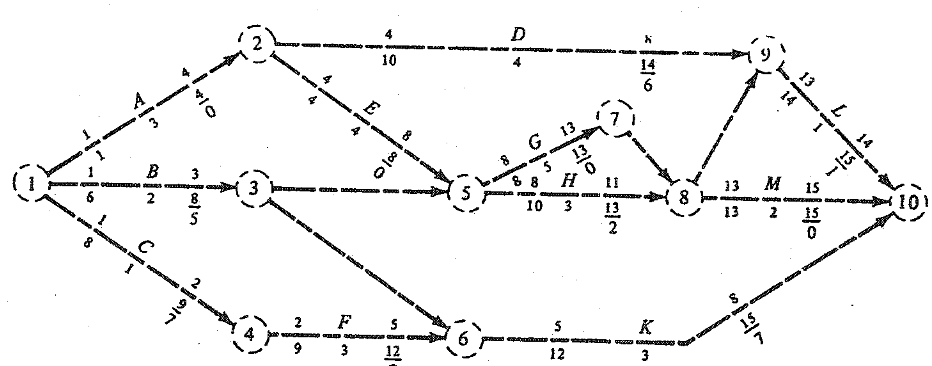


Figure 7.8: Activity-on-arrow network with the total float calculations

(Source: Barrie and Paulson 1992)

As stated earlier, the **critical path** is the path with the minimum float value. Thus, in the case where the target project completion time is set equal to the minimum float value, a critical path is a chain of activities with a 'zero' float (Fig. 7.9). Otherwise, the total float on the critical path may become positive or negative. In addition, if the network has single initial and terminal events, then the critical path may also become the longest path through the project network (Moder and Phillips 1970:71).

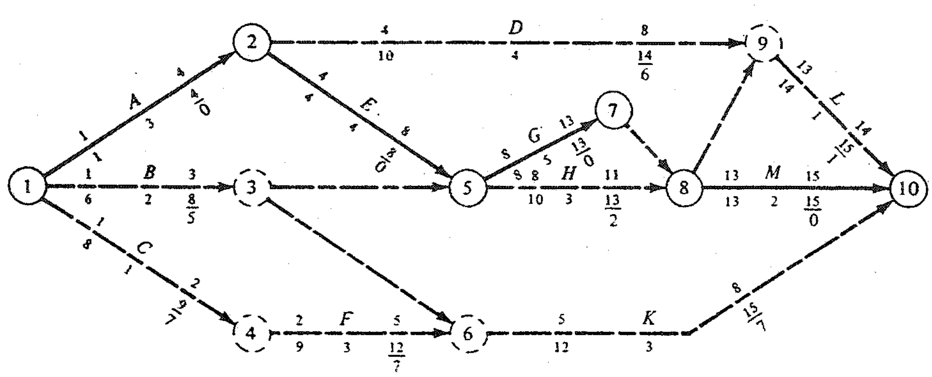


Figure 7.9: Critical path
(Source: Barrie and Paulson 1992)

After the project time is identified, the cost required to execute a project needs to be estimated in order to compare alternatives generated in the mass customisation phase of the choice model. The following section discusses selected economic analysis techniques applicable to the choice model, as part of the value analysis of the given alternatives.

7.2.2. ECONOMIC ANALYSIS

This section introduces some basic techniques required to perform economic analysis incorporating the "time value of money" concepts, as summarised in section 7.2. In order to compare alternatives, both present and future costs for each alternative must be brought to a common point in time (Dell'Isola 1997:115). Accordingly, all costs associated with the project will be converted to today's costs by using the "present worth method" which will be discussed later. However, it is important to note that the economic profiles reflect only part of the value analysis that attempts to compare the cost of each alternative with the performance encompassing the buyers' needs, desires, and expectations for the product that will be purchased.

Project duration is estimated in the preceding section and the time frame of each alternative under analysis may contain some physical, technological or economic life. To illustrate the timing and magnitude of the cash flows associated with an investment alternative, cash flow diagrams are often used (Fig. 7.10).

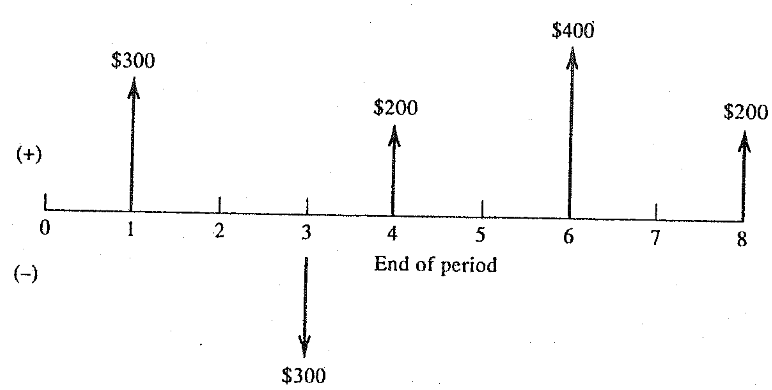


Figure 7.10: Cash flow diagram
(Source: White et al. 1998)

Cash flow diagramming is considered a powerful descriptive technique that is used extensively in evaluating economic alternatives (White et al. 1998:35). As shown in Figure 7.10, a cash flow diagram is structured using a segmented horizontal line as a time scale (or frame) and vertical arrows to indicate a cash outflow. An upward arrow indicates the cash inflow (+), while a downward arrow represents the cash outflow (–). Furthermore, the arrows are placed along the time scale in response to the timing of the cash flows. The length of the arrows may be set to correspond with the relative magnitude of the corresponding cash flow. A rate of interest can be written at the end of the time scale, when necessary.

Economic analysis on the basis of the time value of money concepts requires an explicit demonstration of the time value—i.e. *interest rate.* The time value is often called "minimum attractive rate of return", "hurdle rate", "required rate of return", "return on investment", and "discount rate" (White et al. 1998:158). Regardless of its label, a specific interest rate is required to convert the mix of cash flows under study to a meaningful economic measure. Moreover, Dell'Isola (1997:119) indicates that "Calculation of present worth is often referred to as *discounting* by writers on economics, who frequently refer to an interest rate used in present worth calculations as a "discount rate". Any reference to the discount rate means either the minimum acceptable rate of return for the client for investment purposes, or the current prime or borrowing rate of interest." In order to avoid the confusion in nomenclature, this study uses the term "discount rate" (or "interest rate") when the economic analysis of alternatives is involved.

In establishing this rate, several factors including the source of finance and the rate of return for the industry must be taken into account. As well, any consideration of cash flows in today's economy may need to include a consideration of inflation (White et al. 1998:86). As described in Chapter 2, in recent years, it has been apparent that the costs of goods and services are affected by inflation. Thus, it is appropriate that the interest rate (or discount rate) be established with due consideration of inflation. In order to calculate the interest rate combined with inflation rate, the following formulas will be used:

$$1 + i = (1 + d)(1+j)$$

or

$$i = d + j + dj$$

where:

i = Combined interest rate

j = Inflation rate

d = Real interest rate (absence of inflation)

After the discount rate applied for further economic analysis is identified, the total project cost of the given alternatives will be evaluated with a consideration of the time value. Thus, the following section introduces one of the practical economic analysis techniques, i.e. the *present worth method,* which takes into account both present and future costs involved in a project under study.

7.2.2.1. THE PRESENT WORTH METHOD

The '**present worth method**' requires the conversion of a series of cash flows to a baseline of today's cost (Dell'Isola 1997:115). White et al. (1998:40) also indicates that "Using discrete compounding, the present worth equivalent for the cash flow series is equal to the sum of the present worth equivalents for the individual cash flows." Thus, the present worth of alternative "x" can be represented as:

$$\boxed{PWx\,(i) = \sum_{t=0}^{n} Axt\,(1+i)^{-t}}$$

where:

$PWx\,(i)$ = Present worth of Alternative x using an interest rate of i%

i = Interest (or discount) rate per interest period

n = Planning horizon

t = The number of interest periods

Axt = Net cash flow for Alternative x at the end of period t

In addition, the quantity $(1+i)^{-t}$ is often referred to as the "single payment, present worth factor", denoted (P|F i, t) (White et al. 1998:411). Thus, the formula of the present worth method, as noted above, can also be transformed into:

$$PWx\,(i) = \sum_{t=0}^{n} Axt\,(P|F\ i,\ t)$$

For example, suppose that an investment alternative has the same series of cash flows, as shown in Figure 7.10. The discount rate is estimated at 7% and the discount factors applicable to this economic analysis are identified (Table 7.5).

END OF PERIOD (n)	DISCOUNT FACTOR (i = 7%)
1	0.9346
2	0.8734
3	0.8163
4	0.7629
5	0.7130
6	0.6663
7	0.6227
8	0.5820

Table 7.5: Discount factors at 7% applied for the single sum, present worth factor (Source: White et al. 1998)

Accordingly, the present worth of the alternative under study can be calculated as:

$$PW_1\ (7\%) = \$300\ (P|F\ 7,1) - \$300\ (P|F\ 7,3) + \$200\ (P|F\ 7,4) + \$400\ (P|F\ 7,6) + \$200\ (P|F\ 7,8)$$

$$= \$300\ (0.9346) - \$300\ (0.8163) + \$200\ (0.7629) + \$400\ (0.6663) + \$200\ (0.5820)$$

$$= \$280.38 - \$244.89 + \$152.58 + \$266.52 + \$116.40$$

$$= \$570.99$$

As stated above, the choice model *for mass customisation* is aimed at comparing the given alternatives by analysing the value that concerns not only the cost, but also the performance. Thus, after the cost of each alternative is identified, the next step would be to evaluate the 'performance', which in part reflects the buyer's needs, desires, and expectations for the product to be purchased. Accordingly, the following section introduces some techniques related to performance analysis

7.2.3. PERFORMANCE ANALYSIS

In order to identify the value of each alternative, a performance analysis must be undertaken, in response to the evaluation criteria specified in the second stage of the choice model *for mass customisation*. The performance of alternatives is evaluated based on either a quantitative or a qualitative analysis (Friedman and Noguchi 2001:30). Quantitative analysis is applied to evaluation criteria where the analysis can be carried out using continuous parameters—e.g. fire resistance, thermal insulation, sound transmission, air leakage, transportation time, construction time, and the term of warranty. Qualitative analysis is applied to the other categories—e.g. appearance, comfort, safety, and ease of maintenance. The data that reflects the product performance of the given alternatives may be based on printed publications provided by the company, as well as on personal interviews and observations. Finally, the alternatives are evaluated by rating the performance (or *function*) on each of the criteria on a scale of 1 to 5 (i.e. 1: Poor, 2: Fair, 3: Good, 4: Very Good, 5: Excellent) for both qualitative and quantitative analyses. In addition, a scale of 0 may be used, when the evaluation criterion is not applicable to the alternative under study.

However, in the present circumstances, every evaluation criterion identified in the preceding phase is considered to be weighted equally; thus, the decision-maker's *subjective* preferences (i.e. the buyer's individual needs, desires and expectations for the products that will be purchased) are *not* taken into consideration. In reality, the value of a product (or *alternative*) may differ from one person (or group) to another. Thus, each evaluation criterion applied to the value analysis needs to be weighted by the buyers themselves. Accordingly, the following section aims to introduce some approaches that help encompass the buyers' emotional factors during the evaluation process, as well as facilitate their weighting process.

7.2.3.1. THE 'PAIRED COMPARISON' APPROACH

In this stage, buyers are asked to give a numerical value (or *weight*) to each of the evaluation criteria based on their perceived degree of importance. White, Case, Pratt and Agee (1998:203) *recommend* the use of a "**paired comparison**" approach to ranking the multiple factors, in order to minimise the chance of a "halo effect." [1] To illustrate the paired comparison approach, suppose that five evaluation criteria (A, B, C, D and E) are given in accordance with the project objectives and the following preferences are obtained by comparing two factors at a time:

$$A < B, A < C, A > D, A < E, B > C, B > D, B > E, C > D, C > E, \text{ and } D < E$$

Thus, these paired comparisons yield the following ranking:

$$B > C > E > A > D$$

It is important to note that this ranking is a result of the decision-maker's subjective preferences; thus, the outcome may differ from one person (or group) to another.

Furthermore, Dell'Isola (1997:133) and Parrot (2002) also *recommend* the use of a **criteria scoring matrix** that quantifies the paired comparison approach by assigning a numerical value to each of the given factors, based on the degree of importance perceived by the decision-maker (Table 7.6). Accordingly, through the simple calculation, each factor is given an individual weight (%) that will be applied for further value analysis of alternatives.

In short, an 'evaluation criteria scoring matrix' is developed based on the 'paired comparison' approach. These techniques help the buyer weight each of the task- and non task-related evaluation criteria, which were specified in the preceding phase and used for the value analysis. The buyers' weighting process simply reflects their needs, desires and expectations for the products (i.e. alternatives) that they purchase. Furthermore, the next stage applies a *weighted evaluation* approach to integrating the buyers' criteria-weighting process (which reflects *quality* factors) with the rating of

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[1] *Halo effect* is considered as "a phenomenon that occurs when a high or low ranking on one factor carries over and influences the ranking on other factors" (White et al. 1998:203).

the alternatives' *function*, in order to identify the performance. The following section introduces an *analysis matrix* that actualises the weighted evaluation of alternatives.

B	C	D	E	FACTOR	INDIVIDUAL SCORE	WEIGHT (%)
3B	2C	1A	2E	A	1	4
	3B	3B	3B	B	12	52
		2C	2C	C	6	26
			2E	D	0	0
				E	4	17
					23	99

How important:

3: Major preference

2: Average preference

1: Slight or no preference

Table 7.6: Evaluation criteria scoring matrix

(After Dell'Isola 1997 and Parrot 2002)

7.2.3.2. ANALYSIS MATRIX

Huberman and Miles (1984:21) define a *display* as "an organized assembly of information that permits conclusion drawing and/or action taking" (Fig. 7.11). Furthermore, they emphasise the importance of data displays in analysis, saying that "Valid analysis is immensely aided by data displays that are focused enough to permit viewing of a full data set in one location and are systematically arranged to answer the research question at hand" (Huberman and Miles 1994:432).

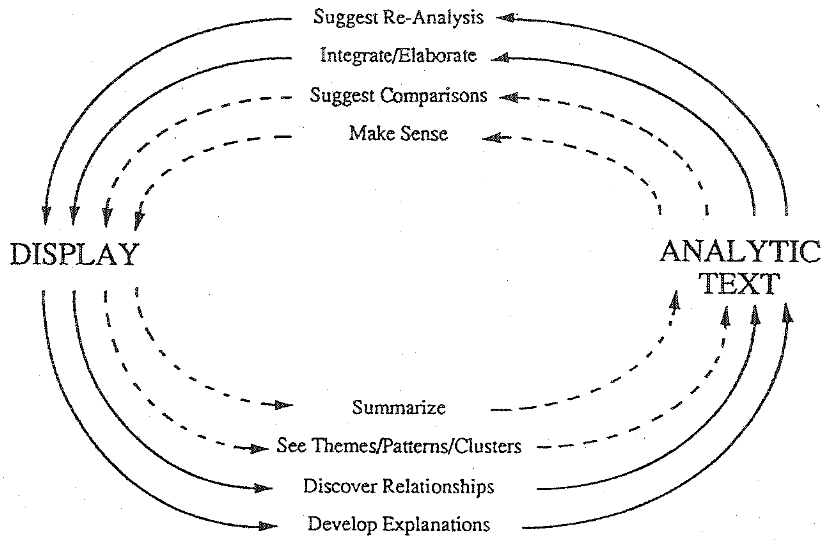


Figure 7.11: Interaction between display and analytic texts
(Source: Huberman and Miles 1994)

In order to display a full data set of weighted evaluations, Dell'Isola (1997:133) introduces the **analysis matrix** in which the functionality of each alternative is listed and rated against each evaluation criterion, as noted above. In addition, within this matrix, the rating and weight of each constraint are finally multiplied and totalled (Table 7.7). Thus, the score of each alternative, which appears at the bottom of the analysis matrix, represents the performance of each alternative that also reflects the potential level of the buyers' satisfaction, in response to their needs, desires and expectations for the product to be purchased.

In short, the value of a product derives not only from the cost of alternatives, but also from the performance. Also, the buyers' task- and non task-related concerns must be taken into consideration during the evaluation process. In the choice model *for mass customisation*, the performance analysis is executed based on the factual assessment of product functions and the weighting attached to their importance as assessed by the buyers themselves, in response to their subjective preferences. Thus, each buyer may give a different weight to each of the evaluation criteria specified in the preceding phase and, as a consequence, the performance score (or level) of alternatives will differ from one person (or group) to another.

EVALUATION CRITERIA	WEIGHT %	ALTERNATIVE				
		1	2	3	4	5
A	4	4 16	3 12	4 16	2 8	5 20
B	52	3 156	4 208	5 260	3 156	4 208
C	26	3 78	3 78	4 104	2 52	4 104
D	0	4 0	3 0	3 0	3 0	5 0
E	17	3 51	4 68	4 68	1 17	3 51
PERFORMANCE SCORE		301	366	448	233	383

Table 7.7: Analysis matrix

(After Dell'Isola 1997)

To assess the *value* of a product, the result of the economic analysis needs to be integrated with the outcome of the performance analysis. Thus, the next stage of the choice model aims to identify the *value* of the given alternatives, which derives from the cost and performance analyses, focusing on aiding the buyers' selections for them.

7.3. SELECTION OF ALTERNATIVES

This stage is the last stage in the choice model *for mass customisation* that concerns the buyers' selection process for the given alternatives. However, it is important to note that this stage is not aimed at identifying the best choice among the alternatives; rather, it attempts to facilitate the buyers' final decision making for the selection of alternatives while visualising the *value* of each. Thus, this stage helps buyers make the optimum choice of alternatives in response to their needs, desires and expectations for the product. In order to visualise the value of alternatives, a *cost-performance graph* will be introduced in this stage; thus, the following section identifies the chart and the features.

7.3.1. COST-PERFORMANCE GRAPH

The '**cost-performance graph**' is developed based on the economic and performance analyses conducted in the preceding stage. In general, the vertical axis of the graph is established to identify the cost of each alternative—i.e. the actual cost obtained by the economic analysis. Instead of the actual cost data, the cost ratio (as compared with the highest cost) can be used in its place, when the actual cost data cannot be displayed. On the other hand, the horizontal axis is used to represent the performance level of each alternative that reflects the buyer's potential satisfaction, as stated earlier.

To illustrate the cost-performance graph, the hypothetical results of the performance analysis of five alternatives are used, as shown in Table 7.7, whilst Table 7.8 shows hypothetical total project costs ranging from \$25,000 to \$65,000 which came from an economic analysis. According to the data used for this value analysis, a cost-performance graph is drawn to show graphically the value of each alternative (Fig. 7.12).

ALTERNATIVE	COST ($)	PERFORMANCE LEVEL
1	50,000	301
2	45,000	366
3	65,000	448
4	25,000	233
5	30,000	383

Table 7.8: Economic and performance profiles of alternatives

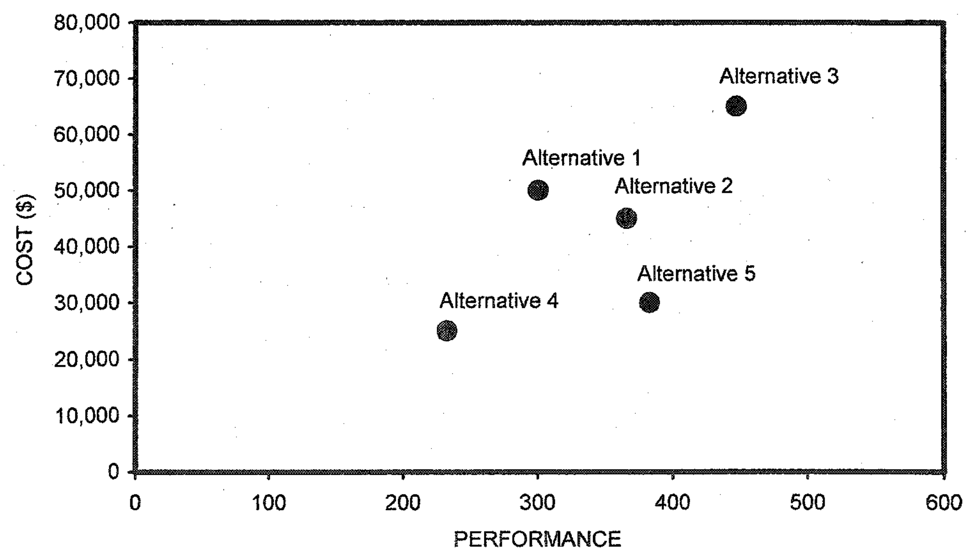


Figure 7.12: Cost-performance graph

According to the results of the value analysis, as shown in Figure 7.12, Alternative 3 achieved the highest level from the perspective of performance; however, it is the most expensive alternative. Thus, Alternative 3 can be referred to as a high cost-performance product, which may be suitable for buyers who focus solely on performance. On the other hand, Alternative 4 has the lowest level for performance and cost; thus, it can be considered as a low cost-performance product, which may be suitable for buyers who pay more attention to the lower-priced products and for whom performance is less of a consideration. The performance level of Alternative 1 is slightly higher than that of Alternative 4; however, second to Alternative 3, the cost is the highest among the alternatives. Even though the performance level of Alternative 2 is higher than that of Alternative 1, the cost is estimated to be lower; thus, Alternative 2 may be considered more preferable to Alternative 1. Finally, Alternative 5 seemingly combines the characteristics of Alternative 4 and 3. Second to these alternatives, Alternative 5 is the highest in performance and the lowest in cost. Thus, Alternative 5 may be considered the most preferable product among the given alternatives. However, it is important to note that this stage of the choice model *for mass customisation* aims to facilitate the buyers' final selection for the alternatives; thus, the choice of these must be left to them.

In addition, the paired comparison approach, as described in the preceding stage, may also be useful in aiding buyers to make the final choice. To illustrate this, the alternatives (1, 2, 3, 4 and 5) are called A, B, C, D, E, respectively; furthermore, suppose the following preferences are obtained by comparing two factors at a time:

$$A < B,\ A > C,\ A > D,\ A < E,\ B > C,\ B > D,\ B < E,\ C < D,\ C < E, \text{ and } D < E$$

Thus, these paired comparisons achieve the following ranking:

$$E > B > D > A > C$$

As stated earlier, the outcome of the paired comparisons depends fully on the decision-maker's *subjective* preferences; thus, it may differ from one person (or group) to another.

7.4. SUMMARY AND CONCLUSIONS

For the purpose of the choice model *for mass customisation*, the value of a product (or service) was re-interpreted by the following relationship:

VALUE = PERFORMANCE / COST

In this conceptual model, the cost factors include the present and future costs of products under study, which are involved in executing a project. On the one hand, performance factors reflect not only product functionality, but also the potential level of the buyers' satisfaction in response to their needs, desires, and expectations for the product to be purchased. Furthermore, this 'value analysis' phase consisted of the last two stages of the choice model—i.e. *evaluation of alternatives* and *selection of alternatives*. In order to facilitate the buyers' choices of the given alternatives generated in the proceeding phase, the economic and performance analyses were executed so as to identify the value. Finally, the outcome obtained by the value analysis was visualised in a simple graphical form. In this phase, some analytical techniques can be applied and these can be summarised as follows:

Evaluation of alternatives: In particular, this stage aimed to identify the economic and performance profiles of alternatives generated in the preceding phase. In the broadest sense, the economic analysis focused on examining the project cost and time factors, based on the time value of money concepts, while the performance analysis concerned quality issues, which encompass product functionality, as well as the buyers' *subjective* judgement. In advance of the economic analysis, project time was estimated by using the 'Program Evaluation and Review Technique' (PERT), 'Network Analysis' and 'Critical Path Method (CPM) Algorithm'. Next, the 'cash flow diagram' and 'present worth method' were reviewed for use in the economic analysis of each alternative. Finally, the performance analysis was executed by using the 'evaluation criteria scoring matrix' (based on the 'paired comparison approach') as well as the 'analysis matrix' that helps integrate the factual evaluation of product functionality with the buyers' subjective judgement—i.e. *weighted evaluation*.

Selection of alternatives: This stage was aimed at *visualising* the value of each alternative, combining the results of the economic and performance analyses carried out in the last stage. Thus, a 'cost-performance graph' that helps the visualisation of the value was introduced. To a considerable extent, this simple graph helps the buyer to understand the relationship between the cost of the alternatives in question and the performance level that reflects their individual needs, desires and expectations for the alternatives to be purchased. Furthermore, a 'paired comparison approach' was also applied for ranking the buyers' choices of alternatives, based on their own judgement.

To analyse the value of alternatives, the cost-quality-time factors involved in a project execution need to be examined; furthermore, the buyers' emotional factors must be taken into account. Thus, the **weighted evaluation** of the given alternatives, which in part encompasses the buyers' subjective judgement (e.g. preference and importance) on the task- and non task-related evaluation criteria, is of importance in identifying the value, which will differ from one person (or group) to another.

Finally, the theoretical framework of the choice model *for mass customisation* was developed and all analytical techniques applied to the model were identified. In order to make it more applicable to the decision-makers (e.g. homebuilders), the choice model needs to be examined by using actual data within the context of a given scenario. Thus, Part III of this thesis will focus on demonstrating the choice model and examining its practicality.

PART III:

DEMONSTRATION

8.1. INTRODUCTION

The choice model *for mass customisation* was developed and the theoretical issues surrounding the model were discussed in Part II. However, its application to the situations in which homebuilders' actual decisions for the selection of homebuilding approaches, as discussed in Chapter 5, come into play remains unclear. Consequently, this chapter focuses on a demonstration of the choice model in order to examine its *practicality*. It is important to note that even though this chapter may introduce some products (and services) that a buyer would consider for the achievement of his project goal, it does not seek to emphasise particular products for further purchase. In order to maintain objectivity in examining the practicality of the choice model, the author generated a demonstration project in collaboration with a selected homebuilder intending to initiate a mass housing development in Quebec from which he would obtain data concerning cost-quality-time-location factors, as discussed in Part II. (As well, the author also tested the proposed choice model in an actual interior design project in Montreal where the homeowner was allowed to select the interior arrangements that helped mass customise his rooms. The information concerning this interior design project was included in Appendix E.) The data related to the mass housing development was collected by means of the author's observations of off-site and on-site construction, interviews with selected company executives and questionnaires, as well as literature reviews relevant to this study. As a result of the demonstration project, the author found that the choice model, which is composed of five decision-making stages, contributes effectively towards eliminating the goal identification uncertainty and goal/purchase matching uncertainty, which are usually involved in buy-or-make decisions, as previously discussed in Chapter 5. Furthermore, he confirmed the adaptability of the choice model to the homebuilder's decision-making for the purchase of products and services that help accomplish his project goal as identified in the first stage. This chapter also identifies the most effective alternative (among the 12 alternatives generated in the third stage) in the fifth stage of the model, through the evaluation process carried out in the fourth stage, in response to the project objectives and specifications formulated in the second stage. Accordingly, the homebuilder's buying decision-making process using the choice model will be described in this chapter.

8.2. PROJECT BACKGROUND

The demonstration of the choice model *for mass customisation* developed in Part II was carried out in collaboration with a selected R-2000 certified homebuilder in Quebec seeking to expand his business to a mass scale. Currently, the company produces less than five single-family dwelling units each year.[1] This family-operated firm conceded that the homes, which they have built over the past few year, were conventional homes rather than R-2000 or industrialised counterparts. The builder explained that, when buying a home, buyers still tend to attach importance to a lower initial cost, rather than to subsequent operating costs, as they do not understand the total monetary value (or *lifecycle cost*) of a house (Talbot 2003). In order to learn about the value analysis approach, which is partially involved in the choice model, the homebuilder agreed to offer the author some technical information concerning this demonstration project.

Henceforth, to simulate the choice model, the homebuilder, as stated above, will be considered a '**model user**' and the author will act as a consultant working for the builder, who is looking to apply more effective homebuilding approaches to his future mass housing development. However, it is important to note that this demonstration project is not aimed at *advocating* any specific products or services. Rather, and more importantly, it focuses on *demonstrating* the choice model itself—i.e. the decision-making process that helps the builder understand the *value* of the new approaches.

This demonstration project relates to the first two phases of the choice model—i.e. the 'mass

[1] Polyôme Construction (R.B.Q. #8001-1497-64).

customisation' phase and the 'value analysis' phase. In the first phase, the alternatives which contribute towards mass customising the builder's housing development, will be identified, while the value analysis concerning the cost-quality-time factors of the given alternatives will be examined in the second phase.

8.3. PHASE I: THE MASS CUSTOMISATION

As described in Part II, the mass customisation phase of the choice model is aimed at identifying the homebuilder's *need* that reflects local homebuyers' *demand* for housing, as well as formulating the project objectives specifications in response to that need. In addition, this phase focuses on generating some alternatives that help the builder accomplish his project goal (see Figure 5.8). In summary, this phase concerns the first three stages of the choice model *for mass customisation*:

1. **Identification of need**
2. **Formulation of objectives and specifications**
3. **Generation of alternatives**
4. Evaluation of alternatives
5. Selection of alternatives

Each stage of the choice model will be simulated in the following sections.

8.3.1. STAGE I: THE IDENTIFICATION OF NEED

The main purpose of this stage is to identify the homebuilder's need to build marketable homes, which reflect the 'local' market demand for housing. However, the homebuilder, selected for this study, who acts as a final decision maker (or *buyer*) for the selection of housing systems that will be identified in the third stage of the choice model, has not yet determined the exact building site for his housing development. Thus, with the builder's approval, the primary and secondary data that the author collected and analysed in Chapter 2 and 3 will be used for this study.

In Chapter 2, today's housing demands were discussed in depth with due consideration given to non-traditional households—e.g. young singles living alone or with other singles, those who are separated, widowed, or living alone, and single parent families. As discussed in Chapter 2, these households are usually small in size and are not often affluent. In particular, based on the demographic trends reflecting a *marriage crisis*, young adults aged 20 to 40 of non-traditional household types, with diverse housing demands, are considered to be prime potential homebuyers. Furthermore, in response to environmental problems faced by today's society, the housing industry is increasingly required to produce energy-efficient homes, in which resource savings in construction is also of concern. Thus, in addition to 'housing affordability', 'housing quality' will be taken into account. This quality factor in part reflects design customisability in response to the wants and needs of individuals, as well as energy efficiency requirements in response to the wants and needs of society.

In addition to the secondary data, as stated above, the primary data that the author collected in order to document the actual situation of a typical townhouse development in the Montreal area also confirms the importance of housing affordability and quality, as described in Chapter 3. As a result of the primary and secondary data applied to the market research concerning consumers' demands for housing, the author concluded that the homebuilder *needs* to build '**quality affordable homes**' that are, and will continue to be, in great demand.

8.3.2. STAGE II: THE FORMULATION OF OBJECTIVES AND SPECIFICATIONS

In the first stage of the choice model, the author concluded that 'quality affordable homes' are in great demand and assumed that the builder would build such homes in his future housing project. Accordingly, this stage aims to formulate the project objectives, as well as specifications. As described in Part II, the objectives will be expressed in the verb-noun form—i.e. *functions*. To build quality affordable homes (i.e. order function), the cost-quality-time-location factors that are involved in most housing development, as described in Chapter 6, will first be taken into account. The cost and quality factors were regarded as the basic functions that directly relate to the accomplishment of the order function, while the time factors are considered the secondary functions that support the accomplishment of the basic functions. To some extent, location factors (such as regulations, climatic conditions, geographical conditions and existing infrastructure's conditions) restrict the freedom of the builder's choices for homebuilding approaches. Thus, location factors are considered as restrictive factors. As stated earlier, the builder has not yet decided on a specific building site for his future housing development; thus, in this demonstration project, the location factors are less of a consideration, while the cost-quality-time factors need to be further discussed.

In order to rationalise the interrelationship between the functions that aim to achieve the order function, the author developed the FAST Diagram that identifies group functions concerning cost, time and quality factors, as well as the lower level functions in response to the group functions (Fig. 8.1). In order to reduce housing costs, the cost factors were classified into initial and operating costs. The former concerns the construction cost, which can be subdivided into direct and indirect costs, as described in Chapter 1, while the latter mainly concerns energy costs.

Furthermore, in order to improve housing quality, the factors related to design and product quality were taken into account. As for the design quality, the author focused mainly on increasing the levels of housing *customisation*, which may be achieved at the time of purchase, as well as of housing *personalisation*, which is likely to be carried out after purchase. Thus, *flexibility* that may help the owners personalise their house needs to be incorporated with the interior space arrangement. As well, the author also considered the appearance of a house (that may be affected by the builder's choice of materials and shapes to be applied to housing design) as a factor that helps harmonise the new home with the surrounding buildings.

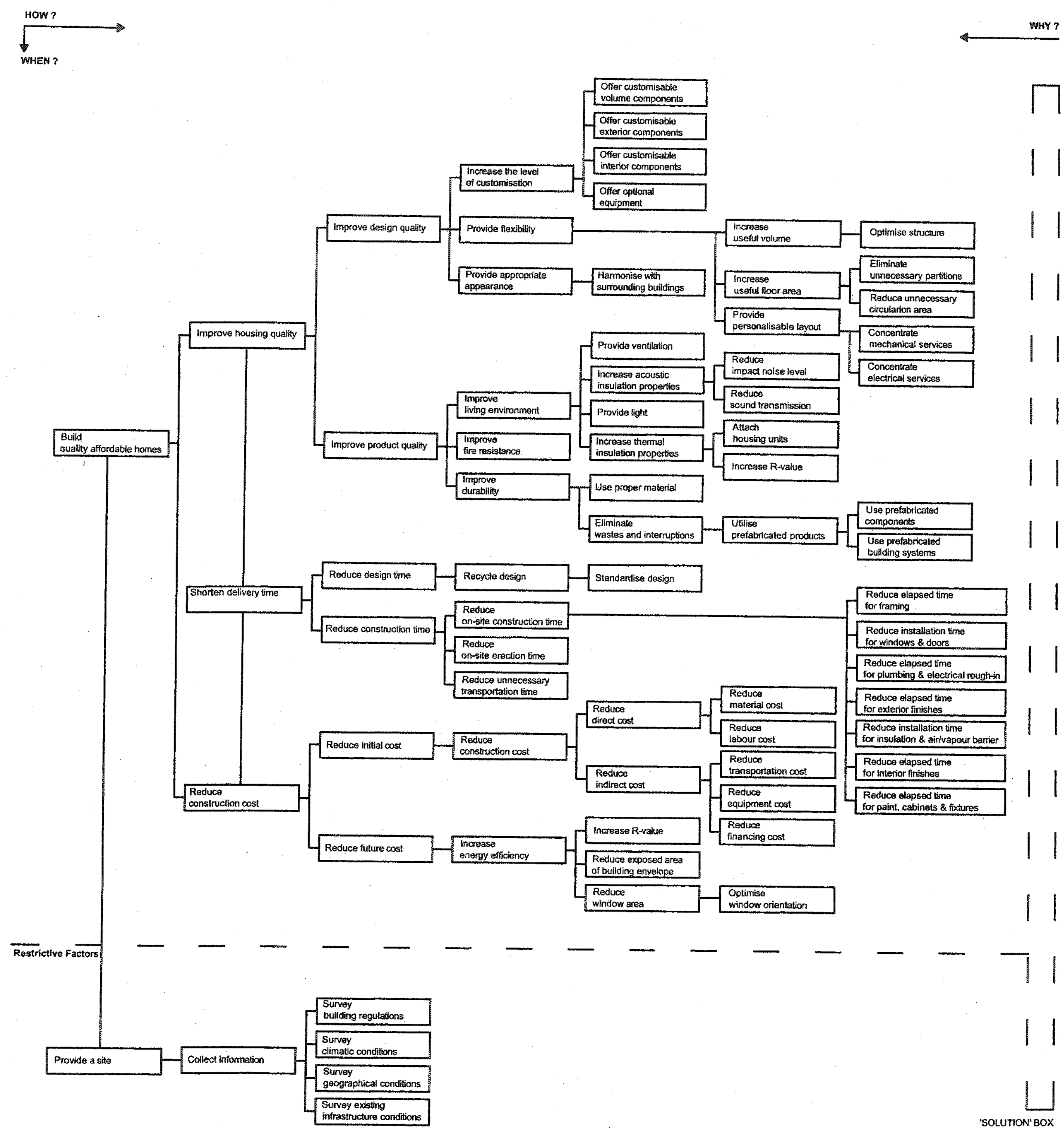


Figure 8.1: The FAST Diagram

Generally speaking, the longer the design and construction time, the higher the cost, where the labour cost is affected by the time elapsed for the project execution. However, the work driven into an earlier completion may result in a reduction in construction quality, which may in turn contribute towards lowering product quality. The author considered the repetitive use of standard housing designs (or drawings) as an effective means of reducing design time, and also assumed that the reduction of on-site construction time can be achieved by increasing in-factory completion of housing components and systems.

However, the author admitted that some functions that appear in the FAST Diagram might not be achieved by the builder's buying actions themselves. For example, the functions, such as "optimise structure", "eliminate unnecessary partitions", "reduce unnecessary circulation area", "concentrate mechanical services", "concentrate electrical services", "attach housing units", "reduce exposed area of building envelop", "increase R-value" and "optimise window orientation" are related to design issues.

After the FAST Diagram that aims to identify the functions required for the accomplishment of the order function, as well as to visualise the interrelationships of the identified functions is complete, the project specifications will be formulated. The specifications will be used for further comparative analysis of alternatives generated in the third stage of the choice model. In other words, the multiple **evaluation criteria** will be developed in response to the functions identified in the FAST Diagram. Accordingly, the author developed the evaluation criteria based on the results of the function analysis, as well as from discussions with the homebuilder, who was also concerned that his "familiarity" with products and services to be applied to his housing development (Table 8.1).

TASK-RELATED FACTOR
QUALITY
Customisability of volume components
Customisability of exterior components
Customisability of interior components
Potential improvement of fire resistance properties
Potential improvement of acoustic insulation properties
Potential improvement of thermal insulation properties
Potential improvement of electrical equipment
Potential improvement of mechanical equipment
In-factory completion of housing components
TIME
Potential reduction in design time
Potential reduction in construction time
COST
Potential reduction of design cost
Potential reduction of construction cost
NONTASK-RELATED FACTOR
Familiarity of products or services to be used

Table 8.1: Evaluation criteria

Furthermore, for the functions that relate to design issues as stated above, the author developed a townhouse model based on the existing houses built in the Bois Franc project in Montreal (Figs. 8.2 & 8.3). This housing model is used to specify the builder's *minimum* requirements for product quality and is also utilised for further comparative analysis of housing systems that the builder will use to make choices that help him to produce lower-cost and high-performance homes. The model house, which the author developed, has a frontage of 20 feet and a depth of 40 feet; thus, the total floor area including the first and second floors can be estimated at 1600 sq.ft. and this area will be used as the basis for cost estimates. Furthermore, each dwelling unit is attached and is built on a basement made of concrete. As discussed in Chapter 1, joining units into groups of two or more can provide significant savings in construction and achieve energy efficiencies. Thus, this design approach itself considerably contributes to sustainability in housing development. An open floor plan that eliminates unnecessary partitions and circulation areas was also applied to the ground floor arrangement. Furthermore, like the Bois Franc project, 2" x 6" studs are used for the exterior load-bearing walls, while 2" x 4" studs are used for the interior load-bearing and non load-bearing walls. The product quality of this model house is expected to be, at least, to the same level as that of a typical *Village renaissance* townhouse built in the Bois Franc project, whose specifications have already been identified in Chapter 3.

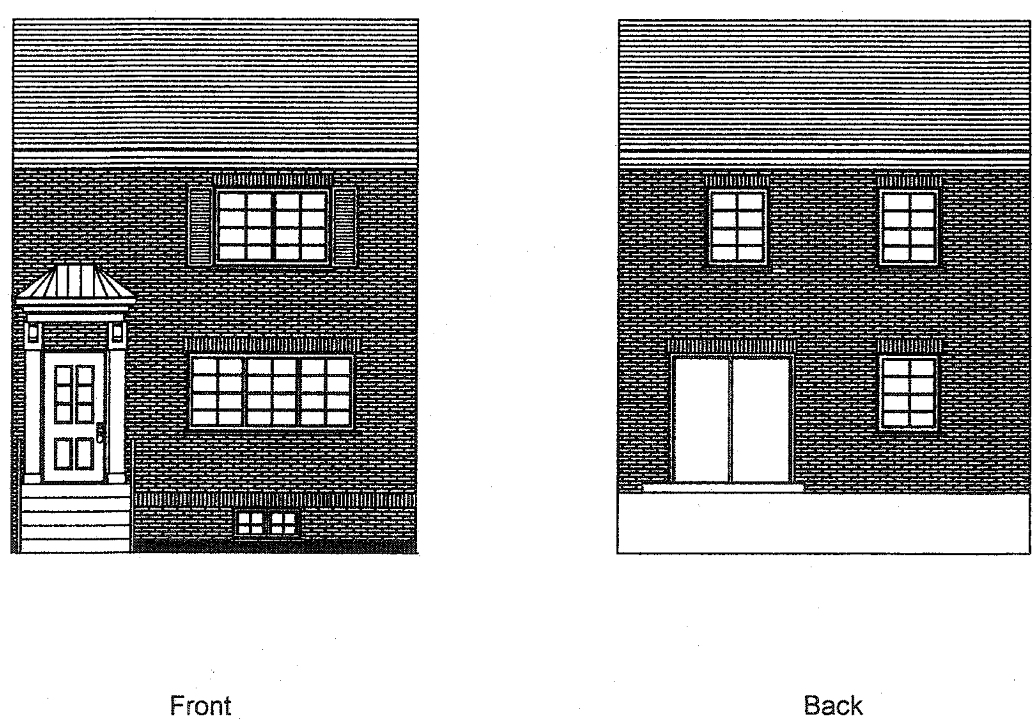
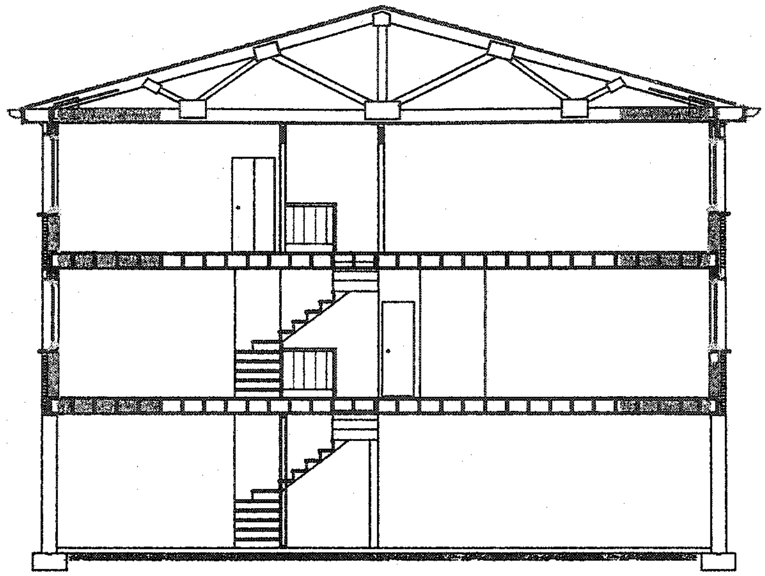
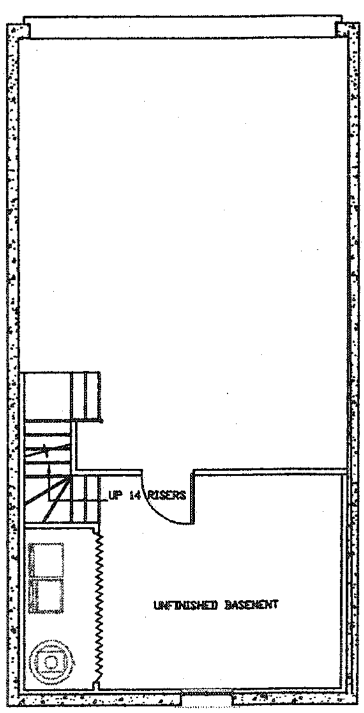


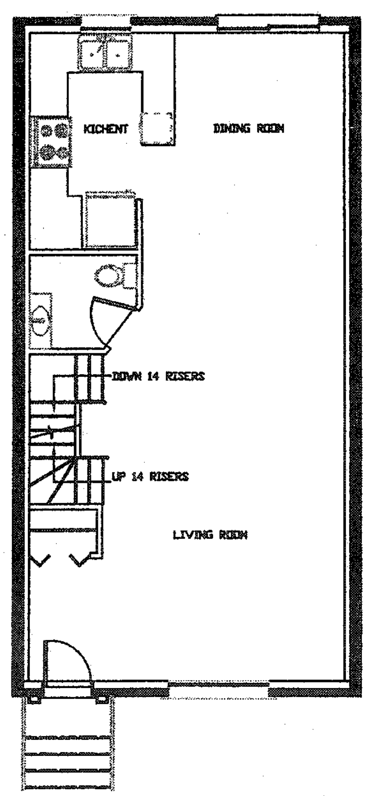
Figure 8.2: The elevations of a model house



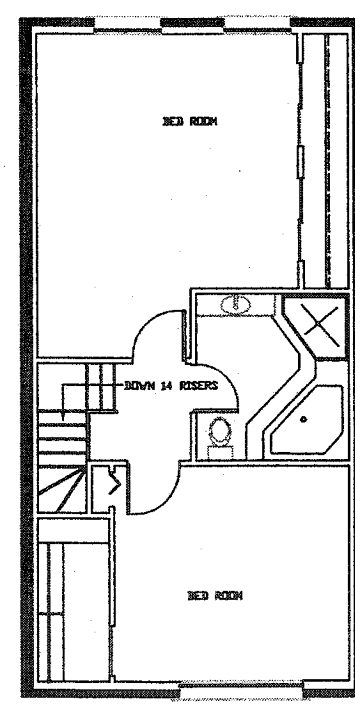
Section



Basement



Ground Floor



Second Floor

Figure 8.3: The section and plans of a model house

This stage of the choice model focused solely on formulating the builder's project objectives and specifications; thus, it identified important functions necessary for the accomplishment of the order function, as well as specifying the builder's minimum requirements for the house to be built. In order to generate the *alternatives* (i.e. products and services) that help carry out the builder's housing development, which aims to meet the wants and needs of individuals as well as of society, an in-depth analysis of the FAST Diagram developed in this stage needs to be carried out. Thus, the next stage will focus on generating alternatives, based on a further analysis of the functions identified in this stage.

8.3.3. STAGE III: THE GENERATION OF ALTERNATIVES

After the evaluation criteria and other supplementary materials (such as drawings and specifications) which represent the builder's needs, desires and expectations for the homes to be built, are prepared, the alternatives, which the builder would consider through further buying actions, will be generated in order to execute his housing development. Accordingly, the following sections firstly review the FAST Diagram developed in the preceding stage, and secondly, identify some products and services for further comparative analysis.

As shown in Figure 8.1, except for the location factors, the FAST Diagram focused on identifying the cost-quality-time factors. As for the quality factors, the improvement of design and product quality was of concern. In terms of design quality, the customisability of housing was taken into account, while the provision of flexibility was also considered important in allowing users to personalise their own house after occupancy. In addition, the author included a function that aims to harmonise the new house with the surrounding buildings. However, the builder has not yet identified a specific construction site; thus, the author adopted a classic appearance of brick housing popular in the Montreal area, as shown in Figure 8.2. Except for the customisability of housing, the other features related to design quality, as stated above, were introduced into the model house developed in the last stage. Thus, in order to produce quality homes that correspond with the consumers' diverse demands housing, 'design' approaches to the delivery of custom housing should be taken into account for the generation of alternatives.

Furthermore, in terms of product quality, the environmental aspects concerning lighting, ventilation, acoustic insulation, and thermal insulation, as well as housing durability were considered to be important. Thus, the model house was developed to identify the minimum product quality that would incorporate these aspects. However, the provision of a model house (or *product*) alone can hardly maintain product quality against external forces—for example, site nuisances (such as bad weather, theft and vandalism that to some extent yield site wastes and interruptions) which may deteriorate product quality occur in the on-site construction *process*. Thus, 'construction' approaches to the improvement of product quality should also be taken into account.

As shown in the FAST Diagram, as noted above, time factors, such as design and construction time, interrelate with cost and quality factors. For example, the reduction of the elapsed time for design activities can be achieved by recycling or standardising design components (and processes). On the other hand, the reduction of elapsed time for on-site construction activities can be accomplished by optimising construction scheduling and/or increasing in-factory completion of housing components and systems. Site interruptions, whose occurrence is hard to predict, inevitably affect construction time; thus, the author was again concerned with design and construction approaches that optimise design and construction time.

As shown in Figure 8.1, construction cost also interrelates with housing quality and delivery time. To some extent, the reduction of construction costs can be achieved by reducing the initial cost that includes direct costs related to labour wages and material costs and the indirect costs that relate to transportation, equipment and financing costs. As well, future costs including energy cost also need to be taken into account. As stated above, energy consumption is affected by housing types; thus, attached housing, whose heat-losing exterior walls are fewer exposed than those of detached housing, was applied to the model house that will be used for further comparative analysis of alternatives. The initial cost may be affected by the builder's selection of design and construction approaches to be applied to his housing development. Thus, based on the review of the FAST Diagram formulated in the last stage of the choice model, **design and construction approaches** will be considered in this study as the *alternatives* from which the builder will make choices (Fig. 8.4).

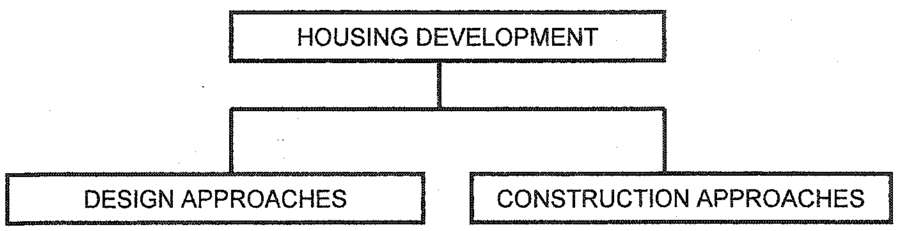


Figure 8.4: The work breakdown structure of a housing development

As stated earlier, this study attempts to aid the homebuilder to make buy-or-make decisions for products and services that to a considerable extent affect the way he will carry out his housing development. Accordingly, the alternatives that relate to design and construction approaches will be generated based on the concept of mass customisation. Furthermore, in order to facilitate the builder's buy-or-make decisions, the model house developed conceptually in the preceding stage will be used for comparative analysis of the given alternatives in terms of the cost-quality-time factors.

As for the design approaches that affect the levels of customisability, which respond to the market's diverse demands for housing, the author presented to the builder three existing design approaches that have been applied by North American homebuilders and housing manufacturers—i.e. the production (or speculative), semi-custom, and custom design approaches. In order to increase the level of design standardisation that helps shorten the design time, as stated above, as well as the level of customisability, the author also included a mass custom design approach, which has been applied by Japanese housing manufacturers, as described in Chapter 4. This relatively new design approach was included in order to examine the potential effects on the delivery of quality affordable homes in a Canadian context (Fig. 8.5).

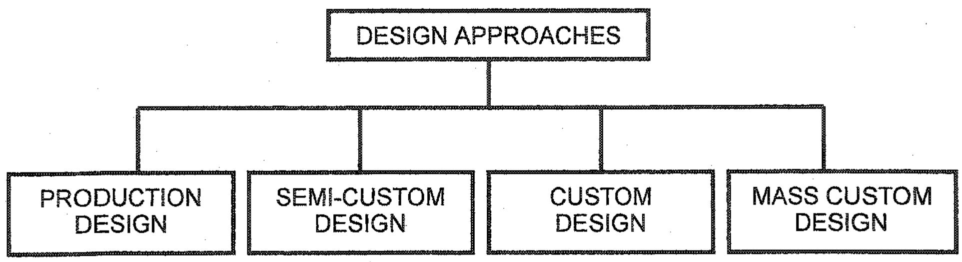


Figure 8.5: The work breakdown structure of design approaches

As for the construction approaches that may affect product quality and on-site construction time, which in turn influence the initial cost, the author presented to the builder both conventional and industrialised homebuilding approaches, in response to the function analysis conducted in the preceding stage. In theory, the higher the in-factory completeness of housing components, the higher the product quality and the shorter the on-site construction time. Thus, the author included process-oriented industrialised building systems, as discussed in Chapter 1, among the alternatives. In particular, the author considered panelised and modular housing systems more applicable to the builder's residential development, in which wood light-frame construction methods are applied. Thus, three construction systems that help build site-built, panelised and modular homes were chosen for further comparative analysis (Fig. 8.6).

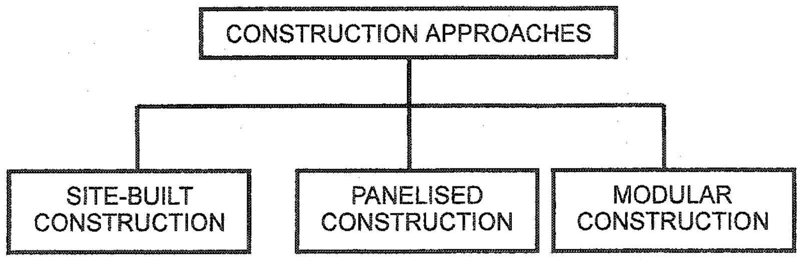


Figure 8.6: The work breakdown structure of selected construction approaches

For this study, the design approaches are considered as service-oriented (or *process*-oriented), while the construction approaches are considered as product-oriented. Accordingly, in order to generate alternatives, the mass customisation system model, i.e. MC = f (PS), which was developed in Chapter 4, was used to integrate the product- and service-oriented approaches.

Furthermore, the total number (of possible *combinations*) of the given alternatives were calculated using the formula that in part reflects the basis of set theory, as follows:

$$n(P \times S) = n(P) \cdot n(S) = 3 \cdot 4 = 12$$

In this calculation, "P" represents the construction approaches (i.e. 3 choices), while "S" represents the design approaches (i.e. 4 choices). Accordingly, in total, 12 alternatives were generated in order to mass-customise the builder's housing development. As described in Chapter 6, coding the WBS permits efficient communication; hence, the production, semi-custom, custom, and mass custom design approaches will be abbreviated as "SD", "SCD", "CD" and "MCD", respectively, while the site-built, panelised, and modular construction approaches will be abbreviated as "SC", "PC" and "MC". In this way, the homebuilder will be able to choose some combinations of the design and construction approaches from the 12 alternatives in order to mass-customise his end product (Fig. 8.7).

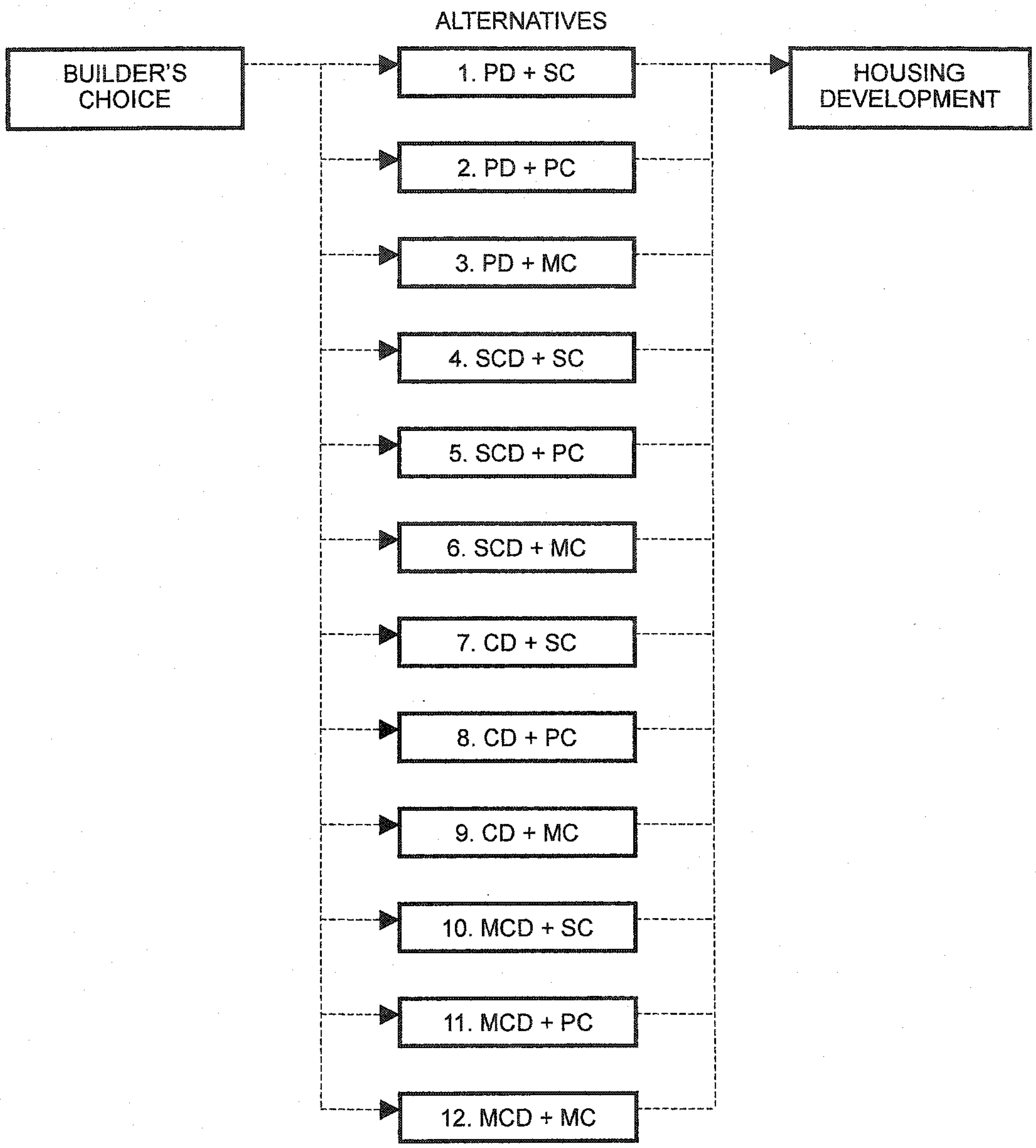


Figure 8.7: The builder's potential choices of alternatives for mass customising housing development

The mass customisation phase of the choice model focused on generating alternatives that contribute towards mass customising a housing development, while offering the homebuilder some choices of the conventional and innovative design and construction approaches. However, without understanding the value of each alternative, the builder is likely to choose an alternative with which he is most familiar, based either on his experience or on *convention*. Thus, to avoid this situation, the value analysis of alternatives, which helps the builder understand the actual *value* of alternatives, will be carried out in the next phase of the choice model. In response to the builder's needs, desires and expectations for the products and services to be purchased, the value of each will be presented visually in order to facilitate the homebuilder's final choices towards the delivery of quality affordable homes identified in the first stage of the choice model.

8.4. PHASE II: THE VALUE ANALYSIS

As described in Part II, the 'value analysis' phase of the choice model aims to aid model users to make their buy-or-make decisions while identifying the value of the alternatives generated in the third stage of the model. Thus, this phase comprises the last two stages of the choice model:

1. Identification of need
2. Formulation of objectives and specifications
3. Generation of alternatives
4. **Evaluation of alternatives**
5. **Selection of alternatives**

This phase focuses on evaluating the alternatives with respect to the cost-quality-time factors, as well as the homebuilder's emotional factors identified in the second stage of the choice model. Accordingly, in the following sections, the last two stages of the choice model will be demonstrated.

8.4.1. STAGE IV: THE EVALUATION OF ALTERNATIVES

This stage aims to evaluate the given alternatives (i.e. design and construction approaches) by analysing cost and performance. As discussed in Chapter 7, none of the cost-quality-time factors are mutually independent; thus, the author examined these factors in depth in order to evaluate the alternatives. Firstly, the project time estimates concerning the design and construction approaches were carried out. The author assumed that the housing project takes place in the Montreal area, since the location factor affects the time elapsed for the transportation of industrialised building systems from the factory to the building site. Secondly, the economic analysis of the alternatives that relies on the interrelationship between the cost and time factors was carried out based on the project time estimated in advance. Finally, the performance analysis of the alternatives, which to some extent reflect quality factors, was conducted in order to identify the value in response to the builder's needs, desires and expectations for the products and services to be purchased.

8.4.1.1. PROJECT TIME ESTIMATES

In this section, time estimates relating to the design and construction approaches presented to the builder were carried out using selected analytical techniques, such as PERT and CPM, as described in Chapter 7. Firstly, the design time was estimated; secondly, the construction time was identified; and finally, the total project time of the given alternatives was computed by summing up the design and construction time.

For this study, the design time represents the sum of the selected design activities. The optimistic time, most likely time, and pessimistic time (as described in Chapter 7) of each design approach were estimated based on the data obtained by the author's personal interviews with the homebuilder as well as housing manufacturers in Quebec. In addition, in collaboration with the builder, the author estimated the time required for the practice of the mass custom design approach, which is relatively new in the North American housing industry.

In order to calculate the design time, the author first selected some typical activities involved in the preliminary and detailed design stages, and then, using the PERT as described in Chapter 7, he estimated the time elapsed for each design activity of a premier (or *first*) dwelling unit, which represents a model house (i.e. the first of a series of housing to be built) for the production, semi-custom, and mass custom design approaches (Table 8.2). Thirdly, they estimated the time elapsed for each design activity of the succeeding (or *subsequent*) housing unit, in which the drawings and specifications prepared for the production of a premier unit can be partly or fully re-used (Table 8.3).

ACTIVITY	DESIGN APPROACHES			
	PRODUCTION	SEMI-CUSTOM	CUSTOM	MASS CUSTOM
MODEL HOUSE DEVELOPMENT	REQUIRED	REQUIRED	N/A	REQUIRED
Optimistic time	10 DAYS	10 DAYS	-	15 DAYS
Most likely time	15	15	-	20
Pessimistic time	20	20	-	25
Expected design time by PERT	15.0	15.0	-	20.0
INITIAL DESIGN CONSULTATION	REQUIRED	REQUIRED	REQUIRED	REQUIRED
Optimistic time	1	1	1 DAY	1
Most likely time	1	2	2	2
Pessimistic time	2	3	4	3
Expected design time by PERT	1.2	2.0	2.2	2.0
PRELIMINARY DESIGN	N/A	REQUIRED	REQUIRED	REQUIRED
Optimistic time	-	1	10	1
Most likely time	-	2	15	1
Pessimistic time	-	3	20	2
Expected design time by PERT	-	2.0	15.0	1.2
FINAL DESIGN CONSULTATION	N/A	REQUIRED	REQUIRED	REQUIRED
Optimistic time	-	1	1	1
Most likely time	-	1	1	1
Pessimistic time	-	2	2	2
Expected design time by PERT	-	1.2	1.2	1.2
WORKING DRAWINGS & SPECS.	REQUIRED	REQUIRED	REQUIRED	REQUIRED
Optimistic time	3	3	3	3
Most likely time	4	4	4	4
Pessimistic time	5	5	6	5
Expected design time by PERT	4.0	4.0	4.2	4.0
BUILDING PERMITS	REQUIRED	REQUIRED	REQUIRED	REQUIRED
Optimistic time	7	7	7	7
Most likely time	14	14	14	14
Pessimistic time	28	28	28	28
Expected design time by PERT	15.2	15.2	15.2	15.2

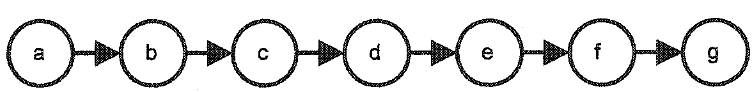
Table 8.2: Time estimates for the design of the first housing unit in housing development

(The data were collected based on interviews with a selected homebuilder and manufacturers in Quebec)

Furthermore, in order to calculate the total design time (i.e. the critical path), the relationship between the design activities selected for this study needs to be identified (Fig. 8.8). As shown in Figure 8.8, the design activities can be connected in a straight line. Thus, the result of this network analysis indicates that the total design time can be calculated simply by summing up all of the activities used for this study.

ACTIVITY	DESIGN APPROACHES			
	PRODUCTION	SEMI-CUSTOM	CUSTOM	MASS CUSTOM
MODEL HOUSE DEVELOPMENT	N/A	N/A	N/A	N/A
Optimistic time	-	-	-	-
Most likely time	-	-	-	-
Pessimistic time	-	-	-	-
Expected design time by PERT	-	-	-	-
INITIAL DESIGN CONSULTATION	REQUIRED	REQUIRED	REQUIRED	REQUIRED
Optimistic time	1 DAY	1 DAY	1 DAY	1 DAY
Most likely time	1	2	2	2
Pessimistic time	2	3	4	3
Expected design time by PERT	1.2	2.0	2.2	2.0
PRELIMINARY DESIGN	N/A	REQUIRED	REQUIRED	REQUIRED
Optimistic time	-	1	10	1
Most likely time	-	2	15	1
Pessimistic time	-	3	20	2
Expected design time by PERT	-	2.0	15.0	1.2
FINAL DESIGN CONSULTATION	N/A	REQUIRED	REQUIRED	REQUIRED
Optimistic time	-	1	1	1
Most likely time	-	1	1	1
Pessimistic time	-	2	2	2
Expected design time by PERT	-	1.2	1.2	1.2
WORKING DRAWINGS & SPECS.	N/A	REQUIRED	REQUIRED	REQUIRED
Optimistic time	-	2	3	1
Most likely time	-	3	4	2
Pessimistic time	-	5	6	3
Expected design time by PERT	-	3.1	4.2	2.0
BUILDING PERMITS	REQUIRED	REQUIRED	REQUIRED	REQUIRED
Optimistic time	7	7	7	7
Most likely time	14	14	14	14
Pessimistic time	28	28	28	28
Expected design time by PERT	15.2	15.2	15.2	15.2

Table 8.3: Time estimates for the design of each subsequent housing unit in housing development by PERT



a-b: Model house development
b-c: Initial design consultation
c-d: Preliminary design
d-e: Final design consultation
e-f: Working drawings & specifications.
f-g: Building permits

Figure 8.8: A network analysis of the design activities

Accordingly, the total design time of the semi-custom, custom and mass custom design approaches to the production of the first housing unit was estimated at 35.4, 39.4, 37.8 and 43.6 days respectively (Table 8.4). As well, the time of the same approaches to the production of a subsequent housing unit was estimated at 16.4, 23.5, 37.8 and 21.6 days, respectively. These results indicate that recycling the drawings and specifications prepared for the first house (or *model house*) helps to drastically reduce the design time elapsed for the creation of each subsequent dwelling unit. In other words, the higher the level of standardisation in design components (i.e. drawings and specifications) and processes, the shorter the time elapsed for the design of a succeeding unit to be built based on a model house. Thus, the custom design approach, which always starts from a blank blueprint for the creation of a one-of-a-kind house does not reduce design time when a number of houses are being built. However, the design time of the custom design approach was estimated to be the second shortest only for the production of the first house and this approach completely satisfies today's market demands for customised products. In comparison with the custom design approach, the semi-custom design approach can be considered as a time-reduction strategy when a number of housing units are being built. However, it may still need a large amount of work on the modification of existing drawings and specifications when a higher level of product customisation is required. Thus, the production design approach can be considered the most efficient approach among the alternatives in reducing the design time, which in turn helps reduce the cost. However, it may contribute towards producing repetitive, mass produced homes, which may fail to satisfy today's market demands for custom housing. Second to the production design, the mass custom design approach achieves the shortest design time for the production of each subsequent dwelling unit, while allowing homebuyers to customise their new home using standard housing components, which can be mass produced. However, the lapsed time for the design of the first unit using the mass custom design approach was estimated to be the longest, since the builder (or architect) may need to spend more time for the creation of several housing components, which must be interchangeable, than for the design of a house itself.

DESIGN APPROACHES	TOTAL DESIGN TIME	
	FOR THE FIRST DWELLING UNIT (DAYS)	FOR EACH SUBSEQUENT DWELLING UNIT (DAYS)
PRODUCTION (PD)	35.4	16.4
SEMI-CUSTOM (SCD)	39.4	23.5
CUSTOM (CD)	37.8	37.8
MASS CUSTOM (MCD)	43.6	21.6

Table 8.4: Total design time for the selected design approaches

In order to estimate construction time, the author selected some key construction activities, such as in-factory production, transportation, on-site erection, and on-site construction. For this study, on-site erection implies the installation of industrialised building systems at the time of their delivery to the building site, while on-site construction covers other on-site activities such as the completion of a conventional home at the building site and the finishing of an industrialised home. Thus, specifically, the time estimates concerning in-factory production, transportation and on-site erection are applied only for industrialised building systems—i.e. panelised and modular systems.

For the construction activities, the time estimates were carried out based on the data obtained mainly by means of questionnaires sent to housing manufacturers in Quebec, as well as from the author's personal interviews with the homebuilder and manufacturers (Tables 8.5, 8.6 & 8.7). In addition, in 2002, the author visited a building site in order to document the construction time elapsed for the on-site erection of a single-storey detached home composed of two modular sections. The four crews using a roller system began the on-site installation work at 12:00 p.m., when the modular sections arrived at the building site, and completed their tasks at 16:30 p.m. on the same day. Thus, it required about 18 man-hours to complete the on-site erection of the house (Appendix D).

MODULAR MANUFACTURER	TIME ESTIMATE IN DAYS		
	IN-FACTORY PRODUCTION	TRANSPORTATION AND ON-SITE ERECTION	ON-SITE CONSTRUCTION
CONSTRUCTION DUMAIS ET PELLETIER INC.	15	2	10
DOMTEC INC.	12	2	14
DOMICILEX INC.	3	2	14
LES MAISONS ALOUETTE	3	1	21
MAISON USINÉES CÔTÉ INC.	2	1	21
AVERAGE DAYS	7.0	1.6	16.0

Table 8.5: Time estimates for the application of modular systems

PANELISED MANUFACTURER	TIME ESTIMATE IN DAYS	
	IN-FACTORY PRODUCTION	TRANSPORTATION AND ON-SITE ERECTION
LES MAISONS ALOUETTE	2	1
TECHNOLOGICAL BUILDING STRUCTURES LTD.	2	2
AVERAGE	2.0	1.5

Table 8.6: Time estimates for the application of panelised systems

ON-SITE CONSTRUCTION STAGE	TIME ESTIMATE BY PERT IN DAYS			
	Optimistic time	Most likely time	Pessimistic time	Expected time
LAYOUT OF BUILDING*	1	2	4	2.2
EXCAVATION AND FOOTINGS*	4	5	7	5.2
FOUNDATIONS, DRAINAGE AND BACKFILL*	5	7	9	7.0
FRAMING (INCLUDING ROOFING AND FLASHING)**	10	12	14	12.0
DOORS AND WINDOWS***	4	5	7	5.2
PLUMBING, HEATING AND ELECTRICAL ROUGH-IN***	7	10	12	9.8
EXTERIOR FINISHES***	7	10	14	10.2
INSULATION, AIR AND VAPOUR BARRIERS**	4	5	7	5.2
INTERIOR FINISHES***	10	12	14	12.0
PAINT, CABINETS AND FIXTURES***	7	10	14	10.2

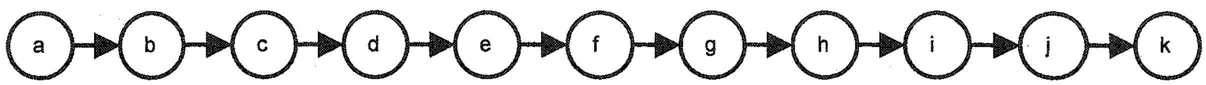
* Applied to the time estimates for all construction approaches

** Applied to the time estimates only for a site-built construction approach

*** Applied to the time estimates for panelised and site-built construction approaches

Table 8.7: Time estimates of on-site construction stages by PERT

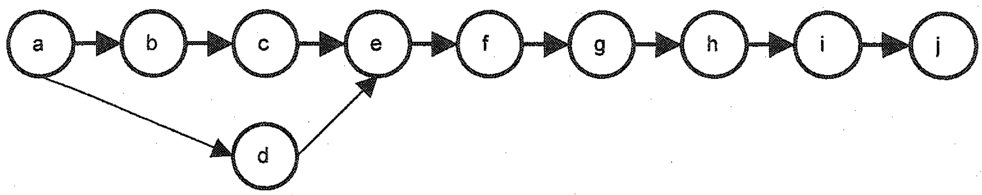
After the expected time for each construction activity is estimated, the network analysis that aims to identify the interrelationship between the activities may need to be carried out (Figs. 8.9, 8.10 & 8.11). In response to the analysis, the critical path that represents the total construction time required for the application of the construction approaches can be identified while also using the forward and backward pass calculations, as described in Chapter 7 (Tables 8.8 & 8.9).



a-b: Layout of building
b-c: Excavation and footings
c-d: Foundations, drainage and backfill
d-e: Framing (including roofing and flashing)
e-f: Doors and windows
f-g: Plumbing, heating and electrical rough-in
g-h: Exterior finishes
h-i: Insulation, air and vapour barriers
i-j: Interior finishes
j-k: Paint, cabinets and fixtures

Figure 8.9: A network analysis of the construction activities applied to site-built housing

As shown in Figure 8.9, the activities within which the site-built construction approach is applied can be connected in a straight line i.e. the longest activity path or *critical path*. Thus, the sum of the time elapsed for each activity is considered the total construction time of the approach under study. As for the panelised system, the in-factory production of wall and floor panels, with which thermal batt insulation is often incorporated, can be carried out in parallel with the on-site construction to build the foundations. Thus, the total construction time can be reduced, even though the time elapsed for the on-site construction is still greater than the time required for the in-factory production, as shown in Figure 8.10. The modular system, in which roughly 90% of housing components may be assembled in the factory, achieved the shortest on-site construction in this time estimate—16 days on average after the on-site erection. Like the panelised system, the in-factory production of housing components can be carried out in parallel with the on-site construction to build the foundations, as shown in Figure 8.11. However, the duration of on-site construction is again the longest and can be considered the critical path, in which the total float is equal to zero in this case, as shown in Table 8.9.

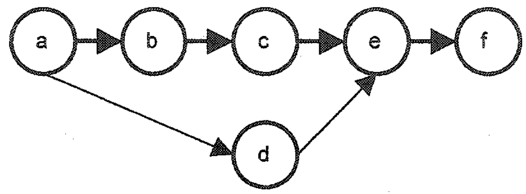


a-b: Layout of building
b-c: Excavation and footings
c-e: Foundations, drainage and backfill
a-d: In-factory production
d-e: Transportation and on-site erection
e-f: Doors and windows
f-g: Plumbing, heating and electrical rough-in
g-h: Exterior finishes
h-i: Interior finishes
i-j: Paint, cabinets and fixtures

Figure 8.10: A network analysis of the construction activities applied to panelised housing

ACTIVITY	DURATION	EARLY START (ES)	EARLY FINISH (EF)	LATE START (LS)	LATE FINISH (LF)	TOTAL FLOAT (LF-EF)
a-b	2.2 DAYS	0 DAY	2.2 DAYS	0 DAY	2.2 DAYS	0 DAY
b-c	5.2	2.2	7.4	2.2	7.4	0
c-e	7.0	7.4	14.4	7.4	14.4	0
a-d	2.0	0	2	10.9	12.9	10.9
d-e	1.5	2	3.5	12.9	14.4	10.9
e-f	5.2	14.4	19.6	14.4	19.6	0
f-g	9.8	19.6	29.4	19.6	29.4	0
g-h	10.2	29.4	39.6	29.4	39.6	0
h-i	12.0	39.6	51.6	39.6	51.6	0
i-j	10.2	51.6	61.8	51.6	61.6	0

Table 8.8: The CPM algorithm for the construction activities applied to panelised housing



a-b: Layout of building
b-c: Excavation and footings
c-d: Foundations, drainage and backfill
a-d: In-factory production
d-e: Transportation and on-site erection
e-f: On-site construction

Figure 8.11: A network analysis of the construction activities applied to modular housing

ACTIVITY	DURATION	EARLY START (ES)	EARLY FINISH (EF)	LATE START (LS)	LATE FINISH (LF)	TOTAL FLOAT (LF-EF)
a-b	2.2 DAYS	0 DAY	2.2 DAYS	0 DAY	2.2 DAYS	0 DAY
b-c	5.2	2.2	7.4	2.2	7.4	0
c-e	7.0	7.4	14.4	7.4	14.4	0
a-d	7.0	0	7	5.8	12.8	5.8
d-e	1.6	7	8.6	12.8	14.4	5.8
e-f	16.0	14.4	30.4	14.4	30.4	0

Table 8.9: The CPM algorithm for the construction activities applied to modular housing

Based on the CPM algorithm that aims to identify the critical path, the total construction time of site-built, panelised and modular construction approaches were estimated at 79.0, 61.8 and 30.4 days, respectively (Table 8.10). Accordingly, when product quality of housing that is often affected by site wastes and interruptions (caused by bad weather, theft, and vandalism) is taken into account, the modular system can be considered the most effective means for maintaining product quality. The use of a modular system helped reduce on-site construction time by approximately 62% in comparison with that of its conventional counterpart. Moreover, to some extent, a panelised system can also be considered an effective means of reducing site nuisances. In comparison with the conventional approach, the on-site construction time could be shortened by approximately 22% by using a panelised building system.

CONSTRUCTION APPROACHES	TOTAL CONSTRUCTION TIME (DAYS)
SITE-BUILT (SC)	79.0
PANELISED (PC)	61.8
MODULAR (MC)	30.4

Table 8.10: Total construction time of the selected construction approaches

Furthermore, the total project time of each alternative generated in the preceding stage can be calculated by totalling the total design and construction times estimated above (Table 8.11). As for the production of the first housing unit, Alternative 3 that represents the combination of the production design and modular construction approaches, achieved the shortest project time while Alternative 9 that encompasses the combination of custom design and modular construction approaches achieved the second shortest time. In contrast, the combination of the mass custom design and site-build construction approaches, or Alternative 10, required the longest project time to produce the first housing unit, while Alternative 4, whereby a semi-custom design approach is combined with a site-built construction system, required the second longest time.

As for the production of each subsequent housing unit, Alternative 3, or the combination of the production design and modular construction approaches, again achieved the shortest project time. Second to this, Alternative 12, or the combination of the mass custom design and modular construction approaches, achieved the shortest project time. In comparison, Alternative 7, or the combination of the custom design and site-built construction approaches, required the longest project time to produce each subsequent dwelling unit, while Alternative 4, or the combination of the semi-custom design and site-built construction approaches, required the second longest time.

NO.	ALTERNATIVES	TOTAL PROJECT TIME FOR THE PRODUCTION OF THE FIRST HOUSING UNIT (DAYS)	TOTAL PROJECT TIME FOR THE PRODUCTION OF EACH SUBSEQUENT HOUSING UNIT (DAYS)
1	PD + SC	114.4	95.4
2	PD + PC	97.2	78.2
3	PD + MC	65.8	46.8
4	SCD + SC	118.4	102.5
5	SCD + PC	101.2	85.3
6	SCD + MC	69.8	53.9
7	CD + SC	116.8	116.8
8	CD + PC	99.6	99.6
9	CD + MC	68.2	68.2
10	MCD + SC	122.6	100.6
11	MCD + PC	105.4	83.4
12	MCD + MC	74.0	52.0

Table 8.11: Total design time of the given alternatives

In addition, it may be worth noting that the number of housing units to be produced also influences the total project time. For example, if 10 homes are built sequentially in a housing development, the total project time of Alternative 3 (PD+MC) can be computed at 487 days and thus this alternative achieves the shortest time among the given alternatives (Table 8.12). Second to this, Alternative 12 (MCD+MC) achieves the shortest time, while the mass custom design approach may help maintain the higher levels of design customisation that meets market demands for today's housing. On the other hand, Alternative 7 (CD+SC) requires the longest project time for the production of 10 dwelling units, while Alternative 4 (SCD+SC) requires the second longest time, when a phased, or fast track, construction approach that necessitates complex construction management is less of a consideration.

NO.	ALTERNATIVES	TOTAL PROJECT TIME AFTER THE COMPLETION OF 10 HOUSING UNITS (DAYS)
1	PD + SC	973.0
2	PD + PC	801.0
3	PD + MC	487.0
4	SCD + SC	1,040.9
5	SCD + PC	868.9
6	SCD + MC	554.9
7	CD + SC	1,168.0
8	CD + PC	996.0
9	CD + MC	682.0
10	MCD + SC	1,028.0
11	MCD + PC	856.0
12	MCD + MC	542.0

Table 8.12: Total design time of the given alternatives for the production of 10 housing units

After the total project time of each alternative is estimated, the next stage would be to conduct an economic analysis to identify the cost factors that in part influence the builder's decisions for the selection of the design and construction approaches. Thus, in the following section, the economic analysis of the given alternatives will be carried out based on the time factors identified in this section.

8.4.1.2. THE ECONOMIC ANALYSIS OF ALTERNATIVES

In order to identify the *monetary* value of each alternative using the present worth method that integrates the time factors identified in the proceeding section with the cost factors, the design and construction costs used for this economic analysis need to be identified. Thus, in advance of measuring the present worth of the given alternatives, the design and construction costs will first be estimated.

The design cost was calculated based on the total design time excluding the expected time for obtaining building permits. Instead, the total cost required for obtaining the permits will be included in the design cost. Thus, the author assumed that a working day is composed of 8 hours at a wage of $40 per hour and the cost of obtaining building permits is $500 in total (Table 8.13).

DESIGN APPROACHES	TOTAL DESIGN COST ($)	
	FOR THE FIRST HOUSING UNIT	FOR EACH SUBSEQUENT HOUSING UNIT
PRODUCTION (PD)	6,964	884
SEMI-CUSTOM (SCD)	8,244	3,156
CUSTOM (CD)	7,732	7,732
MASS CUSTOM (MCD)	9,588	2,548

Table 8.13: Total design cost of the selected design approaches

The construction cost used for this cost analysis includes in-factory production, transportation, on-site erection and on-site construction costs, based on the literature review, as well as the personal interviews with the builder and manufacturers. In particular, the author reviewed a master's thesis by Wiedemann (1990:42) who conducted a thorough investigation of the unit cost of 30 pre-cut, panelised and modular houses produced by 15 manufacturers in Quebec and Ontario. With the builder's *approval*, the author estimated the average in-factory production cost of a modular home at $35.57 per square foot (*excluding* transportation and on-site erection costs, as well as on-site construction cost) based on the cost data obtained from the 14 selected model homes produced by the modular housing manufacturers in Quebec (Table 8.14).

MODULAR MANUFACTURER / UNIT NAME	UNIT SIZE (SQ. FT.)	IN-FACTORY PRODUCTION COST ($)	IN-FACTORY PRODUCTION COST PER SQ. FT. ($/SQ. FT)	TRANSPORTATION AND ON-SITE ERECTION COST ($)
LES CONSTRUCTIONS MARCOUX INC.				
CONTEMPRA	907	40,885	45.08	1,200
MONARCH	917	45,870	50.02	1,200
LES MAISONS ALOUETTE				
MAGANTIC	1,824	80,000	43.86	224
MARLENE	1,040	38,261	36.79	112
LES HABITATIONS NABCO INC.				
CELEBRE	1,008	34,405	34.13	1,441
BROMONT	1,144	39,995	34.96	1,441
HABITEC 2000				
LE NOBLET	1,190	36,280	30.49	3,840
CHATEAU	1,008	34,313	34.04	3,840
DEMTEC INC.				
DU MOULIN II	1,120	35,500	31.70	3,369
BELOEIL	1,014	33,400	32.94	2,250
HABITATIONS MODULAIRES BRENDAU				
L'ARISTOCRATE	1,200	34,080	28.40	825
SERIES-3000	1,312	36,544	27.85	825
HABITATION TRECO				
PRESTIGE	1,660	63,443	38.22	2,170
TRECO-320D	1,312	38,708	29.50	1,770
	AVERAGE		35.57*	1,751

* In-factory production cost does not include transportation cost, on-site erection cost or on-site construction cost.

Table 8.14: Construction cost applied to a modular construction system as delivered

(Source: Wiedemann 1990)

Similarly, as shown in Table 8.14, the average transportation and on-site erection costs of the seven manufacturers selected were estimated at $1,751, given that housing development will take place in the Montreal area. In addition, the on-site construction cost to complete a modular house was also computed at the average of $16,405—the author assumed that the cost to build a foundation is $10,000 and it was used for further cost analysis of all construction systems under study (Tables 8.15 & 8.16). Accordingly, the total construction cost of modular housing, which includes in-factory production, transportation, on-site erection and on-site construction costs (including the cost of building the foundation) was estimated at $85,068. It is important to note that, for this study, the cost estimates do not include indirect costs such as overheads and profit margins.

MODULAR MANUFACTURER UNIT NAME	EXTERIOR FINISHES ($)	PLUMBING AND ELECTRICAL ($)	INTERIOR FINISHES ($)
LES CONSTRUCTIONS MARCOUX INC.			
CONTEMPRA	8,050	1,125	5,123
MONARCH	8,063	1,125	5,315
LES MAISONS ALOUETTE			
MAGANTIC	8,090	1,125	6,763
MARLENE	9,116	1,125	3,992
LES HABITATIONS NABCO INC.			
CELEBRE	8,900	1,125	5,854
BROMONT	9,292	1,125	6,345
HABITEC 2000			
LE NOBLET	9,440	1,125	6,531
CHATEAU	8,900	1,125	5,905
DEMTEC INC.			
DU MOULIN II	9,224	1,125	6,607
BELOEIL	9,116	1,125	5,701
HABITATIONS MODULAIRES BRENDAU			
L'ARISTOCRATE	9,478	1,125	7,159
SERIES-3000	9,710	1,125	7,169
HABITATION TRECO			
PRESTIGE	7,550	1,125	9,538
TRECO-320D	9,710	1,125	7,271
AVERAGE	8,903	1,125	6,377

Table 8.15: On-site construction cost to complete a modular home

(Source: Wiedemann 1990)

CONSTRUCTION COST ESTIMATE	
UNIT SIZE OF MODEL HOUSING (A)	1,600 SQ. FT.
COST PER SQ. FT. (B)	$35.57 SQ. FT.
IN-FACTORY PRODUCTION COST (A x B)	$56,912
TRANSPORTATION AND ON-SITE ERECTION COST	$1,751
ON-SITE CONSTRUCTION COST	$16,405
FOUNDATION*	$10,000
TOTAL	$85,068

* The cost to build the foundation will be used to all construction approaches under study

Table 8.16: Construction cost to build a modular home

As for the cost of panelised construction, the author visited the manufacturing facility of a panelised manufacturer in Quebec and conducted a personal interview with the company's executive. By referring to the company's model house, which is similar to the home developed in the second stage of the choice model (i.e. townhouse), the cost of manufacturing panelised housing components required for the townhouse unit was found to range from $13,000 to $16,000. Thus, the author applied the median for further economic analysis of the panelised construction approach (Table 8.17). This total in-factory production cost includes the floor system, exterior walls, and roof trusses, and interior wall panels, as well as transportation to the building site. However, the on-site erection of the panels needs to be executed by the builder. Thus, for the purpose of this study, the author assumed that the on-site erection cost of the panelised system would be similar to the framing cost of building a site-built home.

PANELISED MANUFACTURER	IN-FACTORY PRODUCTION AND TRANSPORTATION COSTS ($)		
	Minimum	Median	Maximum
TECHNOLOGY BUILDING SYSTEMS	13,000	14,500	16,000

Table 8.17: In-factory production and transportation costs applied to the panelised system

Finally, the author requested the builder to estimate the on-site construction cost of the proposed model house, which was also directly used for the calculation of the cost to build a panelised home (Table 8.18). Based on the cost data collected for this study, the construction cost required for the application of each alternative was identified (Table 8.19). The total project cost that represents the integration of the design and construction costs was also tabulated (Table 8.20).

HOUSING COMPONENTS	ON-SITE CONSTRUCTION COST ($)
EXCAVATION, FOOTINGS, FOUNDATIONS, DRAINAGE AND BACKFILL	10,000
FRAMING	18,000
WINDOWS AND DOORS	4,200
EXTERIOR FINISHES	8,000
PLUMBING AND ELECTRICAL	9,400
INSULATION, AIR AND VAPOUR BARRIER	2,500
INTERIOR FINISHES	11,200
HVAC	2,000
TOTAL	65,300

Table 8.18: On-site construction cost applied to a site-built construction approach

CONSTRUCTION APPROACHES	TOTAL CONSTRUCTION COST ($)
SITE-BUILT (SC)	65,300
PANELISED (PC)	79,800
MODULAR (MC)	85,068

Table 8.19: Total construction cost of the selected construction approaches

NO.	ALTERNATIVES	TOTAL PROJECT COST FOR THE PRODUCTION OF THE FIRST HOUSING UNIT ($)	TOTAL PROJECT COST FOR THE PRODUCTION OF EACH SUBSEQUENT HOUSING UNIT ($)
1	PD + SC	72,264	66,184
2	PD + PC	86,764	80,684
3	PD + MC	92,032	85,952
4	SCD + SC	73,544	68,456
5	SCD + PC	88,044	82,956
6	SCD + MC	93,312	88,224
7	CD + SC	73,032	73,032
8	CD + PC	87,532	87,532
9	CD + MC	92,800	92,800
10	MCD + SC	74,888	67,848
11	MCD + PC	89,388	82,348
12	MCD + MC	94,656	87,616

Table 8.20: Total project cost of the given alternatives

According to the results, as shown in Table 8.20, the most cost effective means to produce the first housing unit is the combination of the production design and site-built construction approaches, or Alternative 1, and the second is the combination of the custom design and site-built construction approaches, or Alternative 7. On the other hand, the most cost effective means to produce each subsequent housing unit is again the combination of the custom design and site-built construction approaches, or Alternative 1. However, the second most cost-effective method is the mass custom design and site-built construction approaches, or Alternative 10. In this case, recycling of standard drawings of housing components helps reduce the design time, while the conventional construction approach can be still considered most effective in reducing the construction costs, in comparison to the industrialised counterparts, even though their construction time is shorter. In particular, the modular construction approach, which achieves the higher level of in-factory construction that helps maintain product quality and the shortest construction time among the alternatives, may require more crews (or sub-trades) to be involved in completing a house. As a result, the project may ultimately be more expensive. If the builder pays attention only to the cost, when building each first or subsequent house, Alternative 1 is the optimal choice, when the time value of money is not of concern. On the other hand, when design quality (i.e. customisability) and product quality are also of importance, other alternatives may be considered more attractive design and construction approaches that satisfy the builder's requirements for the products and services to be purchased.

For the time being, the time factors that affect the project cost are not integrated with the cost factors identified above. Thus, the economic analysis of each alternative will be carried out based on the time value of money concept, as described in Chapter 7. For the purpose of this study, a compounding period will be regarded as the end of each day in response to the time horizons identified in the preceding section. Moreover, inflation will be less of a consideration unless the project time exceeds the period of a year. For this study, the annual discount (on interest) rate of 7% will be used in response to the rate of a traditional 5-year mortgage quoted by the Bank of Canada (2002).

Thus, the period discount rate (i) would be equal to: i = 7%/365 = 0.02%/year/day.

The time (before the selected design activities are complete) will be regarded as the present time—i.e. t = 0. Furthermore, the total design and construction time required for the production of the first and each subsequent housing unit will be used for the computation of the present worth of the given alternatives. It is important to note that this economic analysis is not aimed at identifying the exact profit gained by using the selected design and construction approaches; thus, the indirect costs (e.g. builder's and manufacturers' overheads and profits) involved in housing development are not taken into consideration. However, for the purpose of this economic analysis, the aim is to identify the differences in the light of the monetary value of each alternative; consequently, the author set the selling price of a housing model unit at $120,000. Furthermore, the author assumed that the new house will be sold 7 days after all selected construction activities are completed (Fig. 8.12).

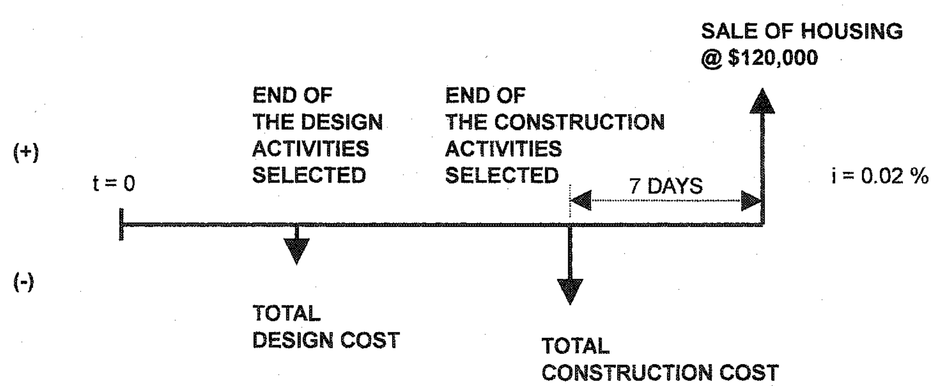


Figure 8.12: An overview of the cash flow diagram

According to the cash flow diagram, as shown in Figure 8.12, the monetary value of each of the given alternatives will be calculated using the following formula of the present worth method, as described in Chapter 7.

$$PWx\,(i) = \sum_{t=0}^{n} Ax_t\,(1+i)^{-t}$$

where:

$PWx\,(i)$ = Present worth of Alternative x (1 to 12) using an interest rate of i%

i = Interest (or discount) rate per interest period (i.e. 0.02%/year/day)

n = Planning horizon of Alternative x (1 to 12)

t = The number of interest periods (i.e. design time, construction time or n)

Ax_t = Net cash flow for Alternative x (1 to 12) at the end of period t

Accordingly, using the cost and time factors identified above, the present worth value of each alternative for the production of a premier housing unit would be calculated as:

PW_1 (0.02%) = \$120,000 (P|F 0.02, 121) − \$6,964 (P|F 0.02, 35) − \$65,300 (P|F 0.02, 79)

= \$117,131.14 − \$6,915.43 − \$64,276.47

= \$45,939.24

PW_2 (0.02%) = \$120,000 (P|F 0.02, 104) − \$6,964 (P|F 0.02, 35) − \$79,800 (P|F 0.02, 62)

= \$117,530.02 − \$6,915.43 − \$78,816.69

= \$31,797.90

PW_3 (0.02%) = \$120,000 (P|F 0.02, 73) − \$6,964 (P|F 0.02, 35) − \$85,068 (P|F 0.02, 30)

= \$118,260.90 − \$6,915.43 − \$84,559.17

= \$26,786.30

PW_4 (0.02%) = \$120,000 (P|F 0.02, 125) − \$8,244 (P|F 0.02, 39) − \$65,300 (P|F 0.02, 79)

= \$117,037.48 − \$8,179.95 − \$64,276.47

= \$44,581.06

$PW_5\ (0.02\%) = \$120{,}000\ (P|F\ 0.02,\ 108) - \$8{,}244\ (P|F\ 0.02,\ 39) - \$79{,}800\ (P|F\ 0.02,\ 62)$

$= \$117{,}436.05 - \$8{,}179.95 - \$78{,}816.69$

$= \$30{,}439.41$

$PW_6\ (0.02\%) = \$120{,}000\ (P|F\ 0.02,\ 77) - \$8{,}244\ (P|F\ 0.02,\ 39) - \$85{,}068\ (P|F\ 0.02,\ 30)$

$= \$118{,}166.34 - \$8{,}179.95 - \$84{,}559.17$

$= \$25{,}427.22$

$PW_7\ (0.02\%) = \$120{,}000\ (P|F\ 0.02,\ 124) - \$7{,}732\ (P|F\ 0.02,\ 38) - \$65{,}300\ (P|F\ 0.02,\ 79)$

$= \$117{,}060.89 - \$7{,}673.47 - \$64{,}276.47$

$= \$45{,}110.95$

$PW_8\ (0.02\%) = \$120{,}000\ (P|F\ 0.02,\ 107) - \$7{,}732\ (P|F\ 0.02,\ 38) - \$79{,}800\ (P|F\ 0.02,\ 62)$

$= \$117{,}459.53 - \$7{,}673.47 - \$78{,}816.69$

$= \$30{,}969.37$

$PW_9\ (0.02\%) = \$120{,}000\ (P|F\ 0.02,\ 75) - \$7{,}732\ (P|F\ 0.02,\ 38) - \$85{,}068\ (P|F\ 0.02,\ 30)$

$= \$118{,}213.61 - \$7{,}673.47 - \$84{,}559.17$

$= \$25{,}980.97$

$PW_{10}\ (0.02\%) = \$120{,}000\ (P|F\ 0.02,\ 130) - \$9{,}588\ (P|F\ 0.02,\ 44) - \$65{,}300\ (P|F\ 0.02,\ 79)$

$= \$116{,}920.52 - \$9{,}504.00 - \$64{,}276.47$

$= \$43{,}140.05$

$PW_{11}\ (0.02\%) = \$120{,}000\ (P|F\ 0.02,\ 112) - \$9{,}588\ (P|F\ 0.02,\ 44) - \$79{,}800\ (P|F\ 0.02,\ 62)$

$= \$117{,}342.15 - \$9{,}504.00 - \$78{,}816.69$

$= \$29{,}021.46$

$PW_{12}\ (0.02\%) = \$120{,}000\ (P|F\ 0.02,\ 81) - \$9{,}588\ (P|F\ 0.02,\ 44) - \$85{,}068\ (P|F\ 0.02,\ 30)$

$= \$118{,}071.85 - \$9{,}504.00 - \$84{,}559.17$

$= \$24{,}008.68$

In the same manner, the present worth of each alternative for the production of a succeeding housing unit would be calculated as:

PW_1 (0.02%) = \$120,000 (P|F 0.02, 102) − \$884 (P|F 0.02, 16) − \$65,300 (P|F 0.02, 79)

= \$117,577.04 − \$881.18 − \$64,276.47

= \$52,419.39

PW_2 (0.02%) = \$120,000 (P|F 0.02, 85) − \$884 (P|F 0.02, 16) − \$79,800 (P|F 0.02, 62)

= \$117,977.44 − \$881.18 − \$78,816.69

= \$38,279.57

PW_3 (0.02%) = \$120,000 (P|F 0.02, 54) − \$884 (P|F 0.02, 16) − \$85,068 (P|F 0.02, 30)

= \$118,711.10 − \$881.18 − \$84,559.17

= \$33,270.75

PW_4 (0.02%) = \$120,000 (P|F 0.02, 110) − \$3,156 (P|F 0.02, 24) − \$65,300 (P|F 0.02, 79)

= \$117,389.09 − \$3,140.89 − \$64,276.47

= \$49,971.73

PW_5 (0.02%) = \$120,000 (P|F 0.02, 92) − \$3,156 (P|F 0.02, 24) − \$79,800 (P|F 0.02, 62)

= \$117,812.41 − \$3,140.89 − \$78,816.69

= \$35,854.83

PW_6 (0.02%) = \$120,000 (P|F 0.02, 61) − \$3,156 (P|F 0.02, 24) − \$85,068 (P|F 0.02, 30)

= \$118,545.04 − \$3,140.89 − \$84,559.17

= \$30,844.98

PW_7 (0.02%) = \$120,000 (P|F 0.02, 124) − \$7,732 (P|F 0.02, 38) − \$65,300 (P|F 0.02, 79)

= \$117,060.89 − \$7,673.47 − \$64,276.47

= \$45,110.95

$PW_8\ (0.02\%) = \$120{,}000\ (P|F\ 0.02,\ 107) - \$7{,}732\ (P|F\ 0.02,\ 38) - \$79{,}800\ (P|F\ 0.02,\ 62)$

$= \$117{,}459.53 - \$7{,}673.47 - \$78{,}816.69$

$= \$30{,}969.37$

$PW_9\ (0.02\%) = \$120{,}000\ (P|F\ 0.02,\ 76) - \$7{,}732\ (P|F\ 0.02,\ 38) - \$85{,}068\ (P|F\ 0.02,\ 30)$

$= \$118{,}189.97 - \$7{,}673.47 - \$84{,}559.17$

$= \$25{,}957.33$

$PW_{10}\ (0.02\%) = \$120{,}000\ (P|F\ 0.02,\ 108) - \$2{,}548\ (P|F\ 0.02,\ 22) - \$65{,}300\ (P|F\ 0.02,\ 79)$

$= \$117{,}436.05 - \$2{,}536.82 - \$64{,}276.47$

$= \$50{,}622.76$

$PW_{11}\ (0.02\%) = \$120{,}000\ (P|F\ 0.02,\ 90) - \$2{,}548\ (P|F\ 0.02,\ 22) - \$79{,}800\ (P|F\ 0.02,\ 62)$

$= \$117{,}859.54 - \$2{,}536.82 - \$78{,}816.69$

$= \$36{,}506.03$

$PW_{12}\ (0.02\%) = \$120{,}000\ (P|F\ 0.02,\ 59) - \$2{,}548\ (P|F\ 0.02,\ 22) - \$85{,}068\ (P|F\ 0.02,\ 30)$

$= \$118{,}592.46 - \$2{,}536.82 - \$84{,}559.17$

$= \$31{,}496.47$

In the present worth method (PW), a minus number represents the *cost*, while a positive number represents the *profit*; thus, the higher the positive quantity, the more profitable the alternative. According to this economic analysis of the given alternatives, in which the time value of money is also taken into account, the most economically profitable alternative is Alternative 1 (PD+SC), whose monetary value was the highest among the alternatives, when the first or each subsequent housing unit was sold at $120,000 (Tables 8.21 & 8.22). Alternative 7 (CD+SC) is the second most profitable alternative for the delivery of the first housing unit, while Alternative 10 (MCD+SC) ranks next to Alternative 1 for the delivery of each subsequent housing unit.

NO.	ALTERNATIVES	PROJECT TIME (DAYS)		PROJECT COST ($)		SELLING PRICE ($)	PW ($) i = 0.02%
		DESIGN	CONST.	DESIGN	CONST.		
1	PD + SC	35	79	6,964	65,300	120,000	45,939
2	PD + PC	35	62	6,964	79,800	120,000	31,798
3	PD + MC	35	30	6,964	85,068	120,000	26,786
4	SCD + SC	39	79	8,244	65,300	120,000	44,581
5	SCD + PC	39	62	8,244	79,800	120,000	30,439
6	SCD + MC	39	30	8,244	85,068	120,000	25,427
7	CD + SC	38	79	7,732	65,300	120,000	45,111
8	CD + PC	38	62	7,732	79,800	120,000	30,969
9	CD + MC	38	30	7,732	85,068	120,000	25,981
10	MCD + SC	44	79	9,588	65,300	120,000	43,140
11	MCD + PC	44	62	9,588	79,800	120,000	29,022
12	MCD + MC	44	30	9,588	85,068	120,000	24,009

Table 8.21: The present worth of the given alternatives for the production of the first housing unit

NO.	ALTERNATIVES	PROJECT TIME (DAYS)		PROJECT COST ($)		SELLING PRICE ($)	PW ($) i = 0.02%
		DESIGN	CONST.	DESIGN	CONST.		
1	PD + SC	16	79	884	65,300	120,000	52,419
2	PD + PC	16	62	884	79,800	120,000	38,280
3	PD + MC	16	30	884	85,068	120,000	33,271
4	SCD + SC	24	79	3,156	65,300	120,000	49,972
5	SCD + PC	24	62	3,156	79,800	120,000	35,855
6	SCD + MC	24	30	3,156	85,068	120,000	30,845
7	CD + SC	38	79	7,732	65,300	120,000	45,111
8	CD + PC	38	62	7,732	79,800	120,000	30,969
9	CD + MC	38	30	7,732	85,068	120,000	25,957
10	MCD + SC	22	79	2,548	65,300	120,000	50,623
11	MCD + PC	22	62	2,548	79,800	120,000	36,506
12	MCD + MC	22	30	2,548	85,068	120,000	31,497

Table 8.22: The present worth of the given alternatives for the production of each subsequent housing unit

The results of this economic analysis indicate that the time value with the interest rate of 0.02%/year/day slightly increases the monetary value of the given alternatives. However, under the circumstances in which the total construction cost of industrialised building systems (i.e. panelised and modular systems) is about 22 to 30% more expensive than that of the conventional approach, the time reduction achieved using the prefabricated systems hardly justifies the cost effectiveness. Thus, in view of this economic analysis, the site-built construction approach is currently the most economically profitable approach, regardless of the design approach it is combined with, even though it requires more time to complete a house. However, in this case, product quality that would be affected by site waste and interruptions is less of a consideration. As for the design approaches, the production design approach is considered the most time and cost effective approach among the alternatives; thus, it is the most profitable design approach for the delivery of housing, when design quality (i.e. customisability) of housing is less of a consideration. Interestingly, in terms of the monetary value, the mass custom design approach, which is a relatively new design approach in the North American housing industry, can be considered the second most profitable approach, regardless of the construction system it is combined with, for the delivery of the subsequent housing units. Unlike the production design approach, the mass custom design approach aims to customise a home in response to the homebuyer's demands for housing.

This economic analysis focused solely on identifying the cost and time factors that in part compose the value of the given alternatives that the builder might choose in order to carry out his housing project. However, the homebuilder *needs* to build a home, which must be marketable in response to the consumers' *demands* for housing. Thus, quality factors that reflect market demands, cannot be ignored when the builder selects the design and construction approaches to be applied to his housing development. Accordingly, in the following section, the performance analysis of the given approaches, that to some extent relates to the marketability of housing, will be carried out in response to the builder's needs, desires and expectations for the sub-contractors' products and services to be purchased.

8.4.1.3. THE PERFORMANCE ANALYSIS OF ALTERNATIVES

This section aims to analyse the performance of the given alternatives, in response to the evaluation criteria developed in the second stage of the choice mode. However, the cost and time factors have already been analysed in depth in the preceding section. Thus, these cost and time factors are eliminated from the criteria, while the quality issues, which to some extent affect the marketability of housing, as stated above, will be taken mainly into account for further analysis (Table 8.23).

FACTOR	EVALUATION CRITERIA
	TASK-RELATED FACTOR
A	Customisability of volume components
B	Customisability of exterior components
C	Customisability of interior components
D	Potential improvement of fire resistance properties
E	Potential improvement of acoustic insulation properties
F	Potential improvement of thermal insulation properties
G	Potential improvement of mechanical equipment
H	Potential improvement of electrical equipment
I	In-factory completion of housing components
	NONTASK-RELATED FACTOR
J	Familiarity of products or services to be used

Table 8.23: The evaluation criteria used for the performance analysis

Furthermore, the author first conducted the comparative analysis of the evaluation criteria, according to the interview with the homebuilder. In response to the degree of importance perceived by the builder, the author attached a numerical value (or *weight*) to each of the evaluation criteria and tabulated the results using the criteria scoring matrix introduced in Chapter 7 (Table 8.24).

B	C	D	E	F	G	H	I	J	FACTOR	INDIVIDUAL SCORE	WEIGHT (%)
A3	C2	A3	A3	A2	A3	A3	A3	A2	A	22	23
	C2	B3	B3	F2	B3	B3	B3	B2	B	17	17
		C3	C3	C2	C3	C3	C3	C2	C	23	24
			D1	D1	D1	D1	D1	J1	D	6	6
				F1	E2	E2	E2	E1	E	7	7
					F3	F3	F2	F1	F	12	12
						G2	I2	J1	G	2	2
							H2	J1	H	2	2
								J2	I	2	2
									J	5	5
									TOTAL	98	100

How important:

3: Major preference

2: Average preference

1: Slight or no preference

Table 8.24: Evaluation criteria scoring matrix

Sequentially, each alternative was evaluated based on either quantitative or qualitative analysis. Quantitative analysis was applied to the evaluation criteria relating to the customisability of housing components, as well as the in-factory completeness of housing components (Tables 8.25 & 8.26).

SCALE: CUSTOMISABLE = 1 & NOT CUSTOMISABLE = 0

	DESIGN APPROACHES			
	PRODUCTION	SEMI-CUSTOM*	CUSTOM	MASS CUSTOM
VOLUME COMPONENT				
Kitchen area	0	1	1	1
Living room area	0	0	1	1
Dining room area	0	1	1	1
Bedroom area	0	1	1	1
Bathroom area	0	1	1	1
Powder room area	0	0	1	1
Staircase arrangement	0	0	1	1
EXTERIOR COMPONENT				
Exterior cladding	0	0	1	1
Roofing	0	0	1	1
Balcony	0	1	1	1
Doors	0	0	1	1
Windows	0	1	1	1
INTERIOR COMPONENT				
Kitchen				
Wall & ceiling finishes	0	1	1	1
Floor coverings	0	1	1	1
Storage arrangement	0	0	1	1
Moulding	0	0	1	1
Living Room				
Wall & ceiling finishes	0	1	1	1
Floor coverings	0	1	1	1
Storage arrangement	0	0	1	1
Moulding	0	0	1	1
Dining room				
Wall & ceiling finishes	0	1	1	1
Floor coverings	0	1	1	1
Storage arrangement	0	0	1	1
Moulding	0	0	1	1
Bedroom				
Wall & ceiling finishes	0	1	1	1
Floor coverings	0	1	1	1
Storage arrangement	0	0	1	1
Moulding	0	0	1	1
Door	0	0	1	1
Bathroom				
Wall & ceiling finishes	0	1	1	1
Floor coverings	0	1	1	1
Storage arrangement	0	1	1	1
Moulding	0	0	1	1
Bathtub	0	1	1	1
Shower	0	1	1	1
Toilet	0	1	1	1
Sink	0	1	1	1
Door	0	0	1	1
Powder room				
Wall & ceiling finishes	0	1	1	1
Floor coverings	0	1	1	1
Storage arrangement	0	1	1	1
Moulding	0	0	1	1
Toilet	0	1	1	1
Sink	0	1	1	1
Door	0	0	1	1
TOTAL	0	26	45	45
CUSTOMISABILITY (%)	0	58	100	100

* A typical *Village Renaissance* townhouse in the Bois Franc project was exemplified

Table 8.25: Potential customisability of a successive housing unit

	CONSTRUCTION APPROACHES		
	Site-built	Panelised	Modular
HOUSING COMPONENTS			
Wall framing	0	1	1
Floor framing	0	1	1
Roof trusses	1	1	1
Roof coverings	0	0	1
Doors and windows	0	1	1
Plumbing pipes and electrical wires	0	0	1
Exterior finishes	0	0	1
Insulation and air/vapour barriers	0	1	1
Interior finishes	0	0	1
Paint, cabinet and fixtures	0	0	1
TOTAL	2	5	10
IN-FACTORY COMPLETENESS (%)	20	50	100

SCALE: IN-FACTORY COMPLETION = 1 & ON-SITE COMPLETION = 0

Table 8.26: Housing components that can be pre-assembled in a factory

On the other hand, qualitative analysis was applied to the evaluation criteria relating to the builder's emotional responses (i.e. familiarity with the products or services to be used) which were analysed based on the author's interview with the builder, as well as other product quality factors. Qualitative analysis was conducted by means of the author's observation of the existing housing models built by site-builders, as well as panelised and modular manufacturers in Quebec. However, the *minimum* product quality was predetermined in the second stage of the choice model, in which the plans, elevations and section of a model house were identified.

According to the evaluation methods and results, as stated above, the alternatives were evaluated by rating the performance of each of the given criteria on a scale of 0 (not applicable), 1(very negative), 2 (negative), 3 (neutral), 4 (positive), and 5 (very positive). Thus, the author developed an analysis matrix that aims to compute the performance score. Simply, the higher the score, the better the performance (Tables 8.27 & 8.28).

EVALUATION CRITERIA	WEIGHT (%)	ALTERNATIVE											
		1	2	3	4	5	6	7	8	9	10	11	12
A	23	0 0	0 0	0 0	0 0	0 0	0 0	5 115	5 115	5 115	0 0	0 0	0 0
B	17	0 0	0 0	0 0	0 0	0 0	0 0	5 85	5 85	5 85	0 0	0 0	0 0
C	24	0 0	0 0	0 0	0 0	0 0	0 0	5 120	5 120	5 120	0 0	0 0	0 0
D	6	3 18	3 18	3 18	3 18	3 18	3 18	3 18	3 18	3 18	3 18	3 18	3 18
E	7	3 21	3 21	4 28	3 21	3 21	4 28	3 21	3 21	4 28	3 21	3 21	4 28
F	12	3 36	3 36	4 48	3 36	3 36	4 48	3 36	3 36	4 48	3 36	3 36	4 48
G	2	3 18	3 18	3 18	3 18	3 18	3 18	3 18	3 18	3 18	3 18	3 18	3 18
H	2	3 6	3 6	3 6	3 6	3 6	3 6	3 6	3 6	3 6	3 6	3 6	3 6
I	2	1 2	3 6	5 10	1 2	3 6	5 10	1 2	3 6	5 10	1 2	3 6	5 10
J	5	5 25	3 15	2 10	5 25	3 15	2 10	5 25	3 15	2 10	3 15	2 10	1 5
PERFORMANCE SCORE		126	120	138	126	120	138	446	440	458	116	115	133

Table 8.27: The analysis matrix applied to the delivery of the first housing unit

EVALUATION CRITERIA	WEIGHT (%)	ALTERNATIVE											
		1	2	3	4	5	6	7	8	9	10	11	12
A	23	0 0	0 0	0 0	0 0	0 0	0 0	5 115	5 115	5 115	5 115	5 115	5 115
B	17	0 0	0 0	0 0	3 51	3 51	3 51	5 85	5 85	5 85	5 85	5 85	5 85
C	24	0 0	0 0	0 0	3 72	3 72	3 72	5 120	5 120	5 120	5 120	5 120	5 120
D	6	3 18	3 18	3 18	3 18	3 18	3 18	3 18	3 18	3 18	3 18	3 18	3 18
E	7	3 21	3 21	4 28	3 21	3 21	4 28	3 21	3 21	4 28	3 21	3 21	4 28
F	12	3 36	3 36	4 48	3 36	3 36	4 48	3 36	3 36	4 48	3 36	3 36	4 48
G	2	3 18	3 18	3 18	3 18	3 18	3 18	3 18	3 18	3 18	3 18	3 18	3 18
H	2	3 6	3 6	3 6	3 6	3 6	3 6	3 6	3 6	3 6	3 6	3 6	3 6
I	2	1 2	3 6	5 10	1 2	3 6	5 10	1 2	3 6	5 10	1 2	3 6	5 10
J	5	5 25	3 15	2 10	5 25	3 15	2 10	5 25	3 15	2 10	3 15	2 10	1 5
PERFORMANCE SCORE		126	120	138	249	243	261	446	440	458	436	435	453

Table 8.28: The analysis matrix applied to the delivery of each subsequent housing unit

As shown in Tables 8.27 and 8.28, this quality analysis, in which 30% of the evaluation criteria concern the level of design customisation, may be more applicable to the delivery of each subsequent housing unit than to the first housing unit. In fact, except for the custom design approach, all design approaches applied to the delivery of the first housing unit aim to produce a model house, in which product customisation is not of concern.

According to the results of this *weighted* evaluation, the given alternatives, which allow the builder to produce homes that can be adequately customised in response to users' diverse demands for housing, achieved the higher score—in particular, for the delivery of the subsequent housing units. As well, the use of a modular construction system that helps maintain uniform product quality in the factory increased the score, although the builder considered his familiarity with the system as the lowest among the alternatives. In response to the builder's needs, desires and expectations for products and services to be purchased, Alternative 9 (CD+MC) for the production of successive housing units was estimated as having the highest score, while Alternative 12 (MCD+MC) ranked second to this. The top two alternatives involve higher levels of customisation and industrialisation of housing that meet today's market demands for housing in terms of the design and product quality—i.e. the *performance*. Thus, these can be considered less risky alternatives in terms of their marketability, when the economic factors analysed in the preceding section are less of a consideration. Accordingly, the cost-quality-time factors analysed in this stage of the choice model must be taken fully into account. Thus, the next stage would be to integrate these factors, so as to identify (or *visualise*) the actual value of each alternative. The last stage of the choice model aims to facilitate the builder's choice of the design and construction systems to be applied to his housing development.

8.4.2. STAGE V: THE SELECTION OF ALTERNATIVES

This final stage of the choice model aims to integrate the results of the economic analysis that corresponded to the estimated project time with those of the performance analysis in which a weighted evaluation of the given alternatives was carried out in response to the builder's task- and non task-related concerns. Thus, this stage focuses on developing a cost-performance graph, as described in Chapter 7, which aims to visually present the value of each alternative. However, in the last stage of the choice model, the author calculated the present worth (PW) of each alternative; thus, the cost factors that will appear in a graph to be developed represent the results of the PW. For the purpose of this study, the graph is henceforth entitled the "benefit-performance graph"—i.e. when the monetary (or present worth) value is higher, the alternative can be considered more economically beneficial from the homebuilder's standpoint (Tables 8.21 & 8.22). Thus, the higher monetary value may allow the builder to reduce the selling price of housing, but only if he does not intend to drastically increase his profit. Furthermore, the higher the performance level, the higher the marketability, as described in the preceding sections. The visualisation of the value of the given alternative in a comprehensive form may facilitate the builder's final buying decisions for the design and construction systems to be applied to his housing development that aim to produce quality affordable homes in response to today's market demand for housing.

According to the results of the benefit-performance graph, regarding the production of the first housing unit, the alternatives that involve a custom design approach achieve the higher performance level, while a site-built construction approach is considered most economically beneficial. Thus, Alternative 7, or the combination of the custom design and site-built construction approaches, can be estimated to be the most effective alternative particularly in executing an infill housing development, in which the design customisation of one or two houses is involved.

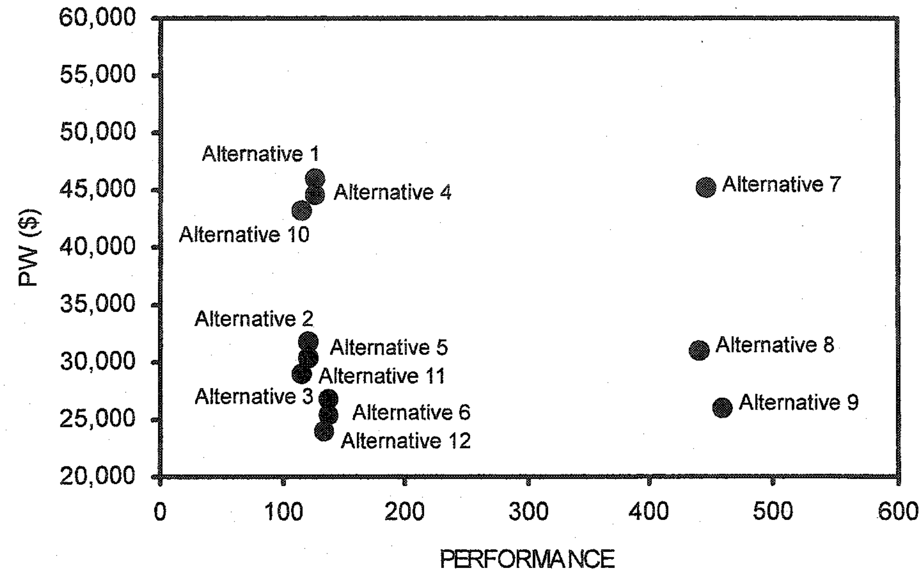


Figure 8.13: Benefit-performance graph for the production of the first housing unit

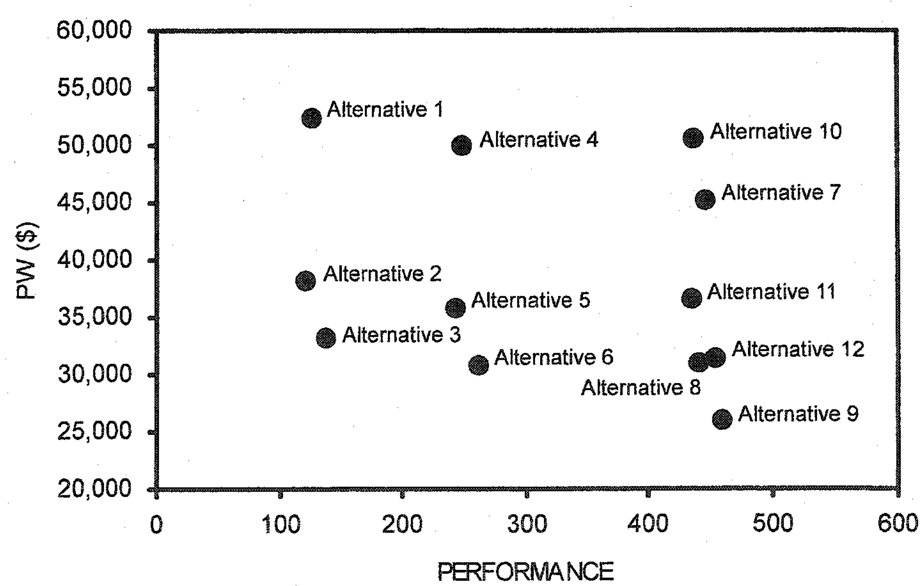


Figure 8.14: Benefit-performance graph for the production of subsequent housing units

As for the production of successive housing units, the application of design approaches, which achieve the higher levels of design customisation that concern volume, exterior, and interior component arrangements and help increase the performance level that may to some extent reflect the homebuilder's (and homebuyers') satisfaction of housing quality. On the other hand, the application of a site-built construction approach can be again considered as being economically beneficial not only for the homebuilder, but also for homebuyers. As stated above, the higher present worth value for project cost and time, the lower the selling price of housing can be. According to the results of the benefit-performance graph, Alternative 10, or the combination of the mass custom design and site-built construction approaches, is estimated to be the most effective alternative in producing numbers of homes which need to be customised in response to market demand. However, as stated above, this mass custom design approach is relatively new in today's North American housing industry. Thus, further research concerning how to mass customise homes may need to be undertaken in order to make this approach more applicable to homebuilders (and housing manufacturers) in North America. The next most cost effective approach is Alternative 4, or the combination of the semi-custom design and site-built construction approaches. Indeed, this may be the optimal Alternative where economic value is more important than performance. However, if the builder pays more attention to the customisability of housing, Alternative 7 may rank second to Alternative 10.

In addition, as shown in Figures 8.13 and 8.14, the use of building systems helped reduce the monetary value of the alternatives, even though some of the alternatives, in which panelised and modular systems are involved, helped to increase performance levels drastically. For example, for the delivery of subsequnt housing units, as shown in Figure 8.14, Alternative 11 (MCD+PC), Alternative 12 (MCD+MC), Alternative 8 (CD+PC), and Alternative 9 (CD+MC) are characterised by their relatively high scores in terms of the housing performance. Furthermore, it may be worth noting that the monetary value of Alternatives 11 and 12, in which a mass custom design approach is applied, was estimated to be slightly higher than that of Alternatives 8 and 9. This result tends to indicate the potential positive effects of a mass custom design approach on increasing the monetary value of the alternatives that involve industrialised building systems without sacrificing housing performance. The increase of the monetary value using the mass custom design approach can be explained by the use of a complete set of standardised design components that greatly contributes towards reducing design time, which in turn reduces design cost. In addition, the standardisation of design components and processes may also help to ensure a uniform product quality, while simplifying communication between the homebuyer and the homebuilder.

Finally, the author demonstrated the paired comparison approach, as described in Chapter 7, based on the interview with the homebuilder. For the purpose of this analysis, the alternative (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12) are called A, B, C, D, E, F, G, H, I, J, K and L, respectively. Furthermore, the following preferences were obtained by comparing two factors at a time:

A > B, A > C, A < D, A > E, A >F, A < G, A > H, A > I, A < J, A < K, A > L

B > C, B < D, B < E, B > F, B < G, B < H, B > I, B < J, B < K, B < L

C < D, C < E, C > F, C < G, C < H, C > I, C < J, C < K, C < L

D > E, D > F, D < G, D > H, D > I, D < J, D > K, D > L

E > F, E < G, E < H, E > I, E < J, E < K, E < L

F < G, F <H, F > I, F < J, F < K, F < L

G > H, G > I, G < J, G > K, G > L

H > I, H < J, H < K, H < L

I < J, I < K, I < L

J > K, J > L

K > L

Accordingly, these paired comparisons achieved the following ranking:

J > G > D > K > A > L > H > E > B > C > F > I

The outcome of this paired comparison reflects the builder's *subjective* preferences over the given alternatives in order to carry out his housing development (Table 8.29).

RANKING	ALTERNATIVE			
	NO.		DESIGN APPROACHES	CONSTRUCTION APPROACHES
1	J	10	MASS CUSTOM (MCD)	SITE-BUILT (SC)
2	G	7	CUSTOM (CD)	SITE-BUILT (SC)
3	D	4	SEMI-CUSTOM (SCD)	SITE-BUILT (SC)
4	K	11	MASS CUSTOM (MCD)	PANSLISED (PC)
5	A	1	PRODUCTION (PD)	SITE-BUILT (SC)
6	L	12	MASS CUSTOM (MCD)	MODULAR (MC)
7	H	8	CUSTOM (CD)	PANELISED (PC)
8	E	5	SEMI-CUSTOM (SCD)	PANELISED (PC)
9	B	2	PRODUCTION (PD)	PANELISED (PC)
10	C	3	PRODUCTION (PD)	MODULAR (MC)
11	F	6	SEMI-CUSTOM (SCD)	MODULAR (MC)
12	I	9	CUSTOM (CD)	MODULAR (MC)

Table 8.29: The results of paired comparisons in response to the builder's preferences

Even though the alternatives are ranked using the paired comparison approach, the final selections will be left for the builder's own decision in response to the results of the benefit-performance graph (see Figures 8.13 and 8.14) established in this last stage of the choice model. In short, in order to facilitate the builder's buying decisions for the given alternatives, this stage aimed to *visualise* the value of each alternative, integrating the evaluation results of the cost-quality-time factors, whilst taking into account the task- and non task-related concerns involved in his buying decisions.

8.5. SUMMERY AND CONCLUSIONS

This chapter aimed to demonstrate the choice model *for mass customisation* developed in Part II of this thesis, in order to examine its *practicality*; thus, the author selected a Quebec homebuilder who wished to initiate a mass housing development in the future. Accordingly, the author focused on demonstrating the choice model in order to assist the selected builder in purchasing sub-contractors' products and services required for the execution of his housing development. As described in Chapter 5, the choice model, which functions as a buyer's decision-making support system, is composed of five consecutive stages: identification of need, formulation of objectives and specifications, generation of alternatives, evaluation of alternatives and selection of alternatives. According to the role played by each, these stages were grouped into two phases: the 'mass customisation' phase and the 'value analysis' phase. The roles and accomplishments of each stage, assigned to this demonstration project, can be summarised as follows:

STAGE I: This stage aimed to identify the selected homebuilder's need to purchase the sub-contractors' products and services that are required to accomplish his housing development. His *need* was considered as the market *demand* for housing; thus, market research was conducted. However, the builder has not yet decided on the specific location for the housing development in Quebec; thus, the author utilised the primary and secondary data concerning housing market trends in Canada and Quebec, which were examined in Chapter 2 and 3 of this thesis. As a result, the author saw the builder's need as the delivery of quality affordable homes, in which product quality and customisability of housing are of concern, while the target market includes non-traditional households which are not often affluent but who have diverse demands for housing.

STAGE II: In response to the results of stage I, this stage focused on conducting the function analysis that aims to identify the how to accomplish the builder's need—i.e. to build quality affordable homes. In this choice model, the functions (in verb-noun form) that help accomplish this project goal were considered as the project objectives. In addition, based on the objectives identified by the function analysis using the FAST Diagram, evaluation criteria, as well as a model house were developed. These are considered as the builder's buying determinants (or *specifications*) to be used for further comparative analysis of the sub-contractors' products and services to be purchased.

STAGE III: According to the results of the FAST Diagram, which identified the key functions that help satisfy the builder's need, some alternatives were generated using the concept of mass customisation—i.e. the combinations of existing standard components, which can be used (or produced) on a mass basis, in order to create a sense of customisation. The author identified three design approaches and three construction approaches, which are already in use in the North American housing industry. Furthermore, he added a relatively new design approach, called the mass custom design approach, which has already been practised particularly in Japan, to the existing design approaches. Finally, the design and construction systems identified were paired according to set theory. Thus, in total, 12 alternatives were generated for further value analysis.

STAGE IV: This stage was aimed at evaluating the given alternatives. Firstly, the project time and cost of each alternative were estimated. Secondly, with a consideration of the time value, the present worth method was applied for the economic analysis, which concerned not only the estimated design and construction costs of each alternative, but also the sale of housing (or *salvage*). In addition, the performance (or functionality) of each alternative was evaluated in response to the builder's needs, desires, and expectations for products and services to be purchased for the accomplishment of his project goal as identified in the first stage of the choice model.

STAGE V: The last stage of the choice model aimed to assist the builder's final selection of the given alternatives, which might contribute towards mass customising his housing development. Thus, a cost-performance graph (or benefit-performance graph) using the results of the present worth method was developed. This integrated the results of the economic and performance analyses in order to identify (or *visualise*) the value of each alternative. Furthermore, the author conducted paired comparisons of the alternatives, in order to rank them, based on an interview with the builder.

According to the results, the combination of the mass custom design and site-built construction approaches was considered the most potentially effective alternative for the builder to accomplish his project goal—i.e. the delivery of quality affordable homes (or *lower-cost and higher-performance housing*) in his mass housing development.

However, it is important to note that this choice model aims to assist the homebuilder's decision making for the generation and selection of alternatives; thus, it does not attempt to emphasise specific products (and services) for further application, or purchase. With respect to the purpose of this study (i.e. the demonstration of the choice model), the author concluded that the proposed choice model well supports homebuilders' buy-or-make decisions and helps reduce or eliminate the '**goal identification uncertainty**' and the '**goal/purchase matching uncertainty**' which are usually involved in such decisions. As well, it aids homebuilders in making the final choices from available alternatives by identifying the total *value* inherent in each of them, while their task- and non task-related concerns about the products (and services) under study are also taken into account.

PART IV:

DISCUSSION

CHAPTER 9: SUMMARY AND CONCLUSIONS

9.1. INTRODUCTION

This chapter provides an overview of the research and analysis carried out for this thesis. Firstly, it summarises the key points made in each of the preceding chapters. Secondly, the conclusions will be presented in response to the main research question identified in Chapter 1.

9.2. THE HIGHLIGHTS OF THIS STUDY

To clarify the interrelationship of the issues discussed in each chapter, this section sums up the key points of this study. A page number is provided to direct the readers to references in the content.

Page reference	
1-5	In 1987, the World Commission on Environment and Development (WCED) first advocated ***sustainable development*** and successfully attracted increased political attention to the associated social, economic and environment issues. The housing industry is no exception and sustainability is a matter of concern in housing development that encompasses the same issues. In view of
6-8	environmental macroeconomics, a ***production and consumption cycle*** needs to be taken into account in order to achieve sustainable development. In fact, the
9-15	production of a house consumes large amounts of energy during construction,
16-20	and following occupancy. Fewer waste materials might be generated by in-factory production rather than by on-site construction, given that site waste and interruptions, such as bad weather, site disturbances, theft and vandalism, can be reduced or eliminated. In addition, computer-cutting of materials can help reduce the amount of wastage.
	To some extent, sustainability in housing development can only be achieved, if homebuilders initiating and supervising the project opt to use the innovative construction (and design) approaches rather than the more traditional
20-24	site-built construction. Their ***choice*** of design and construction approaches, which is made at the early stage of the housing project, is one of the influential factors in realising sustainable housing development. If so, homebuilders need to understand the actual ***value*** of alternatives, which requires an analysis of cost-quality-time factors, when making such a choice.

24-30 Homebuilders are often small in size and this keeps them extremely busy
and overworked; thus, their business activities often develop into *routines*, which
have been streamlined to a point where efficiency is maximised. However,
builders are then reluctant to apply unfamiliar homebuilding approaches, since
34 understanding the potential advantages (or *profit*) may require extra costs and
time. In particular, this tendency can be seen in process-oriented, industrialised
building systems (e.g. ***panelised*** and ***modular systems)***, where in-factory
completion of housing components is relatively high. Such systems may result in
major modifications to a homebuilder's habitual production and consumption
cycle, which can be referred to as an organisational (or industrial) buying routine.
With due consideration for the location in which this study was carried out, a
36 research question was established, focusing on identifying Quebec
homebuilders' buying decisions for the design and construction systems that
help mass customise a housing unit or development that contributes to
sustainability.

Homebuilders need to build homes, which must be marketable; thus, the
builders' *needs* for housing should align with homebuyers' *demands* for housing.
40-45 The profile of contemporary households in Canada is more complex than in the
past and this makes their housing requirements more diverse. In response to
social and economic changes, non-traditional households with fewer children are
becoming more conspicuous; typically, these households are relatively small in
size, and often not affluent. Indeed, many Canadians still face ***housing***
46-56 ***affordability*** issues, while today's consumers are no longer satisfied with
60 *minimum* levels of ***housing quality***—i.e. adequacy and suitability (or *core
housing need*).

Reducing house prices may alleviate housing affordability problems.
However, to produce ***affordable homes***, construction costs need to be reduced
while productivity and output should be increased. Thus, mass (or *large-scale*)
57 housing development strategies may be one of the most effective means of
58-60 producing affordable homes. Post-war mass housing developments bear this out,
but tend to create generic, repetitive homes, which appear as the antithesis to
meeting today's demand for ***customised houses***. Homebuilders are facing a
64-66 *contradiction* between consumer demands for lower-pricing and customisation.
In order to overcome the problem, today's homebuilders may need to develop
strategies to simultaneously implement *mass production* and *customisation*.
64 However, none of the existing design approaches (i.e. ***production***, ***semi-
custom*** and ***custom design***) currently used by homebuilders and housing
manufacturers in North America truly integrate these two opposite concepts.
Therefore, an innovative design approach to tackling this problem needs to be
developed. Moreover, in response to environmental problems facing society
today, homebuilders are also required to produce ***energy-efficient homes*** and
achieve resource savings in construction. The medium density housing
66-70 development composed of townhouses (or *attached units*) that normally contain
fewer corners and windows and less area of exterior walls per house has the
potential to produce such lower-priced energy-efficient homes.

73 In response to both current and future market demands for housing,
homebuilders need to supply '***quality affordable homes***'. In this context,
housing quality not only concerns design *customisation* that meets individual
needs, but also the *energy efficiency* required by society in general. Furthermore,
product quality can be maintained or improved by using industrialised building
76-84 systems where in-factory completion is relatively high. In fact, this thesis has
shown that today's homebuilders are able to produce medium-density housing
85-90 developments using ***conventional*** means of building ***production*** or ***semi-***
95 ***customised*** townhouses, considered to be energy-efficient—like the Village
Renaissance townhouse development in the Bois Franc project. However, in
90-95 practice, the selling price of such a house is often relatively high in comparison to
97 national averages and the home is *not* totally customised. Product quality of
housing still depends entirely on on-site craftsmanship.

101 In order to bridge the design-production ***gap*** between the need for mass
production (or *standardisation*) of housing that helps reduce production costs
and the need for full customisation that meets market demands for housing, a
102-108 concept of ***mass customisation***, invented in 1987 by Stanley Davis, was
130 reviewed. Based on this concept, a ***mass customisation system*** model,
integrating *product-* and *service*-oriented (or *process*-oriented) sub-systems
necessary for mass-producing (or standardising) customisable homes was
proposed. Through the author's investigation of selected Japanese housing
131 manufacturers, a '***mass custom* design**' approach was introduced for future
potential application to the delivery of ***mass custom homes*** in North
America—however, the local housing makers' marginal ability to produce homes
today may need to be taken into account.

158 In view of a production and consumption cycle, the adoption of new products (e.g. building systems) and services (e.g. design approaches) applied to housing development depends entirely on a homebuilders' organisational *buying* decisions made in the early stages of a project. However, builders tend to *routinise* their way of doing business and are reluctant to apply innovative design and construction approaches to their housing developments. Organisational
163 buyers tend to cut down the information search for ***non-programmed*** decisions to determine whether or not to buy an unfamiliar product or service. Thus,
171-177 considering *organisational buying behaviour*, a '***choice model for mass customisation***' was proposed in order to assist homebuilders in making their buying decisions through an understanding of the *value* of the alternatives (e.g. homebuilding approaches) that contribute towards mass customising the end product (i.e. housing unit or development). The choice model focuses on:

1. Identifying the need for a buy-or-make decision
2. Formulating the objectives and specifications for making optimal choices
3. Generating the alternatives for mass customising an end product
4. Evaluating the given alternatives
5. Selecting the preferred alternatives

Furthermore, according to the tasks assigned to each, these five consecutive stages were classified into two phases—i.e. the 'mass customisation' phase and the 'value analysis' phase. In addition, selected ***analytical techniques*** that assist model users (i.e. homebuilders) in making their buy-or-make decisions were introduced in Chapter 6 and 7.

241 To assess its *practicality*, the choice model *for mass customisation*
proposed in this thesis was demonstrated through a case study. The author
242 selected a homebuilder intending to initiate a mass housing development in
Quebec. Data concerning cost-quality-time-location factors were collected
through the author's observations of off-site and on-site construction, interviews
with selected company executives and questionnaires. In addition a literature
review was carried out. The proposed *choice* model was then applied to generate
251-257 and value-analyse 12 alternatives relating to the design and construction
systems (such as the production, semi-custom, custom and mass custom design
approaches and the site-built, panelised and modular construction approaches)
that help produce *quality affordable homes* in a medium-density housing
development. As a result, the author was able to confirm that the proposed
296 choice model has the potential to reduce or eliminate the ***goal identification*** and
goal/purchase matching uncertainties that are usually involved in buy-or-
284 make decisions. In fact, through the ***weighted evaluation*** of the given
287-288 alternatives, the homebuilder considered an alternative homebuilding approach,
293 which combines the mass custom design and site-built construction approaches,
as the most optimal choice, even though the builder is *not* familiar with this new
design approach. The choice model successfully opened the door for the builder
290 to make his final choice of alternatives by identifying the true *value*, while still
taking account of the builder's *task*- and *non task*-related concerns about the
familiar and *unfamiliar* products and services to be purchased.

9.3. CONCLUSIONS

In Chapter 1, the research question was addressed:

How can homebuilders in Quebec choose design and construction systems to generate more efficient (i.e. lower-cost & higher-performance) housing development that contributes to sustainability?

In response to this question, the resulting conclusions are summed up below:

1. Homebuilders' *choices* of design and construction approaches are influential in improving the efficiency of housing development, as well as accomplishing sustainability. A medium-density housing development composed of attached dwelling units helps reduce energy consumption for heating and the amount of materials used for construction. In addition, the use of industrialised building systems helps reduce building material wastage and increases productivity and output.
2. Today's homebuilding industry is still characterised by the 'closed system' with builders' activities quickly developing into *routines*. Their decision-making process for the selection of design and construction systems must therefore be well *programme* and their *task*- and *non task*-related concerns needs to be taken into account.
3. Homebuilders build homes, which must be *marketable*; thus, market demands for housing (i.e. the wants and needs of individuals, as well as of society) must be incorporated into their decision-making process for the selection (or *purchase*) of design and construction systems in view of the *production* and *consumption* cycle.
4. Every homebuilder has his own values, which may differ from others; therefore, the *weighted evaluation* of design and construction

systems must be carried out in response to the buyer's *subjective* assessment of actual inputs with respect to the 'cost-quality-time-location' factors relevant in any housing project.

5. Homebuilders *adopt* innovative design and construction approaches to housing development, *only* if they are convinced of the balance between *profitability* and *performance.* Thus, the ***visualisation*** of the value (concerning the 'cost-performance') of each alternative can be considered an effective means to help homebuilders appreciate familiar and unfamiliar innovative products and services to be purchased for the development of 'lower-cost and higher-performance' housing—perhaps, *quality affordable homes.*

Finally, the author also concludes that the **choice model *for mass customisation*** proposed in this study can function effectively as a *practical* decision-making support tool (or *system*) and can open the door for the model users (i.e. homebuilders) to select alternatives that help mass customise a housing development (or unit) in response to market demands. In addition, the choice model helps analyse the total *value* of the alternatives in response to the buyers' needs, desires and expectations for the products (and services) to be purchased. Thus, the *goal identification uncertainty* and *goal/purchase matching uncertainty* involved in buy-or-make decisions can be reduced, or eliminated, through this '**programmed**' buying decision-making process.

However, some arguments concerning this study remain outstanding and will be examined in the next chapter in order to identify the opportunities for future research.

CHAPTER 10: ARGUMENTS AND OPPORTUNITIES FOR FUTURE RESEARCH

10.1. INTRODUCTION

In the last chapter, the conclusions of this thesis were summarised; however, some issues remain outstanding, as stated in Chapter 9. Thus, these are examined in this chapter along with key topics worthy of future research.

10.2. ARGUMENTS

In order to increase productivity and output, which in turn help reduce construction costs, the author discussed the effectiveness of mass housing development, while the customisability and product quality of housing to meet the wants and needs of both individuals and society were also taken into account. This dissertation aimed to integrate industrialised construction technologies to produce customisable housing having mass production marketing opportunities, in order to generate quality affordable (or lower-cost and higher-performance) housing developments. Thus, a decision-making tool (or *choice model*) that helps identify the potential value of alternatives was proposed in order to encourage builders initiating mass housing developments to consider the application of innovative *design* and *construction* approaches to lower-cost and higher-performance housing developments.

The demonstration project, which was carried out in this thesis, attests to the fact that the application of industrialised building systems for housing development costs more than a conventional system. From the homebuilders' viewpoint, the advantages of the rapid construction afforded by the use of industrialised building systems that reduce financing costs, where time value is taken into account, are not sufficient to reduce the total construction cost, even though product quality can be adequately maintained by reducing or eliminating on-site wastes and interruptions. Despite the fact that the product quality of site-built homes is lower than that of industrialised homes with the higher in-factory completeness of housing components, conventional homes are still the norm in today's housing market. Thus, there is no reason for homebuilders to apply more expensive, industrialised construction approaches. Homebuilders, who tend to be more focused on *profits* than construction *technologies*, are the main housing makers and as such can be considered '**price leaders**' in today's Canadian homebuilding industry. Housing manufacturers in Quebec, who often target upper-middle income groups and sell them relatively expensive products, may need to adjust the selling price of their products to that of the homebuilders', when seeking to work with the project initiators of mass housing developments in order to have mass orders. Offering *discount* unit prices to homebuilders for their mass orders may be effective; thus, further research concerning pricing strategies for discounts to meet the market price of conventional housing may need to be undertaken.

As well, the author also discussed some design approaches. Today's housing manufacturers in Quebec claim that they can customise a home to the same extent as conventional homebuilders. However, their design process for the creation of customised home does not reflect the advantages of industrialised housing, in which standardisation of housing components helps reduce design and construction costs, while in-factory production ensures a steady supply of quality products. Again, if housing manufacturers' design approaches are not differentiated from conventional approaches, there is no reason for homebuilders to work with the manufacturers. Thus, the manufacturers may need to apply an innovative design approach that helps increase the productivity and output of industrialised housing, while the higher in-factory completion of housing components that helps maintain product quality can be well maintained.

In this study, a mass custom design approach was introduced and its potential for reducing design time was underlined—especially for the production of subsequent housing units. As a result of a case study, a homebuilder admitted that it might be the most effective design approach helping not only to reduce design costs but also to improve performance according to the builder's needs, desires and expectations for housing to be built. The use of standardised drawings for housing components provides economies of scale and in combining standardised components a home can be customised through the homebuyers' selection of available components thereby permitting the individualisation of their new home. However, without having the expertise of design professionals (i.e. **architects**), homebuilders, who tend to follow routine homebuilding activities, may hardly apply this new design approach that in part contributes to the development of lower-cost and higher-performance housing. Thus, the question related to this new design method extends to the *how*: How can it be widely introduced?

Generally speaking, the mass customisation of homes requires not only the generation of interchangeable standardised housing components (or *products*), but also design consulting *services*, which enable users to select components in response to their understanding of the value of each alternative. The need for a product and service sub-system characterises the mass customisation model: MC = f (PS). In addition, during the design stage, users' buying choices of standardised housing components are indispensable for mass customising a home; thus, the *choice* model *for mass customisation* proposed in this thesis can also be used to facilitate their buying decisions.

In particular, the mass custom design approach may be more applicable to upgrading prefabricated homes than their site-built counterparts, since the repetitive use of standard housing components helps reduce design and production costs, while allowing manufacturers to maintain a higher level of in-factory completion of the components thereby ensuring a steady supply of quality products. The application of the mass custom design approach may also facilitate the customisation of industrialised housing, in which a user's direct communication with a housing producer for design changes is currently difficult, given that housing is purchased from a *dealer* with limited custom design skills. In addition, the application of this new design approach may also contribute to improving housing purchased at a display home built on a subdivision development, as well as export housing, in terms of design customisability.

Housing manufacturers alike, who usually assign to their in-house technical draftsmen (with little or no architectural design education) the designs of their products, may hardly adopt an innovative design approach in which the knowledge of the architectural design professionals (or *innovators*) may be indispensable for the application. Thus, some of the poor designs visible in industrialised housing, which have caused the public to associate prefabricated homes with *low* quality, may be remedied when manufacturers collaborate with architects or experts in the mass custom design approach for the development of, at least, a *model* house. Through the consideration of the case study presented in Chapter 8, the cost required for the development of a model mass custom housing unit can be amortised by recycling the standard housing components to produce a *certain* number of subsequent units based on the results of a break-even analysis to determine the length of the break-even production run.

The application of the mass custom design approach that reduces design cost and time, whilst maintaining higher product quality, may feature in industrialised housing in Canada. It would also allow manufacturers to customise prefabricated homes to be built in remote areas that hinder the users' direct communication with the manufacturer. In view of the production and consumption cycle, it may perhaps lead to a change in housing manufacturers' sales promotion, given that homebuilders want to learn the *how*. In this case, homebuilders have a reason (or *need* for buying decisions) to collaborate with the manufacturers, who already know *how* to mass customise homes and can offer a *discount* unit price for mass orders, on the development of lower-cost and higher-performance housing.

10.3. OPPORTUNITIES FOR FUTURE RESEARCH

Key topics worthy of future research have become apparent during the research carried out for this thesis. These include:

- The application of the choice model *for mass customisation* to *homebuilders*' decision-making process for their selection of design and construction systems that directly contribute to sustainable housing developments.
- The application of the choice model *for mass customisation* to *homebuyers*' decision-making process for their selection of 'standard housing components' at the design stage that contribute towards mass customising their new home.
- The demonstration of the mass customisation system model for mass customising homes built on *subdivision* developments.
- The effects of the mass custom design approach on the delivery of *dealer-intervened* industrialised housing in Canada.
- The effects of the mass custom design approach on exporting Canadian homes.

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APPENDIXES

APPENDIX A:

LIST OF HOUSING MANUFACTURERS SURVEYED IN QUEBEC

LIST OF PRE-ENGINEERED HOUSING MANUFACTURERS

Panexpert
175 Rue Boyer,
Québec, J0L 2A0
Tel: (450) 454-4636 , Fax: (450) 454-6978
Contact Person: Daniel Tourangeau
E-mail: kefor@panexepert.com

Dunfab Inc.
663 Route 139,
Roxton Pond, Québec, JOE 1Z0
Tel: (450) 372-0008 Fax: (450) 372-9886
Contact Person: Mr.Lacoste

La Charpentrie Inc.
1651 Boulevard du Royaume Ouest,
Chicoutimi, Québec, G7H 5B1
Tel: (418) 549-7731
Web Site: www.lacharpenterie.qc.ca/fr/entre.htm
Contact Person: Sylvain Savard
E-mail: lacharpenterie@lacharpenterie.qc.ca

Domicilex Inc.
3590 Rue de l'Énergie, C.P. 995,
Jonquière, Québec, G7X 7W8
Tel: (418) 547-9301
Web Site: http://www.domicilex.com/accueil.htm
Contact Person: Gaétan Gérard (director)
E-mail: ventes@domicilex.com

Maisons Laprises Inc.
240 des Ateliers,
Québec, G5V 4G4
Tel: (418) 248-0401 Fax: (418) 248-8415
Web Site: www.maisonslaprise.com
Contact Person: Daniel Laprise (president)
E-mail: laprise@maisonlaprise.com,

Les Structures Ultratec Inc.
235 Rue de la Station,
Laurier-Station, Québec, G0S 1N0
Tel: (418) 728-3449 Fax: (418) 728-3516
Contact Person: Michel beaudoin
E-mail: administration@ultratech.qc.ca

Toitures Deslongchamps Inc.
215 Boulevard Industriel,
St-Lin-Laurentides, Québec, J0R 1C0
Tel: (450) 439-5212 and 1-800-590-5212
Web Site: http://www.td.qc.ca
Contact Person: Réjean Cyr, ext:242
E-mail: toitures.deslongchamps@sympatico.ca

Construction Dumais et Pelletier
625 Rue Adélard
Saint-Pascal, Québec, G0L 3Y0
Tel: (418) 492-1554
Contact Person: Alain Pelletier
E-mail: cdpinc@globetrot.net

LorBec Canada Inc.
4 Place du Commerce, Suite 204,
Brossard, Québec, J3W 3B3
Tel: (450) 672-9988
Web Site: www.lorbeccanada.com/intro.html
Contact Person: Jean-Charles Leborgne
E-mail: info@lorbec.canada.com

LIST OF PANELISED HOUSING MANUFACTURERS

Les Maisons Alouette Inc.
316, Rue Principale Ouest,
Sainte-Anne-de-la-Rochelle, Québec, J0E 2B0
Tel: (450) 539-3100
Web Site: www.alouettehomes.com
Contact Person: Mattew Berneshe
E-mail: mbern@maisonalouette.com

Panexpert
175 Rue Boyer,
Québec, J0L 2A0
Tel: (415) 454-4636 Fax: (415) 454-6978
Web Site: http://www.panexpert.com
Contact Person: Daniel Tourangeau
E-mail: kefor@panexepert.com

Les Industries Leblanc Inc.
346 Boulevard Perron, C.P.143,
Carleton, Québec, G0C 1J0
Tel: (418) 364-3208 Fax: (418) 364-6333
Contact Person: Rosaire Lebland
E-mail: indleb@globetrotter.net

Construction Lortie Inc.
213 Chemin Saint Jacques,
Saint-Léonard-de-Porneuf, Québec, G0A 4A0
Tel: (418) 337-2837
Contact Person: Claude Lortie (president)
E-mail: clortie@lortiecontruction.com

Bonneville International Housing Corp.
601 Boulevard De l'Industrie,
Beloeil, Québec, J3G 4S5
Tel: (450) 536-3585 Fax: (450) 536-3360
Contact Person: M Eric Piuze (Director)
E-mail: info@bonneville.qc.ca

Fabrik Estrie Inc.
3415 Rue Dunat,
Rockforest, Québec, J1N 3B7
Tel: (819) 823-1555 Fax: (819) 823-1555
Contact Person: Ginette Lessard

Les Habitations Nabco Inc.
686 Rang de la Riviere Est,
Sainte-Brigitte d'Iberville, Québec, J0J 1X0
Tel: (450) 293-3125
Web Site: nabcohousing.com/findex.html
Contact Person: M. Bessette (Vice president)
E-mail: nabco@nabcohousing.com

Maisons Laprises Inc.
240 des Ateliers, Parc Industriel,
Montmagny, Québec, G5V 4G4
Tel: (418) 248-0401 Fax: (418) 248-8415
Web Site: www.maisonslaprise.com
Contact Person: Daniel Laprise (president)
E-mail: laprise@maisonlaprise.com

G Moisan
350 Avenue des Laurentides,
Québec, G1C 4N3
Tel: (418) 667-0284
Web Site: www.gmoisan.com
Contact Person: Pierre Guay
E-mail: gmoisan@qc.aira.com

Les Produits PBM Ltée
130 Chemin du Moulin,
Saint-Pierre-de-Lamy, Québec, G0L 4B0
Tel: (418) 497-3927 Fax: (418) 497-2613
Web Site: www.mrctemiscouata.qc.ca
Contact Person: Joanne Ouellet
E-mail: prpbm@qc.aira.com

Construction Dumais et Pelletier
625 Rue Adélard,
Saint-Pascal, Québec, G0L 3Y0
Tel: (418) 492-1554
Contact Person: Alain Pelletier
E-mail: cdpinc@globetrot.net

Groupe Multigon and Les maisons usinées Navic Enr.
632 Chemin des Lacs,
Sainte-Anne-des-Lacs, Québec, J0R 1B0
Tel: (450) 224-8255
Web Site: maisonsmultigon.com
Contact Person: Claude Paquette
E-mail: info@maisonsmultigon.com

Les Habitations Mont-Carleton (1994) Inc.
79 Rue de la Gare, C.P. 959,
Carleton, Québec, G0C 1J0
Tel: (418) 364-3168 Fax: (418) 364-3838
Contact Person: Eric Harrison
E-mail: hmc1994@globetrotter.net

Chevrons Dionne
288 Boul. Bégin,
Saint-Pacôme, Québec, G0L 3XO
Tel: (418) 852-2566 & 1-800-463-8648
Contact Person: France Lévesque
E-mail: chevronsdionne@globetrotter.net

Les Industries Fermco Ltée
251 Rue Du Moulin,
Saint-Adelphe, Québec, G0X 2G0
Tel: (418) 322-5747 Fax: (418) 322-5893
Web Site: www.fermco.com
Contact Person: René Paquin
E-mail: rpaquin@fermco.com

Les Toitures P.L.C. Inc.
95 Saint-Augustin-de-Desmaures,
Québec, G3A 1T5
Tel: (418) 878-4060 Fax: (418) 878-4770
Contact Person: Jean-Yves Pouliot

La Charpentrie Inc.
1651 Boul.du Royaume Ouest,
Chicoutimi, Québec, G7H 5B1
Tel: (450) 549-7731
Web Site: www.lacharpenterie.qc.ca/fr/entre.htm
Contact Person: Sylvain Savard
E-mail: lacharpenterie@lacharpenterie.qc.ca

Maison Max
12 des Tournois,
Blainville, Québec, J7C 4Y2
Tel: 434-4000
Contact Person: Pierre Laliberté

Constructions Transit
166 Chemin Senneville,
Québec, H9X 3L2
Tel: (514) 457-6093
Contact Person: Guy Cyr
E-mail: transit@videotron.ca
Product: Panelised,

Domicilex Inc.
3590 Rue de l'Énergie, C.P. 995,
Jonquière, Québec, G7X 7W8
Tel: (418) 547-9301
Web Site: http://www.domicilex.com/accueil.htm
Contact Person: Gaétan Gérard (Director)
E-mail: ventes@domicilex.com

Dunfab Inc.
663 Route 139,
Québec, JOE 1Z0
Tel: (450) 372-0008 Fax: (450) 372-9886
Contact Person: Mr.Lacoste

LIST OF MODULAR HOME MANUFACTURERS

Construction GOSCOBEC Inc.
103 Rue Louis-Philippe-Lebrun, C.P. 907,
Rivière-du-Loup, Québec, G5R 5W5
Tel: (418) 862-9628
Web Site: www.goscobec.com
E-mail: goscobec@goscobec.com

Les Maisons Alouette Inc.
316 Sainte-Anne-de-la-Rochelle,
Québec, J0E 2B0
Tel: (450) 539-3100
Web Site: www.alouettehomes.com
Contact Person: Mattew Berneshe
E-mail: mbern@maisonalouette.com

Bonneville International Housing Corp.
601 Boulevard De l'Industrie,
Beloeil, Québec, J3G 4S5
Tel: (450) 536-3585 Fax: 536-3360
Contact Person: M Eric Piuze (Director)
E-mail: info@bonneville.qc.ca

La Maison Usinex Inc.
114 Milan, Québec, G0Y 1E0
Tel: (819) 657-4268 Fax: (819) 657-4998
Web Site: maisonusinex.com
Contact Person: Raymond Morin
E-mail: maisonusinex@qc.aira.com

Maisons Usinées Côté inc.
115 St-Isidore,
Ville des Laurentides, Québec, J0R 1C0
Tel: (450) 439-8737 Fax: (450) 439-2471
Contact Person: Virginie Côté (Vice president)
E-mail: muc@qc.aira.com

Les Industries Leblanc Inc.
346 Boulevard Perron, C.P.143,
Carleton, Québec, G0C 1J0
Tel: (418) 364-3208 Fax: (418) 364-6333
Contact Person: Rosaire Lebland,
E-mail: indleb@globetrotter.net

Les Résidences Pro-Fab Inc.
395 Route 112 Est, C.P. 340,
Vallée-Jonction, Québec, G0S 3J0
Tel: (418) 253-5166 Fax: (418) 253-5300
Web Site: www.profab.ca

Les Maisons Champoux
29 Rue Champoux, C.P.98,
Notre-Dame-du-Nord, Québec, J0Z 3B0
Tel: (819) 723-2253
Web Site: www.mp.qc.ca/maisons-champoux
Contact Person: Pierre Champoux

RCM Modulaire
28 Rue Industriel,
Saint-Benoît-Labre, Québec, G0M 1P0
Tel: (418) 227-4044
Web Site: www.rcmmodular.com/
Contact Person: Marc Gagnon
E-mail: info@rcmmodulaire.com

Les Habitations Nabco Inc.
686 Rang de la Riviere Est,
Sainte-Brigitte d'Iberville, Québec, J0J 1X0
Tel: (450) 293-3125
Web Site: nabcohousing.com/findex.html
Contact Person: M. Bessette (Vice president)
E-mail: nabco@nabcohousing.com

Maisons Nordique Inc.
115 Chemin Gallichan,
Gallichan, Québec, J0Z 2B0
Tel: (819) 787-6680
Web Site: www.maisonnordique.com/
Contact Person: Richard Racine

Maisons Usinées Expo Inc.
63 Maskinongé, Québec, J0K 1N0
Tel: (819) 227-2277 Fax: (819) 227-2847
Web Site: www.fortune1000.ca/expo
Contact Person: Nathalie Giguère
E-mail: maisonusine@atou.qc.ca

Le Maître Constructeur St-Jacques Inc.
32 Rue Nadeau,
Saint-Jacques-de-Leeds, Québec, J0N 1J0
Tel: (418) 424-3117
Web Site: www.stjacques.specialistes.com
Contact Person: Guylaine Poulin
E-mail: maitreconstructeur@globe-trotter.net

Les Maisons J.Robert Ouellet Inc.
16 Route 185, R.R.3,
Saint-Antonin, Québec, G0L 2J0
Tel: (418) 867-2329
Web Site: http://www.maisonsouellet.com
Contact Person: Carole Plourde

Construction Dumais et Pelletier
625 Rue Adélard,
Saint-Pascal, Québec, G0L 3Y0
Tel: (418) 492-1554
Contact Person: Alain Pelletier
E-mail: cdpinc@globetrot.net

Maisons S. Turner Inc.
1021 Rue de l'Atelier,
Pointe-du-Lac, Québec, G0X 1Z0
Tel: (819) 377-0570 Fax: (819) 377-0831
Contact Person: Katy Turner

Maisons Usinées 2001 Inc.
480 Rue Bourgeois,
Saint-Amable, Québec, J0L 1N0
Tel: (450) 922-3428
Contact Person: André Beauregard (President)

Domicilex Inc.
3590 Rue de l'Énergie, C.P. 995,
Jonquière, Québec, G7X 7W8
Tel: (418) 547-9301
Web Site: www.domicilex.com/accueil.htm
Contact Person: Gaétan Gérard (Director)
E-mail: ventes@domicilex.com

Maisons Usinées Brouillette Inc.
200 Rue des Industries,
Lavaltrie, Québec, J0K 1H0
Tel: (450) 586-0422
Contact Person: Isabelle Brouillette

Maisons Modernes Orford
60 Eastman, Québec
Tel: (450) 297-0677
Contact Person: Petit

LIST OF MANUFACTURED (MOBILE) HOME MANUFACTURERS

Les Industries Leblanc Inc.
346 Boulevard Perron, C.P.143,
Carleton, Québec, G0C 1J0
Tel: (418) 364-3208, Fax: 364-6333
Contact Person: Rosaire Lebland
E-mail: indleb@globetrotter.net

Les Habitations Mont-Carleton (1994) Inc.
79 Rue de la Gare,
Québec, G0C 1J0
Tel: (418) 364-3168 Fax: (418) 364-3838
Contact Person: Eric Harrison
E-mail: hmc1994@globetrotter.net

Maisons Nordique Inc.
115 Chemin Gallichan,
Gallichan, Québec, J0Z 2B0
Tel: (819) 787-6680
Web Site: www.maisonnordique.com
Contact Person: Richard Racine
E-mail: info@maisonnordique.com

Domicilex Inc.
3590 Rue de l'Énergie, C.P. 995,
Jonquière, Québec, G7X 7W8
Tel: (418) 547-9301
Web Site: http://www.domicilex.com/accueil.htm
Contact Person: Gaétan Gérard (Director)
E-mail: ventes@domicilex.com

Les Habitations Nabco Inc.
686 Rang de la Riviere Est,
Sainte-Brigitte d'Iberville, Québec, J0J 1X0
Tel: (450) 293-3125
Web Site: nabcohousing.com
Contact Person: Bessette (Vice president)
E-mail: nabco@nabcohousing.com

Le Maître Constructeur St-Jacques Inc.
32 Rue Nadeau,
Saint-Jacques-de-Leeds, Québec, J0N 1J0
Tel: (418) 424-3117
Web Site: www.stjacques.specialistes.com
Contact Person: Guylaine Poulin
E-mail: maitreconstructeur@globe-trotter.net

Les Maisons J.Robert Ouellet Inc.
16 Route 185, R.R.3,
Saint-Antonin, Québec, G0L 2J0
Tel: (418) 867-2329
Web Site: http://www.maisonsouellet.com
Contact Person: Carole Plourde

Bonneville International Housing Corp.
601 Boulevard De l'Industrie,
Beloeil, Québec, J3G 4S5
Tel: (450) 536-3585 Fax: 536-3360
Contact Person: M Eric Piuze (Director)
E-mail: info@bonneville.qc.ca

APPENDIX B:

SPECIFICATIONS FOR *VILLAGE RENAISSANCE* TOWNHOUSE DEVELOPMENT IN 1999 AND 2002

1- SPÉCIFICATIONS ARCHITECTURALES

1.1) SPECIFICATIONS EXTÉRIEURES:

a) Fondations:

- Murs de fondations de 8" et 10" d'épaisseur, avec acier d'armature aux endroits requis.
- Dalle sur sol de 4" d'épaisseur, renforcée par un tréillis métallique. Le tout coulé sur une membrane pare-vapeur (polythène) ainsi qu'une base de pierre concassée.
- Isolation de fibre de verre R-12, sur le périmetre intérieur des murs de fondations hors terre.

b) Murs extérieurs et toiture:

- Murs extérieurs en colombages de bois de 2" x 6" recouverts de feuilles d'agglomérées 7/16" d'épaisseur. Une fois la charpente érigée, celle-ci est enveloppée d'un pare-air de type "Typar".
- Isolation de fibre de verre R-20 pour les murs extérieurs. Facteur d'isolation des murs extérieurs est approximativement de R-26.
- Toutes les façades extérieures du bâtiment sont recouvertes de briques d'argile de qualité.
- Portes et fenêtres de la façade varient d'une unité à une autre et sont entourées d'une finition décorative. Ainsi, chacune des maisons possède son propre style et se distingue des autres.
- Soffite et fascia en aluminium prépeint.
- Recouvrement de toiture en bardeaux d'asphalte.
- Isolation de fibre de verre R-34.5 au toit.
- Portes de garage des bâtiments ainsi que celle de l'entrée commune sont isolées et recouvertes de métal pré-peint. Prévisions électrique pour ouvre-porte mécanique dans les garages des maisons.
- Les fenêtres de façades sont de type à battants. Le verre est de type thermos à double paroi de verre. Moustiquaires sur toutes les fenêtres ouvrantes.
- Porte-patio de type coulissante simple en PVC blanc à double paroi de verre.
- Porte d'entrée principale en métal peint isolée.

1.2) SPECIFICATIONS INTÉRIEURES :

le village RENAISSANCE

a) Structure :

- Les structures des planchers du rez-de-chaussée et de l'étage sont fabriquées avec utilisation des solives de bois et des poutrelles ajourées en bois pré-fabriquées. La charpente est recouverte avec du contreplaqué embouveté de 5/8" d'épaisseur, collé et cloué aux membres structurels afin d'obtenir des planchers plus rigides et plus silencieux ;
- Lorsque le plancher est couvert de céramique ou d'un recouvrement résilient, une deuxième épaisseur en contreplaqué de 3/8" est ajoutée.
- Toiture montée en fermes de toit préfabriqué.

b) Murs mitoyens :

- Mur en blocs de béton 8". De chaque coté du mur de blocs de béton, un mur de 2" x 4" en colombages de bois est monté.
- Les solives/poutrelles de planchers sont supportées par une structure d'acier ou par des murs porteurs indépendants et non par le mur de blocs de béton ; ceci assure une meilleur insonorisation car on diminue la possibilité qu'un son d'impact se propage à travers le mur de blocs mitoyens.
- Les murs mitoyens porteurs en colombage de bois sont remplis de laine isolante accoustique (fibre de verre) et recouverts d'un gypse 1/2".

c) Les planchers :

- Des tuiles céramiques sont posées sur les planchers suivants: vestibule, salle d'eau et salle de bain. Choix de couleurs par l'acheteur parmi la sélection offerte par le constructeur.
- Recouvrement de vinyle coussiné dans la cuisine / dînette
- Recouvrement de tapis dans toutes les autres pièces de la maison. Tapis avec sous-tapis en mousse d'uréthane de 10mm d'épaisseur. Choix de couleurs par l'acheteur parmi la sélection offerte par le constructeur.
- Marches et contre-marches des escaliers de l'étage et du sous-sol sont recouvertes de tapis. Le reste du plancher du sous-sol est fini béton.

d) Murs et plafonds :

- Tous les murs intérieurs sont de colombages en bois de 2" x 3" ou 2" x 4" lorsque requis. Certains colombages pourraient être plus larges pour recevoir la plomberie.
- Tuiles de céramique aux murs et à la façacde de la baignoire. Choix de couleurs par l'acheteur parmi la sélection offerte par le constructeur.
- Les murs intérieurs du rez-de-chaussée et de l'étage sont recouverts de gypse 1/2" avec bandes de joints.
- Garage et sous-sol sont non-finis.
- Sous-sol : murs recouverts de gypse avec une bande de joint. Plafond non-fini.
- Plafond du garage isolé R-12 en fibre de verre.
- Murs et plafonds du garage sont recouverts de gypse avec une bande de joint.
- Tous les murs et plafonds, à l'exception du sous-sol et du garage, sont peints blanc avec deux (2) couches de peinture au latex (sous-couche et finition).

e) Armoires/vanités :
<u>Cuisine:</u>

- Armoires de cuisine selon les spécifications et design de l'architecte designer, fini mélamine incluant des espaces pour four micro-ondes et lave-vaisselle.
- Portes et armoires, choix de couleurs par l'acheteur parmi la sélection offerte par le constructeur.
- Comptoir de cuisine fini stratifié. Choix de couleurs par l'acheteur parmi la sélection offerte par le constructeur.
- Branchement fourni pour éclairage au néon sous les armoires de cuisine, ou l'espace le permet (15" de longueur et plus).

<u>Salle de bain:</u>

- Vanité de la salle de bain et de la salle d'eau (si requis), est en mélamine avec comptoir en stratifié. Choix de couleurs par l'acheteur parmi la sélection offerte par le constructeur.
- Mur au dessus de la vanité de la salle de bain est recouvert d'un miroir.
- Armoire/pharmacie dans salle de bain.

f) Plomberie :
(voir notre personnel de vente pour plus de détails)

- Conduits d'apport en eau domestique sont en cuivre et les conduits de drainage sont en ABS.

Le village RENAISSANCE

<u>Salle d'eau:</u>

- Soit un attrayant lavabo sur pied ou un lavabo avec vanité et robinet modèle Delta. Les modèles varient selon le type d'unité.

<u>Salle de bain:</u>

- Baignoire: bain en coin ou droit en acrylique selon le type d'unité. Robinetterie de type Delta.

<u>Douche:</u>

- Dans la plupart des modèles de maison douche de coin 38" x 38" de type néo-angle avec base et murs de douche en fibre de verre et porte de douche en verre. Robinet modèle Delta.

<u>Cuisine:</u>

- Évier de cuisine double en acier inoxydable avec un lave légumes.

<u>Général:</u>

- Toute la robinetterie est de marque Delta, fini chrome. Robinets à manette unique dans cuisine et salle de bain.
- Tous les appareils de plomberie, sauf l'évier de la cuisine, sont de couleur blanche.
- Pour laveuse/sécheuse/lave-vaiselle, toute l'électricité, la plomberie et la ventillation requise est prévue, prête à recevoir les appareils.
- Pour votre convenance deux (2) sorties d'eau extérieures sont incluses dans chaque maison (avant, arrière). Une sortie d'eau est prévue aussi dans le garage.
- L'intérieur du garage est protégé du feu à l'aide d'un gicleur automatique.

g) Équipement électrique, mécanique :

- Les entrées électriques de chaque maison sont desservis par un panneau électrique de 150 amp. - 110v/220v. Tout le filage est en cuivre.
- Entrée pour le garage commun 100 amp. - 110v/220v.
- Chauffe-eau électrique de 60 gallons.
- Détecteur de fumée à chaque étage.
- Appareils d'éclairage à l'extérieur (porte avant, porte arrière).
- Appareils d'éclairage dans garage commun.
- Prises de courant sécuritaires dans les salles de bain.
- Interrupteurs série Décora de couleur blanche.
- Prise électrique extérieure à l'épreuve des intempéries (à l'arrière).
- Installations électriques prêtes à recevoir: laveuse, secheuse, réfrigérateur, cuisinière, four micro-ondes et lave-vaiselle

Montclair
Constructeur de l'année

h) Chauffage

- Plinthes électriques avec contrôle de température dans chaque pièce.
- Chauffage avec ventilateur à air forcé dans la salle de bain principale lorsque requis.
- Plinthes électriques au sous-sol (garage, salle familiale).

i) Ventilation :

- Hotte de ventilation dans la cuisine avec évacuation extérieure avec lumière.
- Ventilateur avec évacuation extérieure dans chaque salle de bain.
- Conduit de ventilation avec évacuation à l'extérieur pour la sécheuse.

j) Généralités :

- Main-courante en chêne sur muret de gypse à l'escalier vers l'étage.
- Rampes avec barottins au vestibule.
- Plinthes de bois peintes.
- Portes en masonite imprimé.
- Boiseries de type colonial.

2- AMENAGEMENT EXTERIEUR:

- Escalier de l'entrée et palier avant sont en béton préfabriqué.
- Trottoir avant en pavé-uni.
- Terrain gazonné au complet (avant, arrière et côtés).
- Plantation d'arbustes et vivaces à l'extérieur selon les plans de l'architecte paysagiste Vincent Asselin.
- Terrasse arrière en bois traité sur toute la largeur de la maison et sur 12' de profondeur (environ)
- Pavage d'asphalte à l'entrée du garage et dans l'aire commune.

3- ENTREE SOUTERRAINE:

- Murs de fondations d'épaisseur 8" avec acier d'armature aux endroits requis.
- Dalle structurale en béton préfabriqué.
- Pavage d'asphalte dans l'aire commune.
- Portes de sortie d'urgence aux deux extrémités de l'espace commun.
- Porte de garage en acier peint avec ouvre porte de garage électrique.
- L'entrée et le passage souterrains sont éclairés.
- Système de ventilation naturelle.

4- GENERAL:

- Certificat de localisation inclus.
- Garantie de L'APCHQ, 5 ans.
- Infrastructure de chaussée incluse.
- Chaque maison possède des entrées individuelles: eau, égoût sanitaire et électricité. Celles-ci sont incluses au prix de vente.
- Système de sécurité. Le filage a été installé dans les murs et plafonds non-accessibles pour permettre les branchements futurs d'un système d'alarme pouvant recevoir détecteur de mouvement au rez-de-chaussée et au sous-sol, relié à un panneau de contrôle à l'entrée.
- Aspirateur central. Les conduits pour l'aspirateur central de l'acheteur sont installés.

NOTES:

- Ce devis peut faire l'objet d'ajustements mineurs. Ceux-ci peuvent être dûs à des conditions de construction ou à l'impossibilité d'obtenir certains matériaux. Le promoteur ne sera pas tenu d'envoyer un avis à cet effet.
- Toutes les dimensions des pièces montrées au plan de présentation sont approximatives et les plans sont sujets à des modifications mineures.
- L'équipement et les meubles montrés aux plans ne servent que pour fin de démonstration.
- Toutes les options et ajouts futurs seront aux frais de l'acheteur et ne feront pas partie de ce devis descriptif.

Les Développements Groupe Montclair Bois-Franc
Le 19 septembre 1995

Montclair
Constructeur de l'année

SPECIFICATIONS

VILLAGE RENAISSANCE

VILLE SAINT-LAURENT, QUÉBEC

GROUPE MONTCLAIR

Builder of LA MAISON DE RÊVE 2000 for
LA FONDATION LES AILES DE LA MODE

DOMUS 1998 –Excellence of concept

DOMUS 1996 – Best housing unit

DOMUS 1994 – Excellence of concept
AND – BUILDER OF THE YEAR

DOMUS 1988 - Best multifamily housing unit

ANOTHER QUALITY PROJECT SIGNED MONTCLAIR

1.1 ARCHITECTURAL SPECIFICATIONS

1.1.1 EXTERIOR SPECIFICATIONS

A) FOUNDATIONS

- 8" to 10" thick concrete foundation walls with steel reinforcement as required.
- 4" concrete slab on grade, with 6" X 6" wire mesh reinforcement, poured on ONGC polyethylene vapor barrier over crushed stone base (type DB – ¾" net).
- R-12 fiberglass insulation on interior face of foundation walls.
- Bituminous membrane applied to below grade foundation walls and covered with "DELTA" type or equivalent depressurization membrane.

B) EXTERIOR FINISHES AND ROOF

- Exterior walls framed with 2" X 6" wood studs, covered with 7/16" aspenite sheathing. Once framed, building is wrapped with "TYPAR" or equivalent air barrier. 15lb construction paper installed on exterior surfaces prior to masonry installation.
- R-20 fiberglass insulation for exterior walls.
- Entire exterior of building faced with quality clay brick (see our sales representative).
- Windowsills of natural stone.
- Front door and windows vary from house to house and are framed with a decorative trim, giving each house its own style and character.
- Pre-painted aluminum soffit and fascia, color selected to complement brick.
- Asphalt roof shingles, 25 year guarantee.
- Blown cellulose roof insulation (R-35).
- "GARAGA" type or equivalent insulated (R-8) and pre-painted metal double garage door (for individual garages). Electrical wiring installed for future automatic door opener.
- White extruded PVC casement type windows with double "THERMOS" glass on main and upper floors. Location of fixed and opening window panels per architect's plans (see our sales representative). Screens supplied for all windows that can be opened. Sliding type windows with white frame in basement.
- White single PVC sliding patio door glazed with double glass thermal units.
- Pre-painted metal insulated (R-16) main entrance door.
- Architectural entrance with pre-painted metal roof.

1.1.2 INTERIOR SPECIFICATIONS

A) STRUCTURE

- Floor structure for main and upper floors made with webbed prefabricated joists and/or wood joists, covered with 5/8" tongue and groove plywood, **glued** and nailed into structural members for increased rigidity and quietness.

- For areas finished in ceramic tiles or vinyl covering, a second layer of 3/8" plywood is added.

- Roof constructed with prefabricated roof trusses.

B) FLOORING

- Ceramic tiles on following floors: vestibule, powder room and all washrooms. Choice of colors to be made by purchaser from constructor's samples.

- Padded vinyl flooring in kitchen/dinette. Choice of colors to be made by purchaser from constructor's samples.

- Carpet on all other floor surfaces, with 10mm urethane foam under padding. Choice of colors to be made by purchaser from constructor's samples.

- Stair risers and treads of all staircases covered with carpet. Basement floor in concrete.

C) WALLS & CEILINGS

- All interior partitions are made from 2" X 4" wood studs. Larger or smaller studs may be required in certain areas to accommodate plumbing, ventilation or pocket doors.

- Ceramic tiles on podium of bathtub and its surrounding walls up to a height of 16"(for showerless bathtubs). Choice of colors to be made by purchaser from constructor's samples.

- Interior walls of main and upper floors, as well as mezzanine (if applicable) covered with ½" gyproc, with 1 tape coat and 2 finish coats of joint compound. Water resistant gyproc around bathtubs with shower.

- Basement walls covered with gyproc, with 1 tape coat. Basement ceiling without gyproc.

- Garage ceiling insulated with R-20 fiberglass insulation. Walls and ceiling of garage covered with fire resistant ("FIRECODE") gyproc, with 1 tape coat.

- All walls and ceilings, except for basement and garage, painted white with two coats of latex paint (primer and finish).

D) COMMON ("MITOYEN") WALLS

- Common ("mitoyen") walls from basement to main floor are made of 8" poured in place concrete. From main floor to roof sheathing, an 8" masonry block wall ("Sparlock" type or equivalent) is constructed. Load bearing walls made from 2" X 4" lumber are built on each side of common walls to support floor joists of upper floor and roof trusses. For quality soundproofing, R-12 fiberglass insulation is inserted in between the 2" X 4"s and covered with ½" gyproc. Main floor joists are supported by steel beams anchored to the concrete common ("mitoyen") wall.

E) CABINETS AND VANITIES

E.1 KITCHEN

- Designer kitchen cabinets in melamine finish, ready to receive dishwasher and microwave oven. Choice of colors to be made by purchaser from constructor's samples. Decorative mouldings are standard : a touch of elegance from our designer.

- Counter tops in laminate finish, "QUARTZ" design. Choice of colors to be made by purchaser from constructor's samples.

- Rough-in to receive recessed fluorescent fixtures under kitchen cabinets where space permits – fixtures included.

E.2 BATHROOM AND POWDER ROOM

- Medicine cabinet and bathroom and powder room vanities (if applicable) in melamine finish, with counter tops in laminate finish, "QUARTZ" design. Choice of colors to be made by purchaser from constructor's samples.

- Elegant mirror supplied in bathroom and powder room (if applicable).

F) PLUMBING *(see our sales representative for more details)*

- Domestic water supply pipes in copper, drain pipes in ABS.

- All faucets are "DELTA" or equivalent, chrome finish. Single lever type faucets provided in kitchen sink and shower.

- All plumbing fixtures other than kitchen sink are white.

- Plumbing outlets ready to receive owner's washer and dishwasher (hook-up not included).

- Frost resistant exterior water outlets in front and rear of house and water outlet in garage.

- Interior of individual garage protected against fire by automatic sprinklers system.

F.1 POWDER ROOM

- Attractive pedestal sink or sink with vanity, depending on house model.

F.2 BATHROOM

- Luxurious acrylic bathtub, either corner or conventional model, depending on house model.

F.3 SHOWER

- Corner neo-angle 38" X 38" shower. Fiberglass shower base and walls, with designer type glass doors.

F.4 KITCHEN

- Double stainless steel kitchen sink with vegetable spray.

G) ELECTRICAL AND MECHANICAL EQUIPMENT

- 200 amps. 110v/220v entrance panel. Copper wiring throughout.
- Electrical hot water tank – 227 liters.
- Smoke detector on each floor.
- Exterior electrical fixtures provided (front and rear doors and in common garage).
- Security outlets in bathrooms.
- White "DECORA" series outlets and switches.
- Weatherproof exterior electric outlets provided in front and rear of house.
- Electrical wiring ready to receive owner's washer, dryer, fridge, stove, micro-wave and dishwasher (hook-up not included).
- Security system: wiring installed in walls and ceilings where future access may not be possible to allow owner to install alarm system able to receive motion detectors on ground floor and basement, linked to control panels at entrance and basement, as well as contacts for front door, patio door and garage door.
- PVC conduits provided for future installation of central vacuum system (one outlet on main and upper floor).

H) HEATING

- Electric heating system, with baseboards and temperature control in each room.
- Electric fan activated heater in main bathroom, if required.

I) VENTILATION

- Kitchen stainless steel exhaust fan ducted to exterior.
- Passive air exchanger and heat recovery.
- Exhaust fans ducted to exterior in all bathrooms and powder rooms.
- Dryer exhaust ducted to exterior.

J) INTERIOR – MISCELLANEOUS

- Handrail in natural oak or maple (no tint) on gyproc wall from main to upper floor.
- Bannister in natural oak or maple (no tint), with spindles painted white in vestibule, depending on house model (see our sales representative).
- Masonite embossed interior doors.
- "FONTAINE" style wood trim on main floor and "COLONIAL" style wood trim on upper floor, painted white (see our sales representative).
- Fire door "ULC 20 MINUTES" between individual garage and basement, with hinge door closure.
- High quality hardware.

1.2 LANDSCAPING / PLANTATION

- Pre-cast concrete front entrance stairs and landing.
- Paving stone front walk.
- Grass installed in front, rear and sides (if applicable).
- Oversized rear terrace with large storage compartment in pressure treated lumber.
- Asphalt paving in common driveway and common area of garage.
- Shrubs and perennials planted according to landscape architect's plans.

1.3 UNDERGROUND ENTRANCE

- 10" thick concrete foundation walls, with reinforcing steel where required.
- Poured in place concrete structural slab, with waterproofing membrane.
- Emergency exit doors at both ends of common area.
- 100 amps. entrance panel.

- Permanent fluorescent lighting in common entrance and underground area.
- Mechanical ventilation system, with carbon monoxide detector in common underground area.
- Common garage door insulated (R-16) in pre-painted metal, with a commercial door opener and control.
- The common underground area is not heated, an energy conservation measure.

1.4 GENERAL

- Supply of electricity, cable and telephone via underground conduits for added safety and superior environment, eliminating the visual pollution created by poles and aerial wires.
- Costs of infrastructures (roads, sidewalks, sewers, water main, underground electricity and street lighting) 100 % included in sale price.
- Individual water, sanitary sewer, cable, telephone and electricity entrances. All entrances are included in sale price.
- Certificate of location included.
- Five (5) year APCHQ warranty.

NOTES:

- Minor adjustments and changes to these specifications may occur without notice, due to construction conditions or unavailability of materials.
- All dimensions and areas shown on presentation plans are approximate and these plans may be subject to minor adjustments and changes.
- Equipment and furniture appearing on presentation plans and artist's renderings are strictly used for demonstration purposes.
- All options, modifications and additions are at owner's costs and do not form part of the present basic specifications.

This document is also available in French.

APPENDIX C:

NAMES AND ADDRESSES OF GOVERNMENTAL AGENCIES

ACGIH..........American Conference of Governmental Industrial Hygienists (1330 Kemper Meadow Drive, Cincinnati, Ohio 45240 U.S.A.)

ANSI............American National Standards Institute (11 West 42nd Street, 13th Floor, New York, New York 10036 U.S.A.)

ASCE............American Society of Civil Engineers (345 East 47th Street, New York, New York 10017 U.S.A.)

ASHRAE........American Society of Heating, Refrigerating and Air-Conditioning Engineers (1791 Tullie Circle N.E., Atlanta, Georgia 30329 U.S.A.)

ASME............American Society of Mechanical Engineers (22 Law Drive, Fairfield, New Jersey 07007 U.S.A.)

ASTM............American Society for Testing and Materials (100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959 U.S.A.)

AWPA............American Wood-Preservers' Association (P.O.Box 286, Woodstock, Maryland 21163-0286 U.S.A.)

BNQ..............Bureau de Normalisation du Quebec (70 Dalhousie, Bureau 220, Quebec, Quebec G1K 4B2)

CAN..............National Standard of Canada designation (The number or name following the CAN designation represents the agency under whose auspices the standard is issued. CAN1 designates CGA, CAN2 designates CGSB, CAN3 designates CSA, and CAN4 designates ULC.)

CCBFC..........Canadian Commission on Building and Fire Codes (National Research Council of Canada, Ottawa, Ontario K1A 0R6)

CGA..............Now part of CSA. See CSA.

CGSB............Canadian General Standards Board (Place du Portage, Phase III, 6B1, 11 Laurier Street, Hull, Quebec K1A 1G6)

CHS..............Canadian Hearing Society (271 Spadina Road, Toronto, Ontario M5R 2V3)

CLA..............Canadian Lumbermen's Association (27 Goulburn Avenue, Ottawa, Ontario K1N 8C7)

CMHC..........Canada Mortgage and Housing Corporation (700 Montreal Road, Ottawa, Ontario K1A 0P7)

CSA..............Canadian Standards Association (178 Rexdale Blvd., Etobicoke, Ontario M9W 1R3)

CWC............Canadian Wood Council (1730 St. Laurent Boulevard, Suite 350, Ottawa, Ontario K1G 5L1)

EPA..............Environmental Protection Agency (Office of Radiation and Air, 401 M Street, Washington M6101, DC20460 U.S.A.)

FCC..............Forintek Canada Coropration (319 rue Franquet, Ste-Foy, Quebec G1V 4C7) Turnpike, P.Q. Box 9102, Norwood, Massachusettes 02062 U.S.A.)

FPS..............Forest Products Society (2801 Marshall Court, Madison, Wisconsin 53705 U.S.A.)

HC................Health Canada (Communications Directorate, Ottawa, Ontario K1A 0K9)

HI.................Hydronics Institute (35 Russo Place, Berkeley Heights, New Jersey 07922 U.S.A.)

HRAI.............Heating, Refrigerating and Air-Conditioning Institute of Canada (5045 Orbitor Drive, Building 11, Suite 300, Mississauga, Ontario L4W 4Y4)

IRC...............Institute for Research in Construction (National Research Council of Canada, Ottawa, Ontario K1A 0R6)

ISO...............International Standards Organization (Standards Council of Canada, 1200-45 O'Connor Street, Ottawa, Ontario K1P 6N7)

NBC.............National Building Code of Canada 1995 (See CCBFC)

NFC..............National Fire Code of Canada 1995 (See CCBFC)

NFPA...........National Fire Protection Association (Batterymarch Park, Quincy, Massachusetts 02269 U.S.A.)

NLGA............National Lumber Grades Authority Suite 103-4400 Dominion Street, Burnaby, British Columbia V5G 4G3)

SFPE............Society of Fire Protection Engineers (One Liberty Square, Boston, Massachusetts 02109-4825 U.S.A.)

SMACNA.......Sheet Metal and Air Conditioning Contractor's National Association (4201 Lafayette Center Drive, Chantilly, Virginia 20151-1209 U.S.A.)

TC................Transport Canada (Public Affairs, Tower C, Place de Ville, 330 Sparks Street, 28th Floor, Ottawa, Ontario K1A 0N5)

TPIC.............Truss Plate Institute of Canada (21 Rodinea Road, Maple, Ontario L6A 1R3 Attn: Ken Coo)

UL.................Underwriters Laboratories Incorporated (333 Pfingsten Road, Northbrook, Illinois 60062 U.S.A.)

ULC..............Underwriters' Laboratories of Canada (7 Crouse Road, Scarborough, Ontario M1R 3A9)

WCLIB..........West Coast Lumber Inspection Bureau (6980 Southwest Varns Street, P.O.Box 23145, Portland, Oregon 97223 U.S.A.)

WWPA..........Western Wood Products Association (1500 Yeon Building, Portland, Oregon 97204 U.S.A.)

APPENDIX D:

MODULAR HOUSING ON-SITE INSTALLATION OBSERVATION NOTES

THE ON-SITE INSTALLATION OF A TWO-SECTION MODULAR DETACHED HOUSE: OBSERVATION NOTES

1. CONSTRUCTION SITE

3299 Chemin St-Paul, Le Gardeur, Québec

2. HOUSING MANUFACTURER PROFILE

Maison Usinées 2001

President : André Beauregard

Address : 480 rue Bourgeuois, Saint-Amable, Québec J0L 1N0

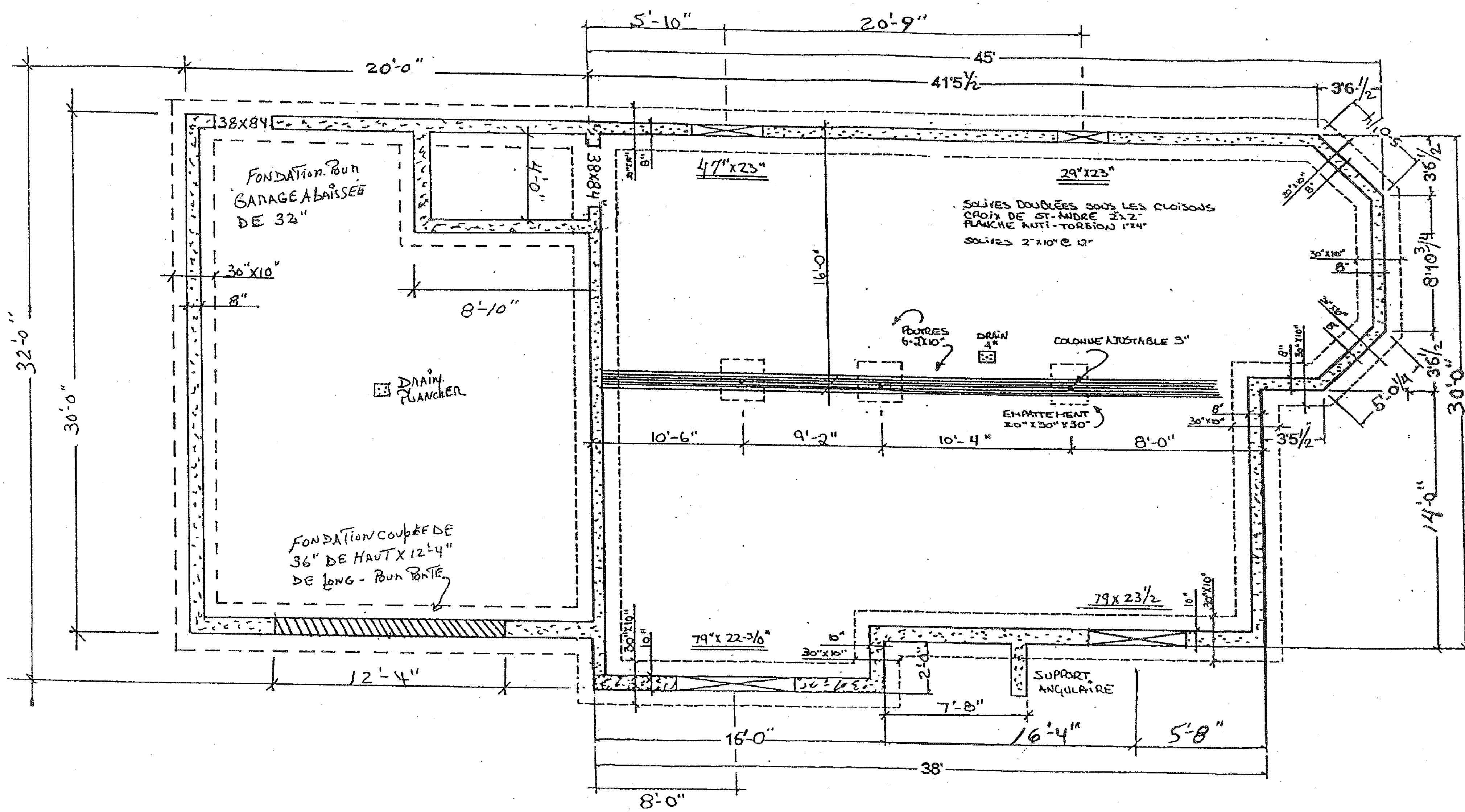
Tel: (450) 922-3428

3. ON-SITE INSTALLATION ACTIVITIES

June 14, 2002

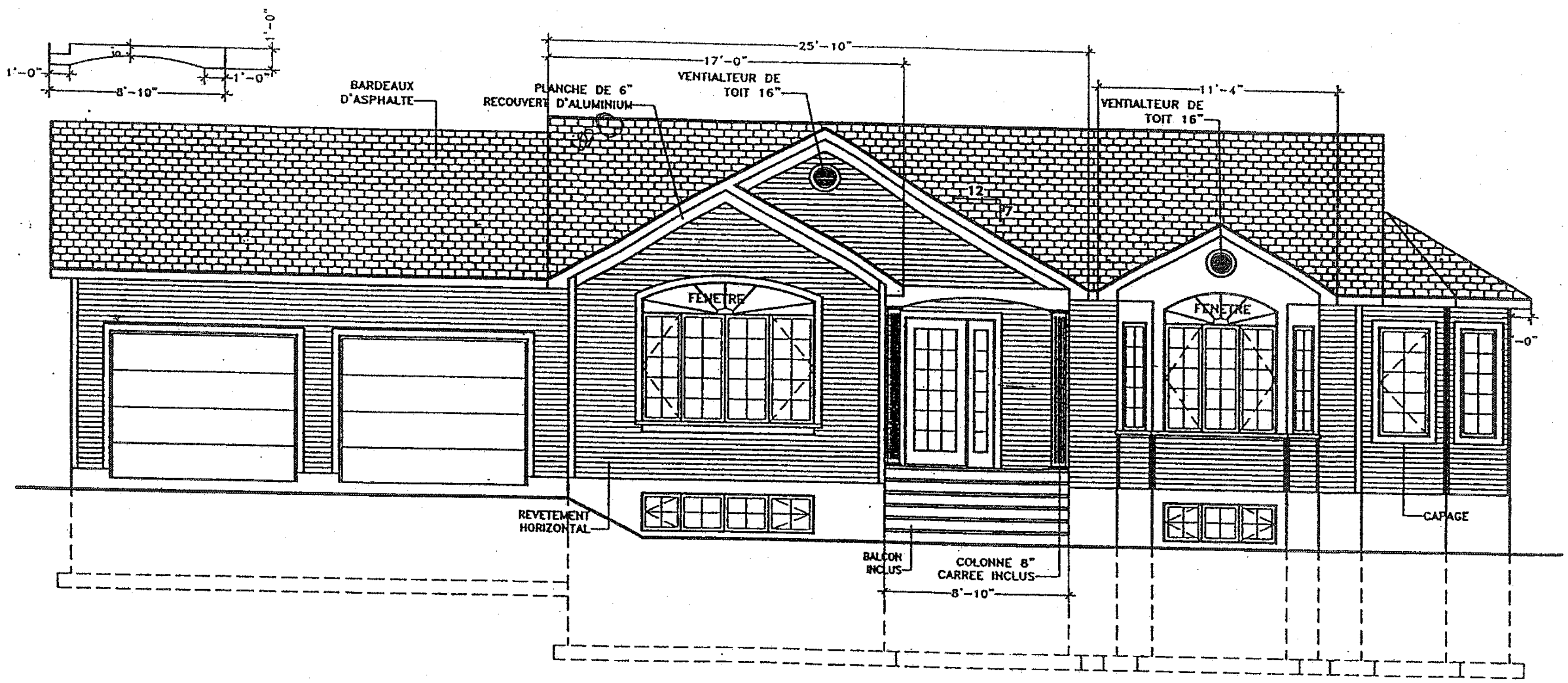
12:00 P.M.
- Two housing modules arrive - Pump out the rain water remaining in the foundation - Problem: One module on the truck hits electrical line during the transportation - Problem: A truck stuck in mud - Lunch break (10 min) - Lift up the first module - Install 4 steel poles under the first module - Install steel rails on the foundation wall
12:45 P.M.
- Lift up a second module - Problem: A worker accidentally dropped a steel bar in the basement - Take measurement between the steel bars placed in the foundation and the steel rails - Fix steel rails on the foundation wall completely - Install parts of a roller system on the steel bars on the foundation wall - Lift down a module at the height of a roller system
13:00 P.M.
- Move a module halfway (2 workers operate the roller levers)
13:35 P.M.
- Move a trailer with a heavy duty machine (1 worker) - Remove temporary coverings of the first module

13:45 P.M.
- Move the second module - Place sill foam gaskets directly under the first module
13:55 P.M.
- Temporarily place the second module onto the foundation
14:05 P.M.
- Roll the first module completely - Partly remove temporary coverings of the second module - Temporarily install sill foam gaskets
14:35 P.M.
- Install steel poles under the second module
14:45 P.M.
- Lift up the second module - Fix steel bars - Problem: Soil under the poles was not level; thus, wood pieces are placed under the pole - Move the trailer - Remove temporary coverings completely - Problem: Cracks occur at the upper part (lintel) of a foundation wall, where a window is placed
15:05 P.M.
- Install sill sheets
15:10 P.M.
- Move the second module almost completely (2 workers operate the roller system by hand. Next, the module is adjusted by a crane)
15:15 P.M.
- Remove extra steel bars and reinforcing materials - Remove remaining temporary coverings
15:25 P.M.
- Lift up the roof of the first module - Lift up the roof of the second module - Unfold the truss of the second module - Move the second module (again temporarily)
15:40 P.M.
- Add batt insulation between modules - Remove plastic sheets that protect modules from damage during transportation
15:45 P.M.
- Move the second module into place (final adjustment)
16:00 P.M.
- Remove steel bars from the basement - Unfold roof trusses
16:15 P.M.
- Remove roller systems - Return steel poles and other roller system equipment to the two trailers
16:30 P.M.
- Complete the on-site installation (including the roof connections)



MAISONS USINEES 2001

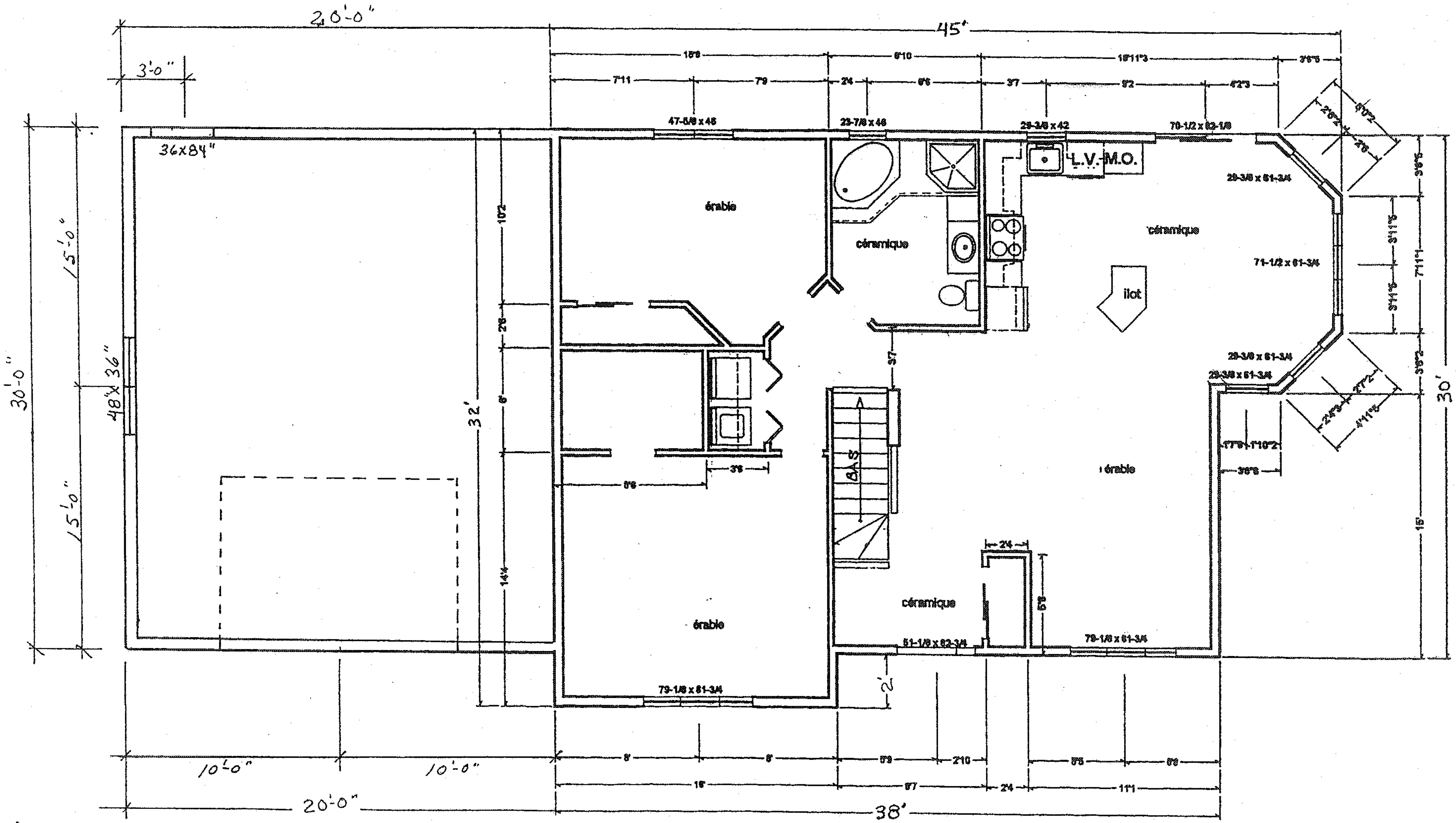
DATE: MARS 2002	DESSINÉ PAR: DB	MODÈLE: 2201	SUJET: FONDATION



MAISONS USINEES 2001

SUJET: ÉLÉVATIONS		NOM DU CLIENT: MOREL · SILVAGGIO	
DATE: MARS 2002	ECHELLE: 1/8"-1/4" = 1:0"	DESSINÉ PAR:	MODELE: 2201

MAISONS USINEES 2001 INC.
480 BOURGEOIS
ST-AMABLE, QC J0L 1N0
TEL: 922-3428

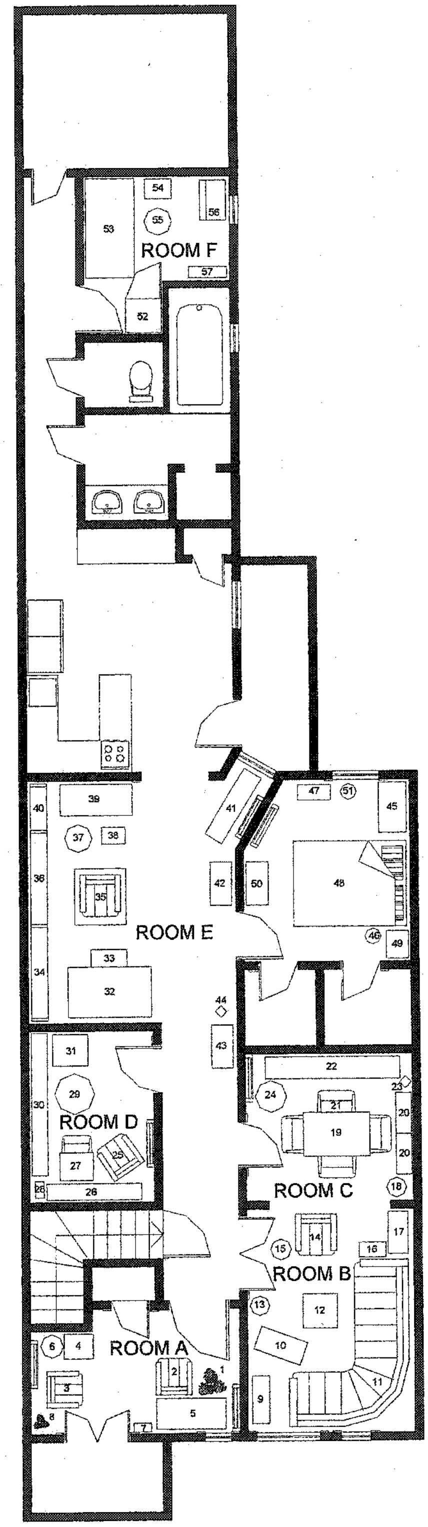


MAISONS USINEES 2001

DATE: MARS 2002	DESSINÉ PAR:	MODÈLE 2201	SUJET: REZ-CHAUSSÉ

APPENDIX E:

THE CHOICE MODEL FOR MASS CUSTOMISATION APPLIED TO AN INTERIOR DESIGN PROJECT IN MONTREAL



EXISTING FURNITURE AND ROOM LAYOUT

ITEM		ROOM A		
		Length	Width	Height
5	Glass table	49 7/8"	21 7/8"	16 1/2"
2&3	Chair 1 & 2	24"	26"	37"
4	Table	21"	17 1/2"	17 5/8"
1	Tree 1	13"	13"	12"
8	Tree 2	17"	17"	68"
6	Stand lamp	16 1/2"	16 1/2"	60"
7	Clock	12 3/4"	6 1/4"	31"

ITEM		ROOM B		
		Length	Width	Height
11	Sofa	113"	88 6/8"	25 1/4"
17	Shelf	30 1/4"	14 1/4"	77"
9	Box	34"	12 1/4"	28 6/8"
10	Decoration Chair	17"	35"	42"
12	Table	24 1/2"	24 1/2"	13 1/4"
14	Armchair	34 1/4"	26"	40"
13	Wood table	14"	14"	13 6/8"
15	Small Table	15"	15"	21 1/4"
16	News paper basket	19 1/2"	10 1/2"	16"

ITEM		ROOM B		
		Length	Width	Height
19	Table	47 1/4"	31 3/4"	28 5/8"
21	Chair 1, 2, 3 & 4	23 1/4"	20 1/2"	27 1/2"
22	Stereo	96 3/4"	15 5/8"	25"
20	Book shelf 1 & 2	29 1/4"	11 1/2"	71 5/8"
23	CD stand	6"	6"	40"
18	Candle stand	15"	15"	49"
24	Wood salad bowl	22 1/2"	22 1/2"	24"

DIMENSION OF EXISTING FURNITURE

ITEM		ROOM D		
		Length	Width	Height
26	Book shelf 1	68 5/8"	11 3/4"	70 1/4"
30	Book shelf 2	101 1/2"	11 3/4"	28 5/8"
28	Book shelf 3	12"	6 1/4"	70 1/4"
31	Video shelf	26"	22 3/8"	49"
27	Desk (and chair)	24"	20"	28 7/8"
25	Rocking chair	22"	30"	42 1/2"
29	Telescope	29"	28"	49"

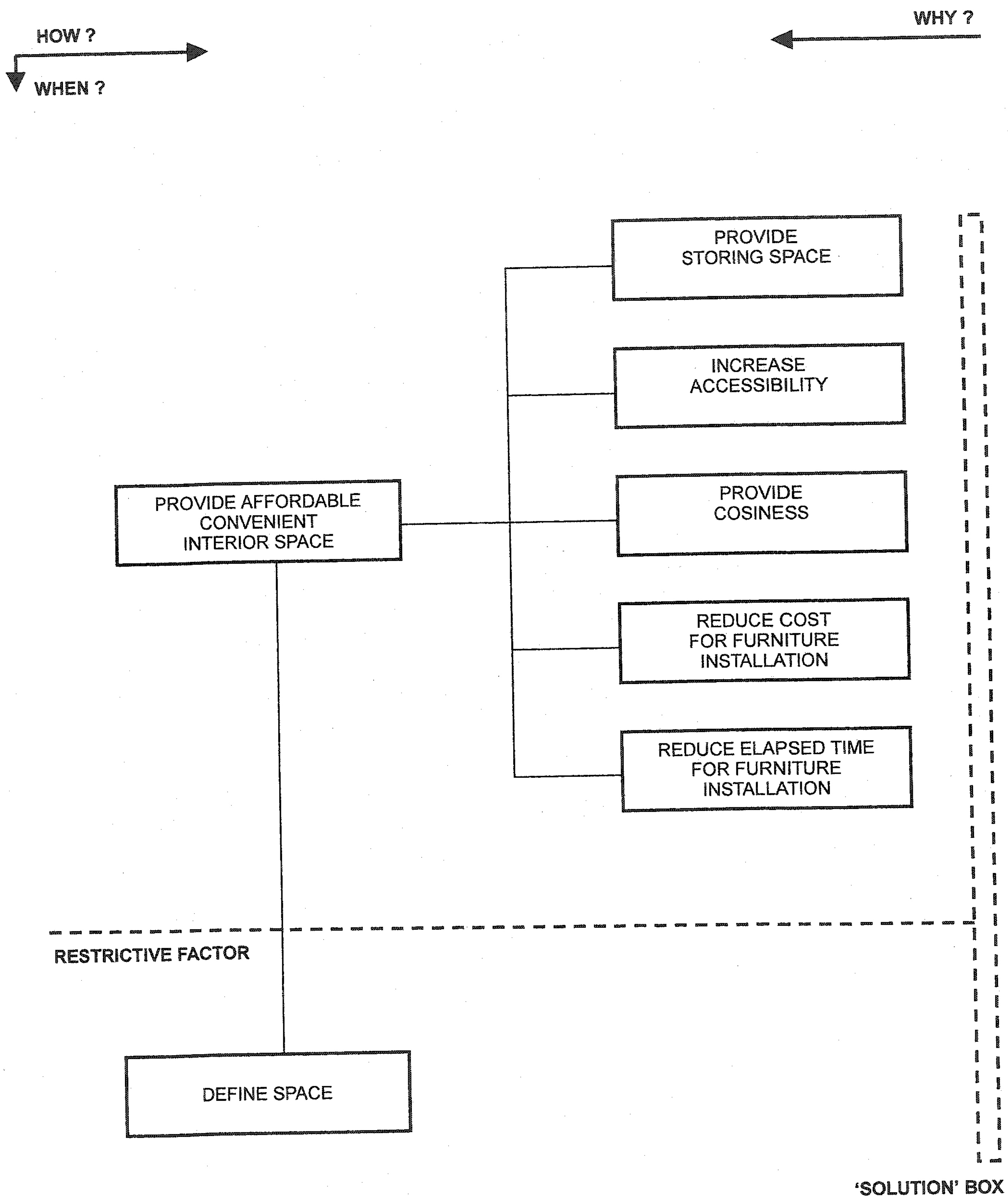
ITEM		ROOM E		
		Length	Width	Height
39	Dining table (future)	52"	22 1/2"	24 1/4"
37	Desk	20"	20"	27"
35	Leather chair (couch)	37"	40"	43"
38	Leo's toy	17"	12"	20"
33	Chair	26"	24"	37"
32	Desk	60"	36"	29"
34	Book shelf 1	67"	12"	28 1/2"
36	Book shelf 2	69 7/8"	12"	70"
40	Book shelf 3	33 1/4"	12"	28 1/2"
41	Exercise machine	43"	24"	42"
42	Glass door shelf	23 1/2"	12"	45"
43	Antique book case	22"	8"	46"
44	Sculpture	10"	9"	39"

DIMENSION OF EXISTING FURNITURE

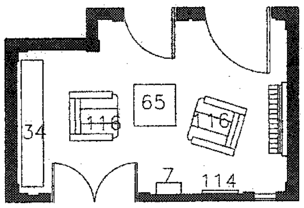
ITEM		ROOM F		
		Length	Width	Height
48	Bed	81"	59 5/8"	21" (under 9 ½")
49	Drawer 1	16"	19 3/4"	26 7/8"
50	Drawer 2	30 5/8"	15 7/8"	34 1/2"
47	Book shelf	23 5/8"	11"	42 3/8"
45	Box	36"	20"	14 1/4"
51	Stand lamp	10"	10"	51"
46	Basket	11 1/4"	11 1/4"	21 1/4"

ITEM		ROOM G		
		Length	Width	Height
53	Futon	71"	35"	34"
54	Table 1	19 1/4"	14 1/2"	25 3/4"
55	Table 2	19 3/4"	19 3/4"	18"
56	TV	28 1/2"	20"	35"
57	Book shelf	27 3/4"	8 1/4"	33"
52	Wood drawer	24"	24"	60"

DIMENSION OF EXISTING FURNITURE

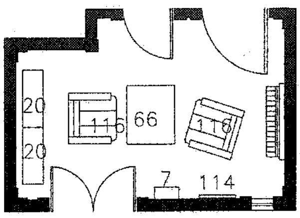


FAST DIAGRAM



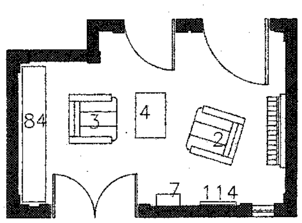
ALTERNATIVE 1

ITEM		ALTERNATIVE 1				
		Length	Width	Height	Store	Price
34	Book shelf 1	67"	12"	28 1/2"	---	---
116	Easy chair "OPPALA"	81 cm	60 cm	66 cm	IKEA	$29
65	Lack side table	55 cm	55 cm	45 cm	IKEA	$29
7	Clock	12 3/4"	6 1/4"	31"	---	---
114	Mirror "MANOR"	---	19 1/4"	23 1/4"	SEARS	$129



ALTERNATIVE 2

ITEM		ALTERNATIVE 2				
		Length	Width	Height	Store	Price
20	Book shelf 1 & 2	29 1/4"	11 1/2"	71 5/8"	---	---
116	Easy chair "OPPALA"	81 cm	60 cm	66 cm	IKEA	$29
66	Table "POANG"	75 cm 58 cm	64 cm 48 cm	46 cm 40 cm	IKEA	$92
7	Clock	12 3/4"	6 1/4"	31"	---	---
114	Mirror "MANOR"	---	19 1/4"	23 1/4"	SEARS	$129



ALTERNATIVE 3

ITEM		ALTERNATIVE 3				
		Length	Width	Height	Store	Price
84	Customized storage	---	---	32", 48", 60", 72"	SEARS	$29 $39 $49 $59
2&3	Chair 1 & 2	24"	26"	37"	---	---
4	Table	21"	17 1/2"	17 5/8"	---	---
7	Clock	12 3/4"	6 1/4"	31"	---	---
114	Mirror "MANOR"	---	19 1/4"	23 1/4"	SEARS	$129

ROOM A: GUEST ROOM & LIBRARY
ROOM LAYOUT OPTIONS

ROOM A: GUEST ROOM & LIBRARY

COST

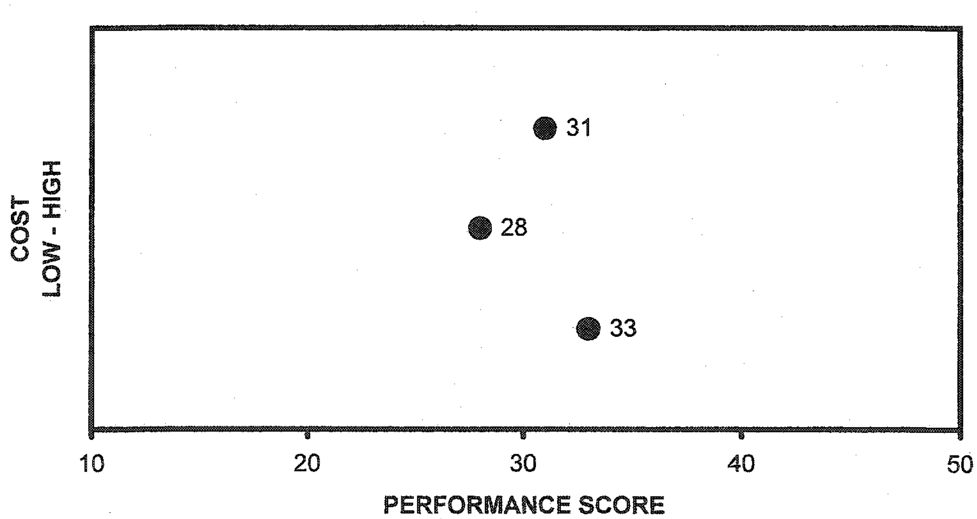
	ALTERNATIVE		
	1	2	3
Higher		X	
Middle	X		
Lower			X

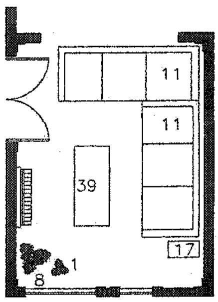
PERFORMANCE

EVALUATION CRITERIA	WEIGHT FACTOR*	ALTERNATIVE		
		1	2	3
Coziness	2	3 6	3 6	3 6
Storing Capacity	3	3 9	4 12	5 15
Accessibility	3	3 9	3 9	3 9
Ease of Installation	1	4 4	4 4	3 3
PERFORMANCE SCORE		28	31	33

* Level of Importance: 1 = Not important 2 = Neutral 3 = Important

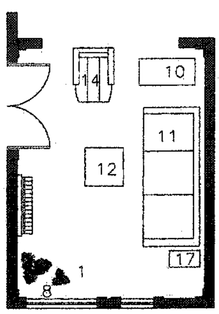
COST-PERFORMANCE GRAPH





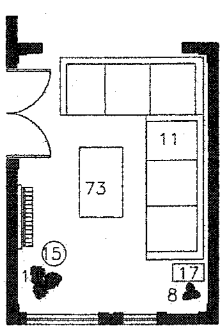
ALTERNATIVE 1

ITEM		ALTERNATIVE 1				
		Length	Width	Height	Store	Price
1	Plant 1	13"	13"	12"	---	---
8	Plant 2	17"	17"	68"	---	---
11	Sofa	113"	88 6/8"	25 1/4"	---	---
17	Shelf	30 1/4"	14 1/4"	77"	---	---
39	Table (Modified)	52"	22 1/2"	24 1/4"	---	---



ALTERNATIVE 2

ITEM		ALTERNATIVE 2				
		Length	Width	Height	Store	Price
1	Plant 1	13"	13"	12"	---	---
8	Plant 2	17"	17"	68"	---	---
11	Sofa	113"	88 6/8"	25 1/4"	---	---
17	Shelf	30 1/4"	14 1/4"	77"	---	---
10	Decoration chair	17"	35"	42"	---	---
12	Table	24 1/2"	24 1/2"	13 1/4"	---	---
14	Armchair	34 1/4"	26"	40"	---	---



ALTERNATIVE 3

ITEM		ALTERNATIVE 3				
		Length	Width	Height	Store	Price
1	Plant 1	13"	13"	12"	---	---
8	Plant 2	17"	17"	68"	---	---
11	Sofa	113"	88 6/8"	25 1/4"	---	---
17	Shelf	30 1/4"	14 1/4"	77"	---	---
15	Small Table	15"	15"	21 1/4"	---	---
73	Table "BASSE PLANO"	110 cm	70 cm	25 cm	Meubles & Decoration	$367

ROOM B: LIVING ROOM
ROOM LAYOUT OPTIONS

ROOM B: LIVING ROOM

COST

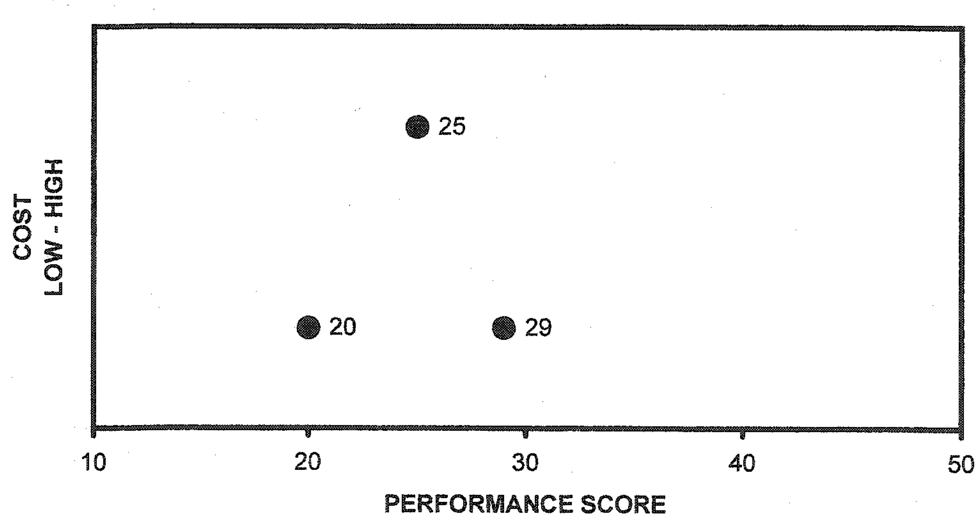
	ALTERNATIVE		
	1	2	3
Higher			X
Middle			
Lower	X	X	

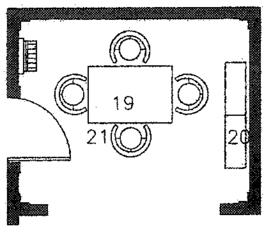
PERFORMANCE

EVALUATION CRITERIA	WEIGHT FACTOR*	ALTERNATIVE		
		1	2	3
Coziness	3	5 / 15	2 / 6	4 / 12
Storing Capacity	1	5 / 5	3 / 3	4 / 4
Accessibility	2	3 / 6	4 / 8	3 / 6
Ease of Installation	1	3 / 3	3 / 3	3 / 3
PERFORMANCE SCORE		29	20	25

* Level of Importance: 1 = Not important 2 = Neutral 3 = Important

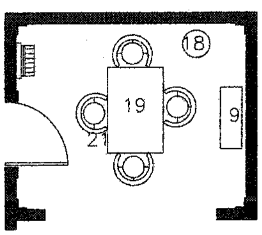
COST-PERFORMANCE GRAPH





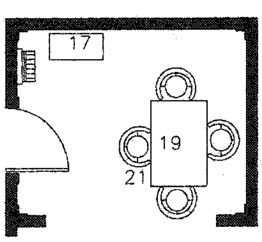
ALTERNATIVE 1

ITEM		ALTERNATIVE 1				
		Length	Width	Height	Store	Price
20	Shelf 1 & 2	29 1/4"	11 1/2"	71 5/8"	---	---
19	Table	47 1/4"	31 3/4"	28 5/8"	---	---
21	Chair 1, 2, 3 & 4	23 1/4"	20 1/2"	27 1/2"	---	---



ALTERNATIVE 2

ITEM		ALTERNATIVE 2				
		Length	Width	Height	Store	Price
9	Box	34"	12 1/4"	28 6/8"	---	---
19	Table	47 1/4"	31 3/4"	28 5/8"	---	---
21	Chair 1, 2, 3 & 4	23 1/4"	20 1/2"	27 1/2"	---	---
18	Candle stand	15"	15"	49"	---	---



ALTERNATIVE 3

ITEM		ALTERNATIVE 3				
		Length	Width	Height	Store	Price
17	Shelf	30 1/4"	14 1/4"	77"	---	---
19	Table	47 1/4"	31 3/4"	28 5/8"	---	---
21	Chair 1, 2, 3 & 4	23 1/4"	20 1/2"	27 1/2"	---	---

ROOM C: DINING ROOM
ROOM LAYOUT OPTIONS

ROOM C: DINING ROOM

COST

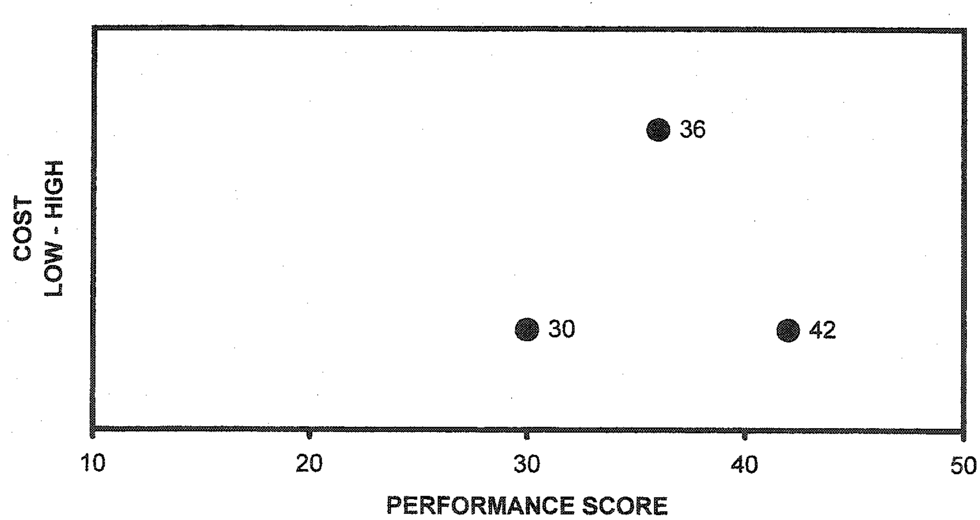
	ALTERNATIVE		
	1	2	3
Higher			
Middle			
Lower	X	X	X

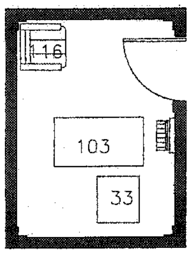
PERFORMANCE

EVALUATION CRITERIA	WEIGHT FACTOR*	ALTERNATIVE 1		ALTERNATIVE 2		ALTERNATIVE 3	
Coziness	3	5	15	2	6	4	12
Storing Capacity	3	5	15	3	9	4	12
Accessibility	3	3	9	4	12	3	9
Ease of Installation	1	3	3	3	3	3	3
PERFORMANCE SCORE			42		30		36

* Level of Importance: 1 = Not important 2 = Neutral 3 = Important

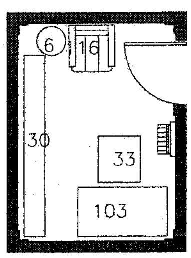
COST-PERFORMANCE GRAPH





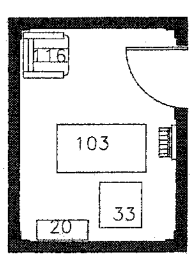
ALTERNATIVE 1

ITEM		ALTERNATIVE 1				
		Length	Width	Height	Store	Price
33	Chair	26"	24"	37"	---	---
103	Desk & shelving unit "MIKAEL"	140 cm	28 cm/ 75 cm	76 cm/ 90 cm	IKEA	$139
116	Easy chair "OPPALA"	81 cm	60 cm	66 cm	IKEA	$29



ALTERNATIVE 2

ITEM		ALTERNATIVE 2				
		Length	Width	Height	Store	Price
33	Chair	26"	24"	37"	---	---
103	Desk & shelving unit "MIKAEL"	140 cm	28 cm/ 75 cm	76 cm/ 90 cm	IKEA	$139
116	Easy chair "OPPALA"	81 cm	60 cm	66 cm	IKEA	$29
30	Book shelf 2	101 1/2"	11 3/4"	28 5/8"	---	---
6	Stand lamp	16 1/2"	16 1/2"	60"	---	---



ALTERNATIVE 3

ITEM		ALTERNATIVE 3				
		Length	Width	Height	Store	Price
33	Chair	26"	24"	37"	---	---
103	Desk & shelving unit "MIKAEL"	140 cm	28 cm/ 75 cm	76 cm/ 90 cm	IKEA	$139
116	Easy chair "OPPALA"	81 cm	60 cm	66 cm	IKEA	$29
20	Book shelf 1 & 2	29 1/4"	11 1/2"	71 5/8"	---	---

ROOM D: STUDY
ROOM LAYOUT OPTIONS

ROOM D: STUDY

COST

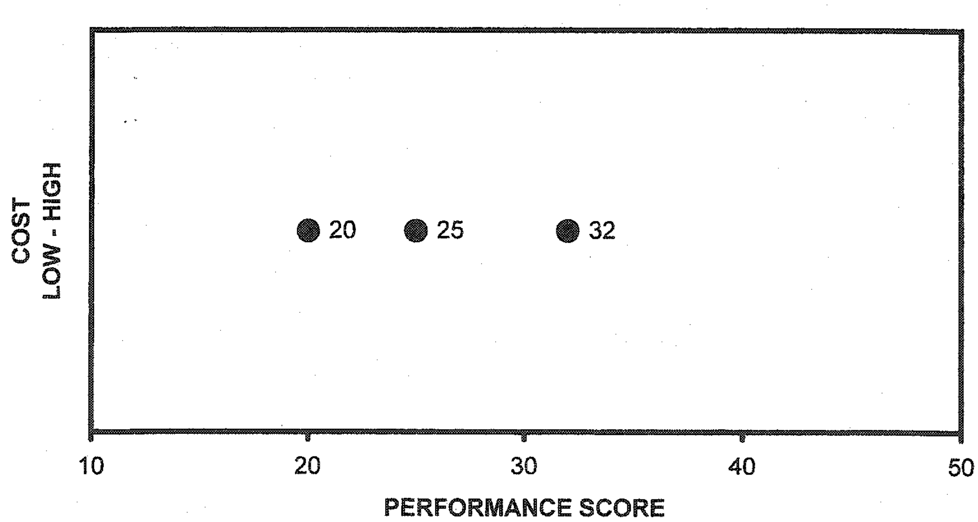
	ALTERNATIVE		
	1	2	3
Higher			
Middle	X	X	X
Lower			

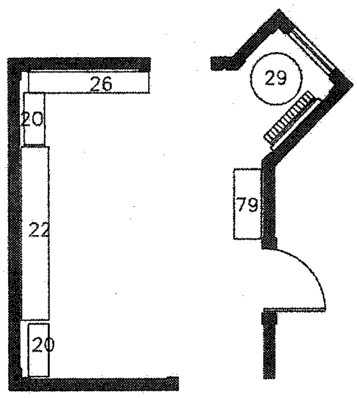
PERFORMANCE

EVALUATION CRITERIA	WEIGHT FACTOR*	ALTERNATIVE 1		ALTERNATIVE 2		ALTERNATIVE 3	
Coziness	2	2	4	3	6	2	4
Storing Capacity	3	2	6	4	12	3	9
Accessibility	3	2	6	4	12	3	9
Ease of Installation	1	4	4	2	2	3	3
PERFORMANCE SCORE			20		32		25

* Level of Importance: 1 = Not important 2 = Neutral 3 = Important

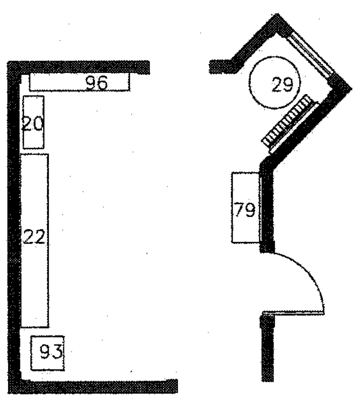
COST-PERFORMANCE GRAPH





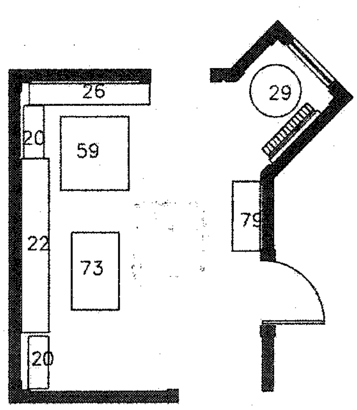
ALTERNATIVE 1

ITEM		ALTERNATIVE 1				
		Length	Width	Height	Store	Price
26	Book shelf 1	68 5/8"	11 3/4"	70 1/4"	---	---
20	Book shelf 1 & 2	29 1/4"	11 1/2"	71 5/8"	---	---
22	Stereo	96 3/4"	15 5/8"	25"	---	---
29	Telescope	29"	28"	49"	---	---
79	Shelf unit "DOCENT"	40 cm	98 cm	178 cm	IKEA	$140



ALTERNATIVE 2

ITEM		ALTERNATIVE 2				
		Length	Width	Height	Store	Price
116	Easy chair "OPPALA"	81 cm	60 cm	66 cm	IKEA	$29
22	Stereo	96 3/4"	15 5/8"	25"	---	---
33	Chair	26"	24"	37"	---	---
96	Bookcase & transparent red plastic "EXPEDIT"	37cm	149 cm/ 33 cm	149 cm/ 33 cm	IKEA	$199/ $20
32	Desk	60"	36"	29"	---	---



ALTERNATIVE 3

ITEM		ALTERNATIVE 3				
		Length	Width	Height	Store	Price
26	Book shelf 1	68 5/8"	11 3/4"	70 1/4"	---	---
20	Book shelf 1 & 2	29 1/4"	11 1/2"	71 5/8"	---	---
22	Stereo	96 3/4"	15 5/8"	25"	---	---
29	Telescope	29"	28"	49"	---	---
79	Shelf unit "DOCENT"	40 cm	98 cm	178 cm	IKEA	$140
59	Sofa bed "BEDDING"	104 cm/ 140 cm	200 cm	91 cm	IKEA	$399
73	Table "BASSE PLANO"	110 cm	70 cm	25 cm	Meuble & Decoration	$367

ROOM E: MUSIC ROOM & LIBRARY
ROOM LAYOUT OPTIONS

ROOM E: MUSIC ROOM & LIBRARY

COST

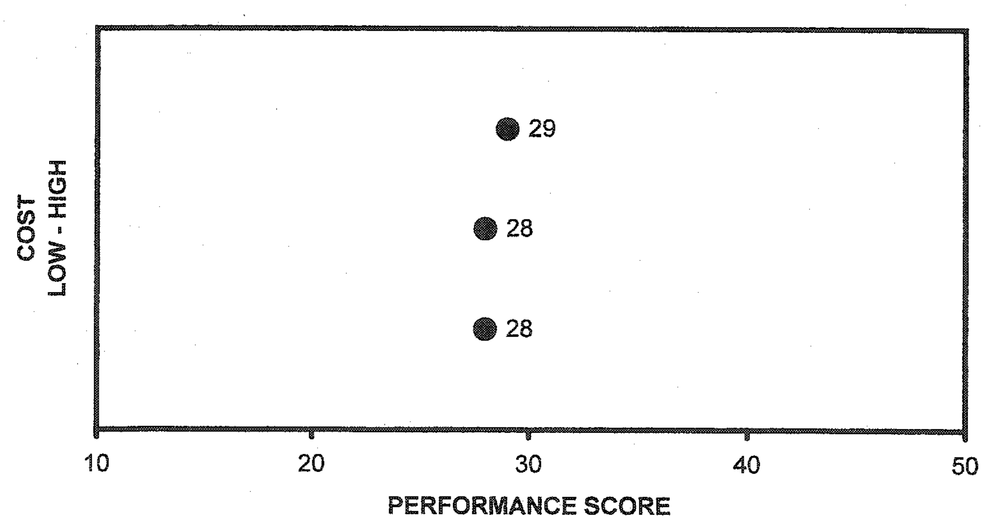
	ALTERNATIVE		
	1	2	3
Higher			X
Middle		X	
Lower	X		

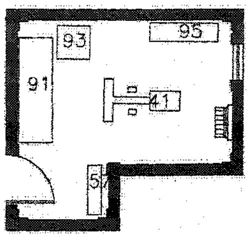
PERFORMANCE

EVALUATION CRITERIA	WEIGHT FACTOR*	ALTERNATIVE		
		1	2	3
Coziness	2	3 / 6	3 / 6	4 / 8
Storing Capacity	3	3 / 9	3 / 9	3 / 9
Accessibility	3	3 / 9	3 / 9	3 / 9
Ease of Installation	1	4 / 4	4 / 4	3 / 3
PERFORMANCE SCORE		28	28	29

* Level of Importance: 1 = Not important 2 = Neutral 3 = Important

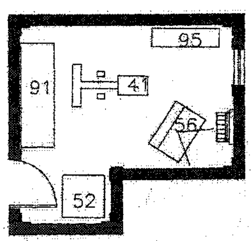
COST-PERFORMANCE GRAPH





ALTERNATIVE 1

ITEM		ALTERNATIVE 1				
		Length	Width	Height	Store	Price
57	Book shelf	27 3/4"	8 1/4"	33"	---	---
93	Four-sided swivel Audio/Video storage	18 3/4"	18 3/4"	52"	SEARS	$199
91	TV bench "OPPLI"	50 cm	150 cm	40 cm	IKEA	$129
95	Sliding door Audio/Video storage unit	10 1/2"	38"	51"	SEARS	$269
41	Exercise machine	43"	24"	42"	---	---



ALTERNATIVE 2

ITEM		ALTERNATIVE 2				
		Length	Width	Height	Store	Price
52	Wood drawer	24"	24"	60"	---	---
56	TV	28 1/2"	20"	35"	---	---
91	TV bench "OPPLI"	50 cm	150 cm	40 cm	IKEA	$129
95	Sliding door Audio/Video storage unit	10 1/2"	38"	51"	SEARS	$269
41	Exercise machine	43"	24"	42"	---	---

ROOM F: EXERCISE ROOM
ROOM LAYOUT OPTIONS

ROOM F: EXERCISE ROOM

COST

	ALTERNATIVE 1	ALTERNATIVE 2
Higher	X	
Middle		
Lower		X

PERFORMANCE

EVALUATION CRITERIA	WEIGHT FACTOR*	ALTERNATIVE 1		ALTERNATIVE 2	
Coziness	2	2	4	4	8
Storing Capacity	1	3	3	3	3
Accessibility	2	4	8	3	6
Ease of Installation	1	4	4	3	3
PERFORMANCE SCORE			19		20

* Level of Importance: 1 = Not important 2 = Neutral 3 = Important

COST-PERFORMANCE GRAPH