Université de Montréal

Designing Supplementary Space in Multi-Family Housing

by

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A thesis presented to the Université de Montréal

in fulfillment of the thesis requirement for the degree of

Doctor of Philosophy in Built Environment Planning

Montréal, Québec, Canada, 2020

Université de Montréal

Université de Montréal

Faculté des études supérieures

Cette thèse intitulée:

Designing Supplementary Space in Multi-Family Housing

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A été évaluée par un jury composé des personnes suivantes :

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- Professeur Virginie Lasalle (représentant du doyen de la FESP) -------

Dedicated to my wife Sahar

RÉSUMÉ

La démographie et les modes de vie ont considérablement évolué au cours des dernières décades. De tels changements sont destinés à influencer la conception de l'habitation et ils incluent notamment une série de besoins émergents: s'en suivent des besoins additionnels en espace pour répondre à l'arrivée de ces activités additionnelles au niveau du logement. La planification en vue de répondre à ces besoins émergeants constitue le principal thème de la présente thèse. Dans le cas de la maison unifamiliale détachée, le sous-sol est disponible pour offrir des espaces appropriés à ces besoins émergents. Par contre, une telle ressource n'est normalement pas présente dans le cas d'un édifice multifamilial.

La thèse propose un espace additionnel spécifique en vue de répondre à ces besoins émergents : l'espace supplétif. Même si un tel espace n'est pas envisagé dans les publications du domaine, des précédents existent quant à sa présence en planification multifamiliale. Le but de la présente étude est d'offrir des lignes directrices quant à la conception et l'intégration d'un tel espace supplétif. Elle va s'appuyer sur l'approche systémique en raison de la logique de déduire la solution à partir d'une analyse de l'objectif.

L'application de l'approche systémique implique donc que tous les critères correspondant à la nature spécifique de l'espace supplétif seront extrapolés à partir de l'objectif. Dans le cas la présente étude, ce sont les critères du bureau à domicile qui seront d'abord précisés car il s'agit de l'activité émergente la plus exigeante.

Les critères seront traités comme vecteurs d'un modèle générique indicatif de la manière d'organiser l'espace supplétif. Ce modèle visera le bureau à domicile en vue d'offrir les solutions pertinentes et il se concentrera principalement sur les critères d'intimité visuelle et spatiale. La contribution du modèle sera de suggérer des lignes directrices en vue d'incorporer l'espace supplétif à l'intérieur des édifices résidentiels de type multifamilial, ce que la planification conventionnelle n'offre pas.

C'est le concept d'adaptabilité qui est à la base de toute stratégie visant à permettre le changement en architecture et en habitation, d'autant plus lorsqu'il s'agit d'un espace supplétif. À cet effet, l'espace supplétif va recourir à l'approche *Open Building* afin d'appliquer le concept d'adaptabilité, en raison de ses avantages majeurs tant au niveau conceptuel que constructif. Différentes applications de l'approche *Open Building*, telles que le projet NEXT21 et le protocole KSI (*Kikou support and Infill*), offrent des exemples susceptibles de constituer d'efficaces lignes directrices pour la conception d'un espace supplétif.

La faisabilité du modèle d'espace supplétif proposé est vérifiable et démontrable dans le monde réel. Les systèmes constructifs industrialisés sont en mesure de permettre le changement sans démolition car leurs joints mécaniques « à sec » rencontrent généralement les normes DfD (*Design for Disassembly*), non seulement en ce qui concerne l'espace supplétif mais pour l'ensemble du logement.

Mots clef: Besoins émergents, espace supplétif, lignes directrices de conception, approche systémique, critères, adaptabilité, *Open Building*, changement sans démolition.

ABSTRACT

Demographics and lifestyles have changed considerably in the past few decades. These changes are bound to influence the design of housing and they notably include a series of emerging needs: additional spatial needs due to additional activities brought to the traditional housing premises. Planning for those emerging needs is the main theme of this thesis. In a typical single-family detached house, the basement is available to accommodate the spatial requirements for these emerging needs. However, such a provision does not typically exist in multi-family housing.

This thesis proposes a specific additional space to accommodate these emerging needs: the supplementary space. Although such a space has not been explored in the literature, there are precedents for its application in multi-family floor planning. The objective of this study is to provide guidelines for the design and the integration of this supplementary space. It relies on the systems approach as the design-decision methodology due to its logic of deducting the solution from the analysis of the objective.

Applying the systems approach means that all the criteria corresponding to the specific purpose of the supplementary space will be extrapolated from the objective. However, once the supplementary space is being used to deal with emerging needs, it will then introduce its own relevant criteria. This study will start with the criteria for designing a home office because this is the most demanding emerging needs activity. The criteria are organized as vectors of a generic model indicating how the supplementary space can be formulated. The model will target the workplace at home and subsequently offer solutions to them. This study focuses on the planning provisions dealing mainly with visual and spatial privacy. The overall outcome of the model is to suggest guidelines to incorporate the supplementary space within multi-family residential buildings, a feature not offered in traditional planning.

The concept of adaptability is the key design strategy to accommodate change in architecture and housing, even more in the case of a supplementary space. Therefore, the supplementary space model will apply the concept of adaptability through the Open Building (OB) approach; elaborating more on the practical design and construction features. Different OB applications, such as the NEXT21 project and the KSI (Kikou Support and Infill) protocol in Japan, are examples that can be used as efficient guidelines to design a supplementary space.

The feasibility of the supplementary space model can be validated and served in the real world. Industrialized building systems are capable of accommodating change without demolition as their dry mechanical joints are generally at meeting the DfD (design for disassembly) standards, not only for the supplementary space but also for the whole dwelling unit.

Keywords: Lifecycle, lifestyle, technology, emerging needs, supplementary space, systems approach, criteria, generic model, housing types, open building, DfD (design for disassembly)

ACKNOWLEDGEMENTS

Sincere thanks to my advisor, Professor Roger-Bruno Richard, for his endless support on all levels, from academic to moral to personal. His continued insight, guidance, and patience throughout this lengthy journey made the whole thing possible. His generosity, availability, and attention are things not all graduate students are lucky enough to have.

I would also like to thank my wife, Sahar, for always standing by me. Her enduring support, energy, and sacrifice motivated me to persist. Thank you for your patience, cooperation, and endless love during the past eight years of my life.

I would like to acknowledge the *Faculté de l'aménagement* at the *Université de Montréal* for the bursaries and funding provided to me during my Ph.D. studies. Special thanks to Professors Mithra Zahedi, Virginie Lasalle and Dean Raphaël Fischler , *Mesdames* Danielle Vinet, Mirlande Félix, and all other great people in the faculty for helping me.

Last but not least, thanks to my children, Davin and Arvin, for their presence. Their childish creativity has constantly inspired me, even though they are not aware of it.

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LIST OF ACRONYMS

ARC	Automotive Recyclers of Canada
C&D	Construction and Demolition
CMHC	Canada Mortgage and Housing Corporation
CNC	Computerized Numerically Controlled
DfD	Design for Disassembly
GDP	Gross Domestic Product
ICT	Information and Communication Technology
IFD	Industrialized Flexible and Demountable
KSI	Kikou Support and Infill
NEF	New Economic Foundation
OB	Open Building
OED	Oxford English Dictionary
SAR	Stichting Architecten Research

PREFACE

The research started by witnessing the new way of today's life, created by modernism and technology. Technology has changed many aspects of our lives, including how we interact, socialize, and work. Furthermore, society has undergone substantial demographic and lifestyle changes have become important phenomenon's impacting on our lives. Perhaps no part of architecture and built environment has been affected by these dramatic changes as much as housing has. We live constantly different from the past. Conventional housing delivery is incapable of accommodating these changes, and the question of how these changes should be implemented in housing design is the subject of this thesis.

My master's studies focused on an Open Building as the main design methodology to address changes in architecture and housing. My work collected principles, theories, and practical strategies related to this approach. Later, at the outset of my Ph.D., I examined Open Building as dealing only with traditional activities (such as eating, sleeping, bathing, etc.), but ignored non-standard ones such as working from home or co-residence. These new activities can be called "emerging needs." Provisions for emerging needs require a different design approach than do traditional activities. That was the main motivation of this PhD study: how to bring about new design guidelines that accommodate these new activities in the floor plan.

In the case of emerging needs, there is typically more than one stakeholder in the household, and sometimes these stakeholders have different interests. To accommodate the interest of each stakeholder's demands, this research uses a deductive methodology. Once the stakeholders are identified, the specific criteria for each are proposed to generate a synthesis. The result aims at a generic model (or a series of models) and guidelines to facilitate the introduction of a specific (supplementary) space to accommodate emerging needs in multi-family dwellings. The supplementary space is meaningful within a framework in which the principles of open building and DfD bring another level of adaptability. Not only the floor plan, but also the construction is open to respond to future needs.

1 Dwelling Unit Changes and Emerging Needs

Demographics and lifestyles have changed the postwar socio-economic situation in the Canadian housing market; up to a point where several residential buildings have become obsolete, outdated and old-fashioned. It is the reason many buildings are being knocked down. In the past, obsolescence was mostly associated with physical deterioration due to chronic use; nowadays there are many examples of functional obsolescence due to an incapacity to accommodate the emerging needs.

Emerging needs are additional activities brought to the traditional housing premises. The following schemes are the most common scenarios of emerging needs: workplace at home, elderly parents or teenage co-residence, nanny's suite, permanent caregiver, domestic helper, and visitor suite.

In a typical single-family detached (SFD) house, the basement is available to accommodate the spatial requirements for emerging needs. However, such a provision does not exist in multi-family housing (MFH). The conventional layout of a dwelling unit within a multi-family building is limited to the living room – kitchen – bathroom – bedrooms.

1.1 Housing and Household

The definition of housing depends on the discipline, with economists, sociologists, and anthropologists each having their own version of the term. In the realm of the built environment, housing "refers to construction and assigned usage of buildings collectively for the purpose of sheltering people" (Henilane, 2016). According to the Canada Census of Population (2011) and the Canada Mortgage and Housing Corporation (CMHC, 2013), a household consists of one person or a group of people who share accommodation as their only or main residence. A household may consist of a family—a couple or single parent with or without children—or of a person or group of people who live in the same space. It must also have a distinct entrance and legal entity (CMHC, 2013; Statistics Canada, 2016b).

1.2 The Evolution of Canadian Housing

Housing is an important part of urban policy since it's an essential good. Its visibility and durability shapes our current and future urban environments. Since unsatisfactory housing affects the well-being of families, access to housing is considered a basic human right and an integral contributor to the economy, society, and culture (Hossain & Latif, 2009). The United Nations (UN) considers satisfactory housing based on the economic, social, and cultural values in six parts: "legal security of tenure; availability of accessible services, facilities and infrastructure; habitability; accessibility (e.g. access to employment, health services, schools, etc.); cultural adequacy; and affordability" (Karamujic, 2011, p.2).

From a macroeconomic perspective, the housing is one of the most important sectors of industrialized countries such as Canada. This sector accounts for almost one-third of fixed capital stock and has accounted for 30% of household expenditures in Canada in 2017.

The total value of Canadian real estate in 2018 was over $8.7 trillion, more than five times the $1.4 trillion it was worth in 2005, which represented more than 75% of all Canadian wealth (Statistics Canadian, 2019).

1.2.1 Postwar Optimism, CMHC and NHA Creation

Canadians started the postwar period with a mixture of optimism and edginess about their future. On one hand, there was a sense of hope for better housing, and on the other hand, there was a recollection of the Great Depression in the 1930s, combined with the pressure of wartime exigencies production, which shrank their quality of life. The housing stock was not properly maintained, getting outdated and old. Some interpreted the downfall of the stock as the return of economic hardship of the 1930s (McInnis, 2002).

Those fears proved to be wrong by the 1950s, as the economy grew rapidly. By the 1960s, the fertility rate increased, and with the flow of immigrants, the economy and the production of housing boosted. In addition, the quality of existing housing stock substantially improved, an improvement that was described as housing progress (Miron & Clayton, 2013).

The *National Housing Act* (NHA) was passed by the federal parliament to promote the construction of new housing, modernizing and updating existing housing, and improving the living conditions in 1938. The Canadian Housing Mortgage Corporation (CMHC) was established in 1946, after World War II. One of the goals of the CMHC was to implement the NHA; this was the beginning of the involvement of federal and provincial governments in housing. The CMHC became an important entity to enforce Canadian housing policies. Even though the main agenda of the CMHC was to oversee mortgage insurance for private housing, it also played an important role in developing policies for subsidies and social programs (Miron & Clayton, 2013).

1.2.2 The Emergence of the American Dream Through Suburbia

The prewar urban form was mostly focused on intensification and density, was compact and self-sufficient, and had the capacity for rapid circulation—the "streetcar city" forms. In his book, *Landscape Architecture in Canada*, Ron Williams describes a streetcar city as: "composed of many small, semi-autonomous urban villages, each with its own local culture, its churches and schools, its commercial street, its movie theatre." (Williams, 2014, p.390).

The chain of events between the 1950s and 1970s, such as easier transportation, expansion of real estate development, industry, and the establishment of highway systems, led Canadians and Americans to move to the suburbs of the major cities. Another important contributor was the emergence of an "automobile culture" that changed the streetcar city to a new model of "suburbia"—a model that relied on faster, private transportation; highways; and the lower cost of construction and real-estate value (Figure 1.1). Governments and the mortgage system also helped in the creation of this new model (Foster, 2003). The government policies promoted and regulated through the CMHC made it easy for large-scale industry development to take place in the suburbs (Mason, 2002).

Figure 1.1. Parc Vauquelin Subdivision advertisement ,1962. Québec City (Landry & Angeles, 2011)

The result of such a large-scale, industrial mass-housing furthered the expansion of suburbia. In a few decades, the outskirts of major Canadian cities changed from potato fields to communities of thousands. It also resulted in the spread of low-density development and the infrastructure that would follow. Mississauga, Brampton, Surrey, Markham, and Vaughn are examples drawn from the three most populated cities in the early 20th century. Each of these examples did not have more than a few thousand people in the 1920s; however, by now, all have passed the half-million mark in population. According to Council of Canadian Urbanism, more than 67% of Canadians live in what is called "auto suburbs" where a car is essential to move around (Gordon, Hindrichs, & Willms, 2018). Figure 1.2 shows the population increase of Victoria Park Village in

Toronto within 20 years.

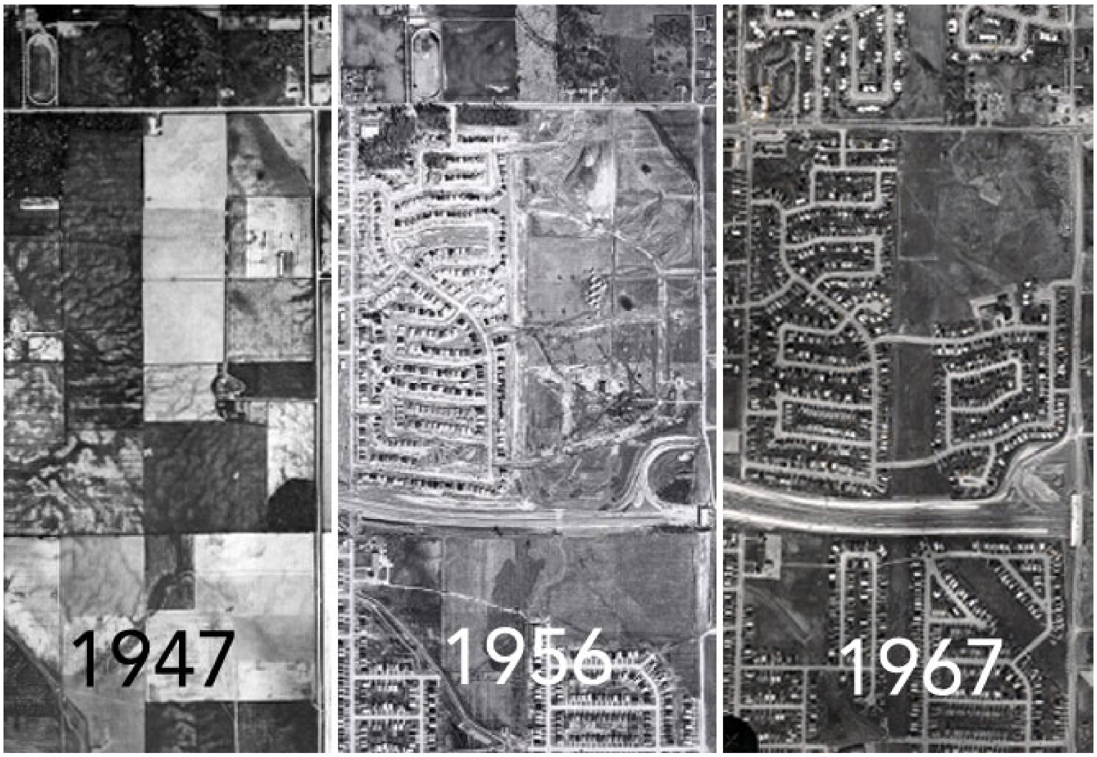

Figure 1.2. Twenty years development of Victoria Park Village. Toronto (Cruickshank, 2000)

1.2.3 Third Wave Urbanisation, Multi-Family Housing

Although the second half of the twentieth century is characterised by the development of suburbia and urban sprawl, other dramatic changes reshaped urban regions in terms of moving upwards rather than outwards. New demographic trends have emerged with regard to family size and structure, as well as immigrant settlement patterns. When combined with rising fuel costs, these factors have transformed Canadian cities toward multi-family dwellings, especially apartments and apartment condominiums. The return of multi-family housing in Canada's largest urban centres reflect not only lifestyle choices but also important demographic, economic and societal changes (Rosen & Walks, 2013).

According to Statistics Canada (2017), dwelling types have changed over time in the following ways:

- The suburban home of the 1950s: from 1957 to 1959 single-family homes accounted for more than 60% of the new housing stock. The introduction of CMHC mortgage loan insurance in 1954 made single-family homes more appealing (Figures 1.3 & 1.4).

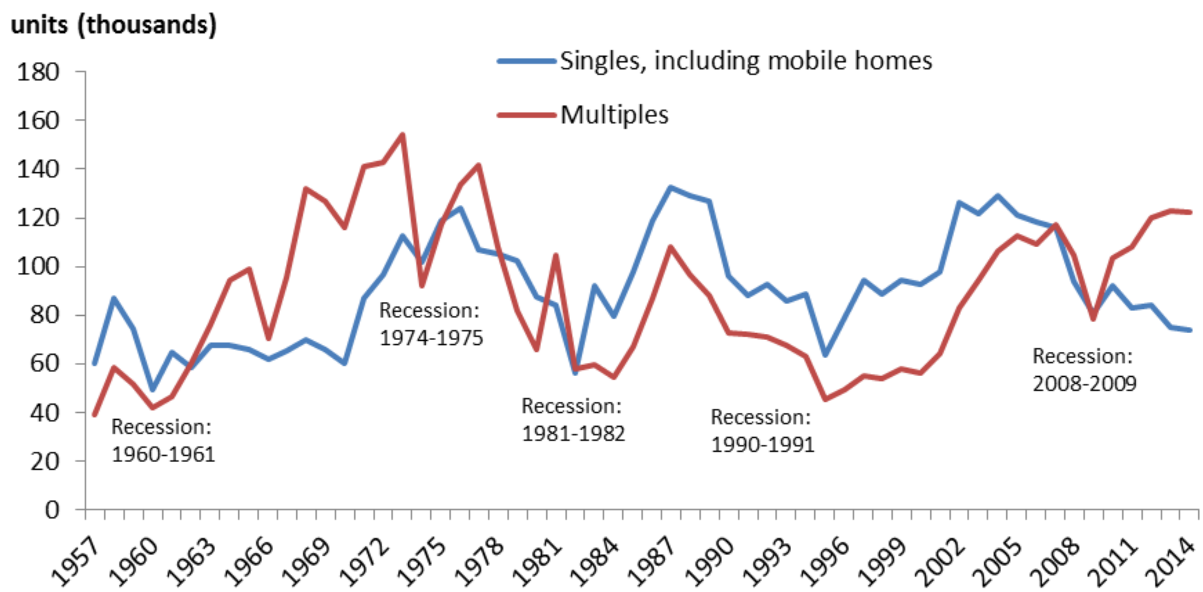

Figure 1.3. Building permits, single family vs multi-family housing, Canada, 1957-2014(Statistics Canada, 2017)

- The apartment boom of the 1960s: from 1962 to 1973, a major shift in building permits occurred where more than 60% of permits were issued for multi-family homes. This was determined by increased demand generated by the baby boom and the arrival of European immigrants.

- Residential construction in the 1970s: single-family home construction started to increase between 1974 and 1982, largely due to the recession of the mid-1970s. In

1974, the number of single-family homes and apartments accounted for equal proportions of the total housing.

- Return of single-family homes in the 1980s: in the period between 1983 and 2006, slower population growth combined with the recession and high mortgage interest rates resulted in the decline of residential construction in general. Single-family homes underwent a more rapid recovery and began to exceed the number of multi-family homes.
- Multi-family housing rise at the beginning of the new century: at the national level, apartment-condominiums became dominant from the early 2000s, especially in major cities (Statistics Canada, 2017).

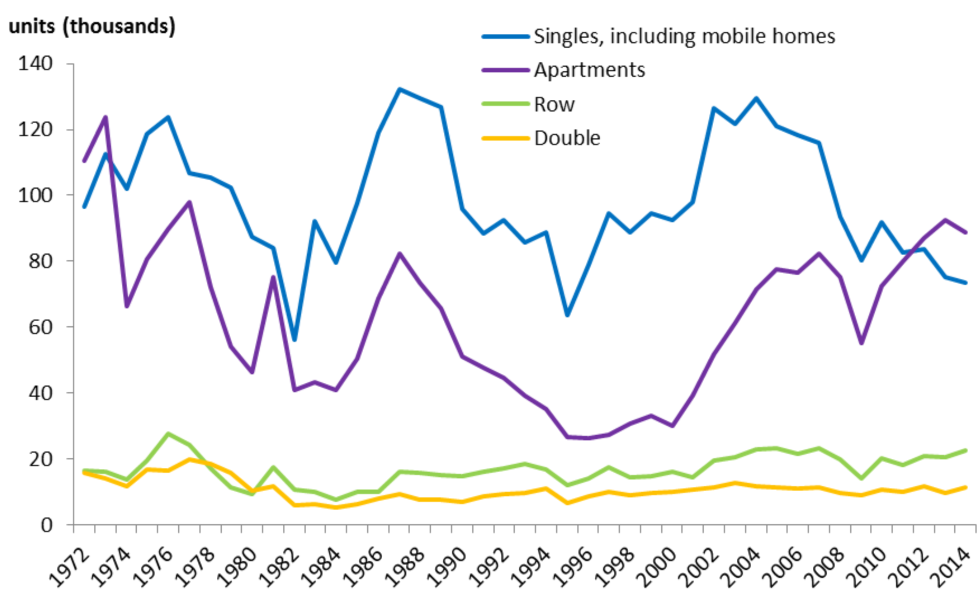

Figure 1.4. Building permits, type of dwelling, Canada, 1972 to 2014 (Statistics Canada, 2017)

In multi-family housing, multiple dwellings are located within one or several buildings in one complex. A multi-family dwelling can be a rental apartment building or a condominium. According to the CMHC, the number of apartment dwellings increased more than threefold between 1976 and 2006 (an average of 4% per year), making condominium ownership the fastest-growing dwelling type during this period (CMHC, 2013). As mentioned in the introduction, this study focuses on multi-family housing.

In 2014, there was more multi-family housing construction than any other housing type in Canada's three largest cities. In Toronto, multi-family homes accounted for 54% versus 27% of single-family homes; in Montréal, this was 75% versus 16%, while it was 67% versus 16% in Vancouver. In addition, this had a bearing on the social geography of the city, as local government policies promoted residential development in urban cores. Therefore, development in downtowns and inner cities (which had dramatically expanded from the previous century) was encouraged and resulted in what is known as 'third wave urbanisation' (Figure 1.5). This new development type relies on increased density and intensifications inside the city core (Scott, 2011).

Figure 1.5. "Third wave of urbanization", Vancouver city skyline, 2019

1.3 Construction and Demolition Waste, Typical End of Life of Building

Construction consumes 32% of the entire world's natural resources, including 12% of its water and 40% of the total energy used. Nearly 25% of all wood and 40% of all materials extracted from the earth are being used for construction. This industry also generates construction and demolition (C&D) waste, which, according to Statistics Canada, is cast-off material produced by construction, demolition, and renovation. C&D contains different components such as wood waste, concrete, drywall, asphalt, masonry, metal, shingles, insulation, etc. (Yeheyis, Hewage, Alam, Eskicioglu, & Sadiq, 2013), and it comprises 20-30% of municipal waste. C&D has a negative impact on all sectors, including the environment, the economy, public health, and social well-being (Yeheyis et al., 2013).

After World War II, new regulations were created regarding C&D management, most of which were designed to reduce the environmental impact of C&D. The main C&D management system was developed to minimize waste through recycling and reuse, with the safe discharge and disposal of materials as the last resort. According to Statistics Canada, C&D waste comes mainly from improper planning and design, residue of raw materials, and unexpected changes in building use. Improvements in planning and building design will contribute to waste reduction in all stages of a building's life cycle. The following table lists the various C&D materials and their capacity to be reused and/or recycled (Yeheyis et al., 2013).

Table 1.1. Waste type and its recycling/reusing potential (Huang, Lin, Chang, & Lin, 2002)

C&D waste	Recycle/reuse potential	Biodegradable potential	Potential for landfilling	Potential for incineration
Concrete	Recycled aggregate for road base, and for concrete	No	Yes	No
Steel	Recyclable to steel	No	No	No

C&D waste	Recycle/reuse potential	Biodegradable potential	Potential for landfilling	Potential for incineration
Brick and block	Backfill, recycled aggregate	No	Yes	No
Insulation	Insulate attic or as sound proofing on interior walls	No	No	Yes
Glass	Finer glass as pozzolans in cement	No	Yes	No
Ceramic	Possibly recyclable as filling material as a coarse aggregate for concrete	No	Yes	No
Aluminum	Recyclable to aluminium	No	No	No
Plastic	Recyclable to any form	Some can be biodegradable	No	Yes
Paint	Reusable as paint/concrete admixture	Some can be biodegradable	No	Yes
Wood	Recyclable to veneer board/paper pulp	Yes	Yes	Yes
Gypsum board	Recyclable to new board, crushed wall as clay and silt mixture and can be composed	Yes	No	No
Card board	Composting, fire kindling, paper production	Yes	Yes	Yes
Asbestos	No	No	If properly sealed	No

Involvement of different machinery, raw materials, and manpower consumes a great deal of energy and resources in the building industry (Crowther, 2000). Moreover, in many cases, if the need for change cannot be met within the building itself, there will be a need for using explosives and bulldozers (Figure 1.6). Once the life of a building comes to an end, all the energy and materials invested in construction, along with non-recyclable materials, go to incinerators or landfills. The failure of buildings adapting to the changes of their inhabitants results in the buildings' abandonment. Abandonment leads to demolition and disposal.

Figure 1.6. Sequence of demolition

1.3.1 Functional, Technical, Economic Life-Time of the Building

In most cases, the technical and functional service life of a building is roughly 50 years, but buildings which are only 15 years old are being demolished to make space for fresh construction. The average functional service life of a building is dropping, which necessitates faster return on investments. To prolong a building's life cycle, the building design should contemplate economic and sustainable solutions, where the design becomes the building's use over time, and not the building itself.

Functional life span is closely tied to how the building is used, and its technical life span is established by its physical state. The relationship between supply (technical life span) and demand (functional life span) is what will determine the service life of the building. Under specific conditions, economic life span is considered to be as a result of this balance (Ang, Wyatt, & Hermans, 2001). The economic life span comes to an end once the functional requirements do not match up with the technical specifications. The consequences of this can be the replacement of components or demolition of the structure.

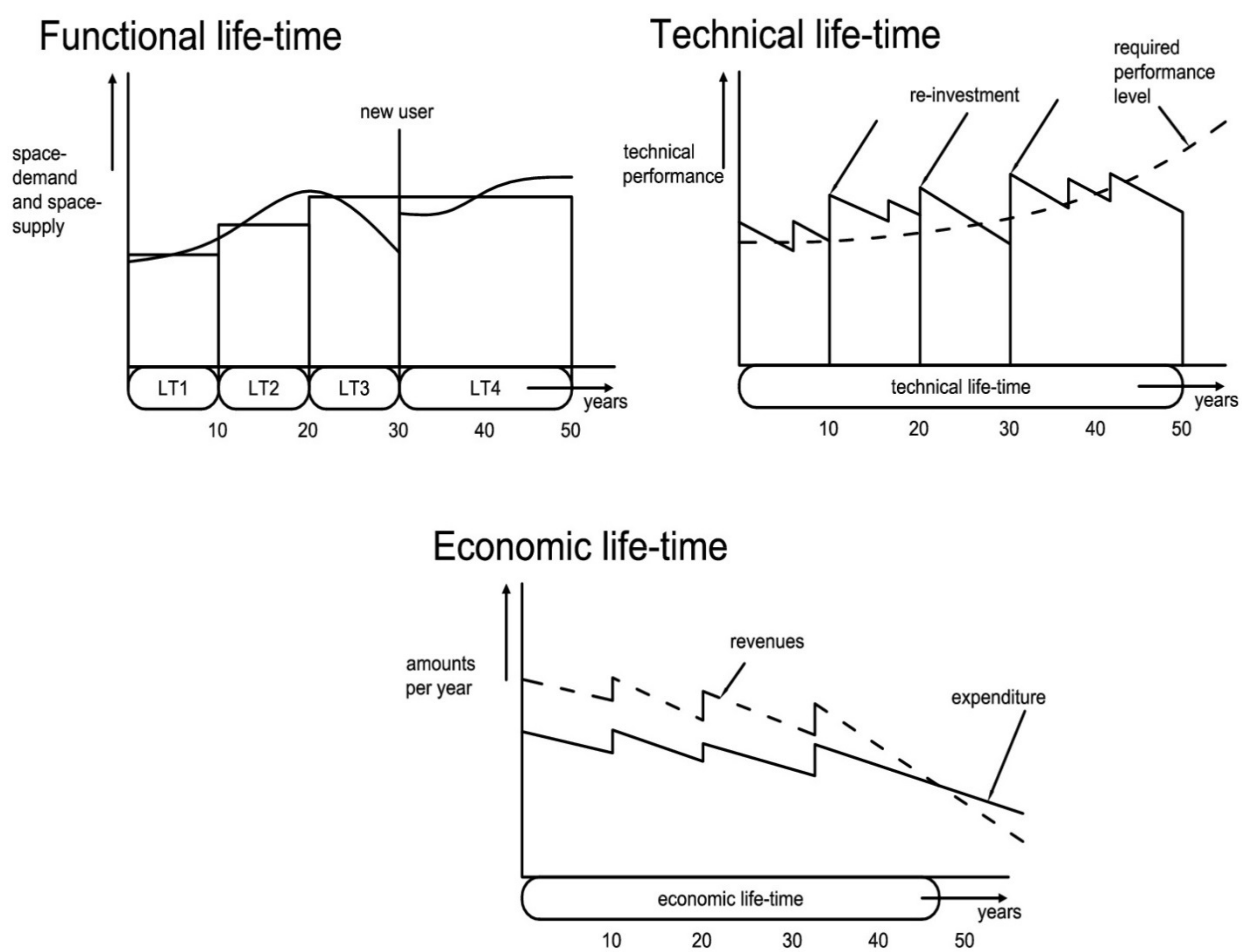

Figure 1.7. Functional, technical, and economic life-time of building (Altas & Bilec, 2012)

In Figure 1.7, the top graph depicts the rise and fall of a user's organisation. There were two distinct periods of change across 30 years, and the second graph denotes the technical performance these changes needed.

A building's technical life is the period of time that the building meets its technical performance requirements for a specific maintenance strategy. A building's economic life is depicted in the third graph, which can be defined as the length of time that a building meets the return on investment criteria of the owner (Ang et al., 2001). In every instance of functional or technical change, the revenue and expenditure graph also changes.

1.3.2 Obsolescence in Multi-Family Housing

Obsolescence is the process of becoming outdated and old-fashioned. It is the reason many buildings are being knocked down. In the past, obsolescence was mostly associated with physical deterioration due to chronic use. However, nowadays, it is also caused by **changes in people's needs** and expectations, such as **socio-economic and lifestyle shifts (social obsolescence)** (Pinder & Wilkinson, 2000). Obsolescence is considered the point at which the life cycle of a building ends and it can no longer continue performing its function or change to a new one. The awareness of the huge ecological burden of construction and the consequent need for the sustainable improvement of the built environment underpins the significance of extending the life cycle of buildings (Thomsen & van der Flier, 2011).

Thomson and van der Flyer (2011), in their article "Obsolescence at the End of the Life Phase of Buildings", emphasize the importance of delaying obsolescence and facilitating sustainable improvement:

> "Given its immobile, long lasting character on the one hand and the high uncertainty about their future lives on the other hand, minimizing obsolescence helps with physical, economical and environmental

investments.” (p. 83).

Figure 1.8. Obsolete apartments (Laughlin & Johnson, 2011)

Another explanation for obsolescence in housing is the consideration of housing as an object of consumption in recent times. In the past, the focus of this paradigm was on housing production led by needs. From the 1960s onward, the goal of that paradigm became accommodating the taste of its users, with the capacity to change, so the housing was viewed as an object which needs to be customized to delay the obsolescence (Kintrea, 2007). In most cases, conventional design has no provision to reconfigure or reuse buildings for further use to delay the obsolescence, so if a building cannot be repurposed, it will be demolished (Figure 1.8).

1.3.3 A Conceptual Model of Obsolescence

Obsolescence’s various categorisations can be divided into external and internal factors on one hand, as well as behavioural and physical factors on the other hand (Iselin & Lemer, 1993). According to Thomsen and Flier (2011), when utilised into a quadrant matrix, the results can be conceptualized similar to the methods used for building evaluations (Thomsen & van der Flier, 2011).

Internal factors are associated with the typical transformations within the building itself. Such transformations may be physical, such as deterioration of materials through weather and time or else as a result of poor design, absence of or poor maintenance, adaptation and bad initial construction (quadrant A Figure 1.9). They also can be behavioural, such misuse, change in function, use, and occupants' behaviour. (quadrant C Figure 1.9).

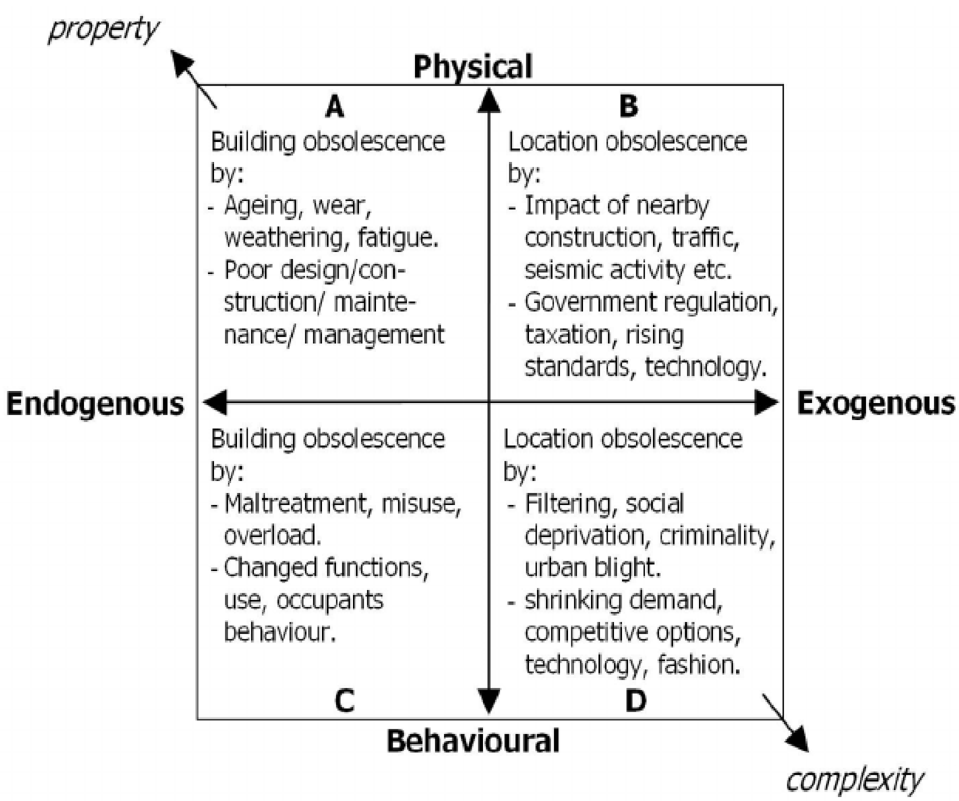

Figure 1.9. Conceptual model for obsolescence (Thomsen & van der Flier, 2011)

Exogenous elements and external factors are connected to influences from the outside world. They may have physical repercussions such as new construction, or air pollutions, as well as alterations in governmental regulations such as new construction codes and standards (quadrant B Figure 1.9). They may also result in behaviour-related repercussions such as the social deprivation process in the neighbourhood, or fall in market value due to emerging technologies, a drop in demand or the options of better alternatives (Thomsen & van der Flier, 2011) (quadrant D Figure 1.9).

The diagonal line going from quadrant A to D boosts the complexity concerning the scale and participants and the related fall in control. Within quadrant A, the physical factors may be easily controlled and managed by the owners. Those main uses within quadrant C are less elementary and are not as easily controllable, though several environmental elements seen within quadrant B usually lie outside of the control of the owner, as do those extremely multifaceted factors seen in quadrant D. If one looks to the opposite quadrant, dangers that are posed by the exogenous behavioural corner may experience several important side effects. Owners' responses must be obtained with well-timed anticipation and intervention in instances when direct control fails. Several of those elements seen in Figure 1.9 are interrelated. This interrelation may be seen by looking at the environmental challenges and energy efficiency of the building (Thomsen & van der Flier, 2011).

A building's energy efficiency performance is established through the energetic quality of the construction and its spatial design (quadrant A). This efficiency is measured using the Energy Performance of Building Directive (EPBD) (quadrant B), though this is dependent on the actions of the users (quadrant C). High energy fees and low EPBD ratings may lower the market status of the structure (quadrant D), and thus have either negative effects on the opportunity for improvement in either A, C or B directions, therefore increasing obsolescence. Similar thinking can be utilised with regard to social deprivation, which poses an additional threat (Thomsen &

van der Flier, 2011).

1.3.4 An Example of Obsolescence: Toronto Regent Park

An example of obsolescence is the Regent Park social housing project in Toronto, where short-sighted planning and construction produced dwellings that became unsuitable within 30 years of their construction, which is a relatively short timeframe (Figure 1.10).

Figure 1.10. Regent Park demolition, 2004 (Laughlin & Johnson, 2011)

Regent Park initiated with great hope as the largest social-housing project in Canada after World War II, located close to some of Toronto's historic slum districts on the eastern end of city. Most of the residents of this neighbourhood were poor and working-class, while concerns about crime, social problems and sub-standard housing led the authorities to plan for affordable public housing after the war. Families started to move there in the 1950s and the project reached a population of 7,500 by the 1960s (Figure 1.11). The development was originally designed to be a ‘garden city’, the buildings were placed in ‘pastoral’ settings that faced each other and backed onto the street for noise prevention.

Throughout the 1970s, a large number of immigrants arrived from all over the world and as a consequence, the intimacy of Regent Park deteriorated. A city of Toronto report advised that 60% of Regent Park development’s population were immigrants, with more than 70 different languages spoken there. Cultural conflicts led to rising demographic and socio-economic changes in Regent Park. By the 1980s, the problem of drugs was added to the mix as drug crime and violence increased, and tension between residents and the police rose in the 1970s and 1980s.

City of Toronto Archives,

Figure 1.11. Left: Regent Park housing project in 1951s. Right: completion of project in 1958 (August, 2014)

Residents faced continual economic hardships, racism and negative stereotyping, with more than 70% of residents living below Statistics Canada's low income cut-off rate. As a result, Regent Park became one of the poorest neighbourhoods in Canada; by 1990, it had become clear that Regent Park had failed. A number of different redevelopment plans were proposed until 2003, when the council officially endorsed a new master plan called "Regent Park Revitalisation". The proposed master plan comprised a mix of townhouses, mid to high-rise apartment buildings and various amenities. The plan will include 2000 rent-geared-to-income (RGI) units, 700 affordable housing and 3000 market condominium units. The development is set to take place in five phases, with construction starting in 2006. Phase one and two were completed in 2012 and 2018, while phase three, four and five are estimated to be completed by 2021, 2026, and 2030 (Figure 1.16).

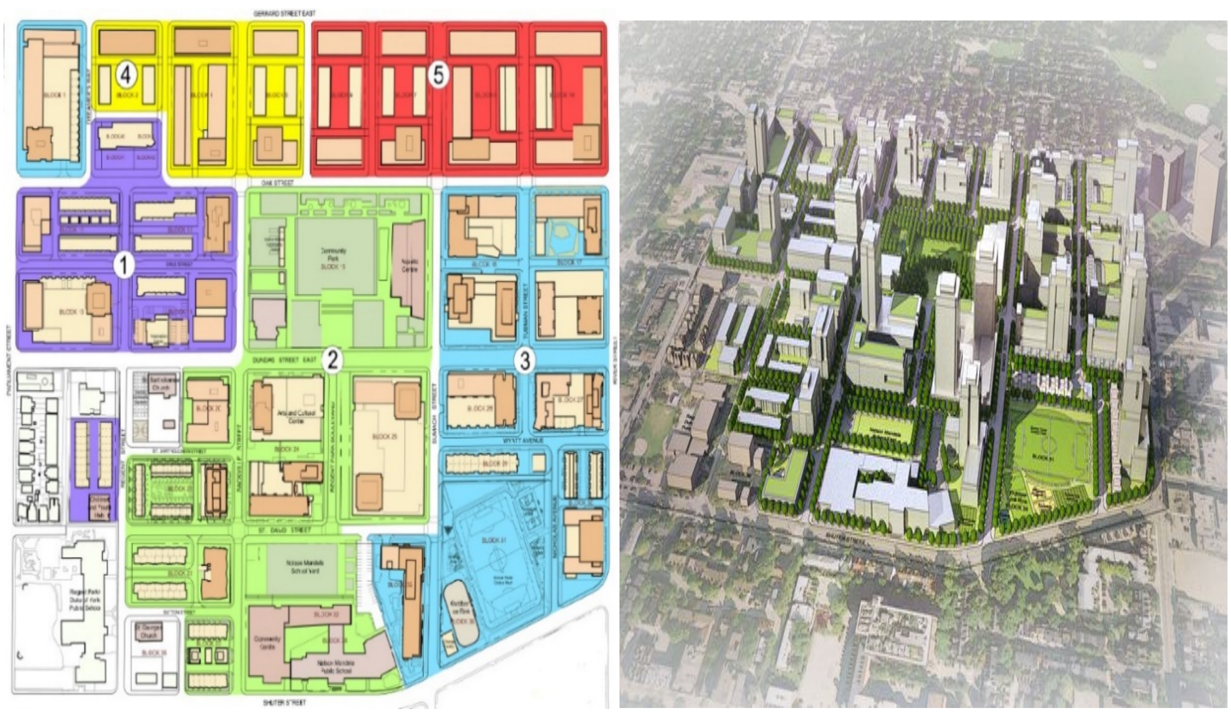

Figure 1.12. Five phases of Regent Park revitalization (August, 2014)

1.4 Demographic, Lifestyle, and Life Cycle Changes

In what is an unprecedented boom, the world's population rose from 2.5 billion in 1950 to 7.6 billion in 2018 (United Nations, 2017). Canada's population increased from 14 million in 1950 to 37.06 million in 2018. By contrast, the number of Canadians per household dropped from 3.4 in 1981 to 2.4 in 2016, and will fall to 1.8 by 2030 (Statistics Canada, 2016a). The main reasons for this dwindling household size are the growing instability of conjugal unions, the birth of fewer children, and the prevalence of living alone (Statistics Canada, 2004). As a result family structures changed dramatically: the number of single-parent families rose from 11% in 1981 to 19.2% in 2016, and from 2001 to 2016, the number of common-law couples increased by 10% to reach 1.6 million (Statistics Canada, 2016a). Moreover, according to Census records, the proportion of one-person households increased from 9% in 1981 to 16% in 2016 (Statistics Canada, 2016a). Figure 1.13 shows historical and projection of Canada population.

While these statistics show that Canadian society is changing, housing design has remained relatively static (Statistics Canada, 2004). As a result, rather than housing accommodating itself to the needs of its users, occupants must adapt to their housing (Altaş & Özsoy, 1998).

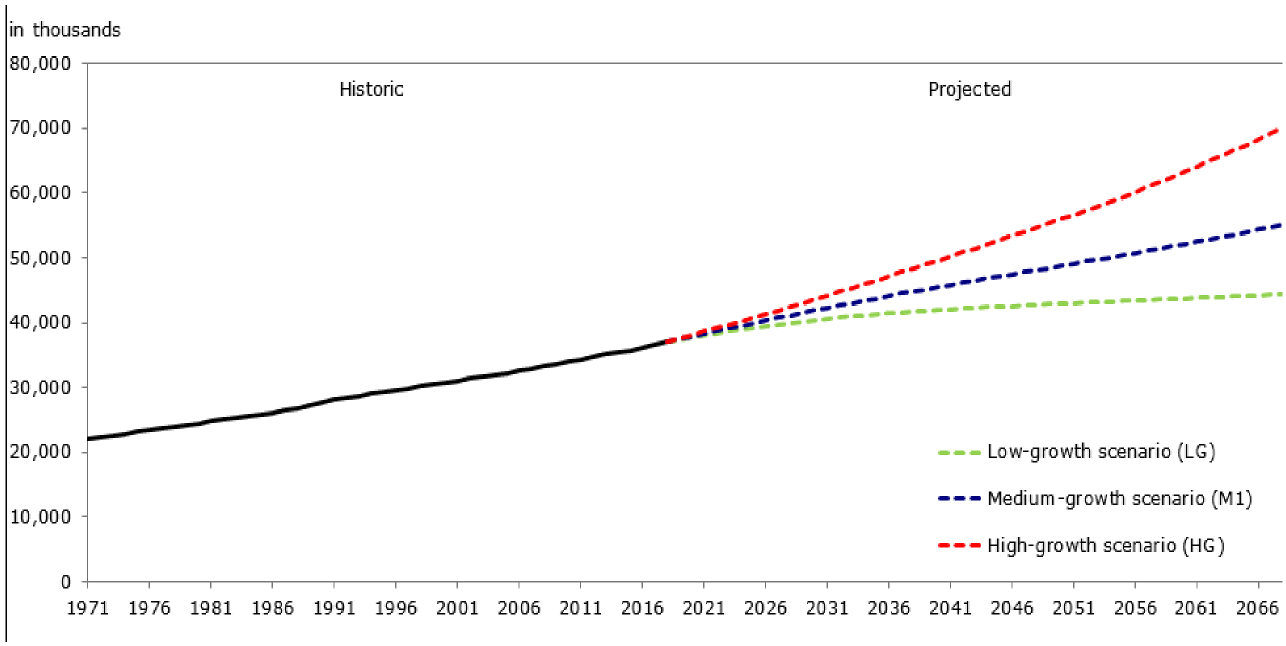

Figure 1.13. Canada population projection, based on low, medium, and high growth (Statistics Canada, 2019)

To increase satisfaction among residents, housing design must change to reflect current demographic trends. Socio-economic factors also influence housing design and structure (Niger, 2012). Not only do they determine what occupants can afford to acquire, but they also define the spatial needs and preferences of the occupants (Case, Quigley, & Shiller, 2013).

Lifestyle: Many scholars use the concept of lifestyle to understand consumer behaviour related to housing. In their article, "Culture, Lifestyle and the Meaning of Dwelling", Coolen and Ozaki (2006) define lifestyle as "function of individual characteristics that have been shared and formed through social interaction and is an expression of one's attitude towards life" (Coolen & Ozaki, 2004, p.5). According to Wentling (1955), architects "no longer provide shelter. [They] are the producers of lifestyle oriented environments" (Beamish, Goss, & Emmel, 2001, p.34). According to Beamish et al.

(2001), “lifestyle is an individual’s way of living,” which goes beyond his/her choice of furniture or automobile to encompass his/her goals and priorities (p. 3). Different factors affect the lifestyle of a household, such as age, economic status, culture, and the presence and age of children. Social class, in the form of income, education, and occupation, also determines lifestyle choices. In urban areas, lifestyle classifications include *familism*, where the dwelling is chosen for family comfort and activities; *careerism*, where proximity to the workplace is important; and *consumership*, where access to services and shops is the deciding factor (Beamish et al., 2001).

The increasingly popular phenomenon of professionals working from home can decrease urban traffic and changing mobility (Moos, Andrey, & Johnson, 2006). Today, more than 15% of Canada’s labour force works entirely or partly from home (Khan, 2010; Statistics Canada, 2016a). More than 40% report occasionally working from home, although not necessarily on a paid basis (Lister & Harnish, 2011). In Hong Kong, 25% of the workforce in the Information and Communication Technology (ICT) sector work from home and the number is expected to grow, especially within large companies (Leung & Zhang, 2017). Nearly 20 million Americans operate an in-home business, according to the National Association of Home Based Businesses (Bureau, 2009), and it can be inferred that these enterprises are common in Canada as well. Clearly, architects must diversify their floor plan designs to accommodate people with a wide range of lifestyles, including home-based workers.

Life Cycle: While individuals can influence their lifestyle, they have little to no choice in their life cycle. While different disciplines, including psychology, sociology, economics, and biology, conceptualize the life cycle differently, it is generally defined as “the transformation (maturation, generation, and decline) of any living organism or organization" (O'Rand & Krecker, 1990, p.243). In literature on the household, it is mainly associated with the family, and refers to "a sequence of a priori stages in the family's progression from marriage to widowhood" (O'Rand & Krecker, 1990, p.253). The life cycle of a household is primarily determined based on the advancing age of the householders and the presence and ages of their children.

Since the beginning of the twentieth century, various researchers have delineated the stages or periods that a family experiences during its life span (Beamish et al., 2001). One of the most commonly used classification systems for the nuclear family in architecture and housing is Duvall's eight stages of the family life cycle:

a) the single stage, which pertains to individuals under 35 with no children;
b) the couple stage, which means being married without children;
c) the childbearing family stage, which involves being married with the birth of a first child;
d) the pre-school family stage, in which the toddler needs attention of parent or caregiver;
e) the school-age family stage, which entails being married with older children;
f) the family shrinkage stage, in which the oldest child has left home;
g) the middle-age family stage, in which the parents are over 48.9 years old and have no children left at home (empty nesters); and
h) the aging family stage, which lasts from retirement until death (Beamish et al.,

2001, p.6).

The transition from one phase of the life cycle to another involves different spatial needs. For instance, the prolonged presence of teenagers in the household represents a life stage that has evolved to require architectural adaptation. In Canada and the United States, the idea of giving a separate space (bedroom) to teens began in the early twentieth century. A study published in 1934, commissioned by the White House Conference on Child Health and Protection, showed that more than 32.7% of single-family American households offered a separate bedroom for each of their teens (J. Reid, 2012). By the 1970s and 1980s, the adolescent bedroom had become an established part of the family home. Three factors made it possible to offer bedrooms to teenagers in the post-war era: a higher standard of living, a size increase in single-family detached houses, and a trend toward smaller families (J. Reid, 2012). The Canadian Mortgage and Housing Corporation (CMHC), in its *Newcomer's Guide to Canadian Housing* (2007), recommends that teenagers have their own private space.

1.4.1 Housing Choices and Preferences

Housing is one of the most important aspects of life. For many people, purchasing a home is their largest capital expenditure, and its quality is a major indicator of their standard of living. Research on residential choice has taken various directions. Many scholars consider economics as the deciding factor. Others use a structural perspective that includes tenure type, focusing on homeowners versus renters. A third approach emphasizes the importance of the user's changing lifestyle and life cycle of the household in selecting a home. The Danish sociologist Thomas Højrups provides a basis for understanding how lifestyle affects housing choice, which is in line with Heidegger's philosophy of the dwelling:

> "The dwelling represents shelter from wind and weather, but as a home it represents the residents as individuals and is therefore the object of considerable rearrangements. Heidegger (2000) says that the fact that people constantly arrange and build is basic; We do not dwell because we have built, but we build and have built because we dwell, that is, because we are dwellers. But in what does the nature of dwelling consist?" (Bech-Danielsen, Jensen, & Kiib, 2004, p.200).

One of the fundamental needs in housing is shelter; most houses fulfill this requirement. After this basic need is met, buyers seek to fulfill other needs, such as space organization, community, comfort, privacy, aesthetics, and neighbourhood. These choices are limited by the income and financial status of the occupants. Only a small percentage of wealthy households do not have restrictions on their housing selection and can choose the best options (Clark & Dieleman, 1996). Having real choices in housing means being able to select the most preferred choice from different alternatives. In social housing, these options are limited, since to some extent, the neighbourhood, layout, and amenities are dictated to the residents; but in most cases, consumers can exercise some degree of housing preference.

According to Morris and Winter (1988), housing preference can be defined as the quality and quantity of features that residents would like to have. Housing preference, along with housing satisfaction and expectations, have been major topics in recent architectural literature. A housing preference study attempts to understand the housing situation from the consumer's point of view, as opposed to market-oriented approaches, which focus on market and investor satisfaction.

1.4.2 Household Changes

Global changes in how people live and families mature have contributed to creating a demand for new types of housing over the past fifty years, with which the market must keep pace. Canada's population has almost tripled from 1941 to 2016. Since the 1950s, the dominant market segment has consisted of single detached house buyers. However, a significant demand for large, privately-owned apartments emerged by the 1960s and 1970s, resulting in the drop of single-family housing to 57% from 83%.

On the other hand, the average age of home buyers is rising. By 2050, it is estimated that, globally, purchasers will be predominantly over fifty and that the world's population will also have doubled. Population growth and increasing globalisation will lead to higher rates of immigration, inevitably increasing the rate of change in housing markets all over the world (Beaulieu & Miron, 1993).

The demographic changes brought on by increased mobility are already influencing the planning and design of new urban environments. Heynen (2000), in his book *Architecture and Modernity,* cites the opinion of Winy Maas as:

> "Classic urbanism cannot adequately handle the pace of change and growth of society. Recently created urban centres are already insufficient for new programs, even before they have opened. Newly completed classic office buildings change ownership within three years after realisation. Some suburbs that are less than 20 years old change to accommodate new

standards" (Heynen, 2000, p.128).

According to a study by one of the largest housing corporations in Amsterdam, a dwelling with a fifty-year life span starts to change after three years (Figure 1.14). Usually, after 25 years, the whole dwelling is transformed, not only in terms of its interior spaces, but also in terms of its purpose. That is, a housing project can become a school, office, or another occupancy type after fifteen years (Durmisevic, 2006).

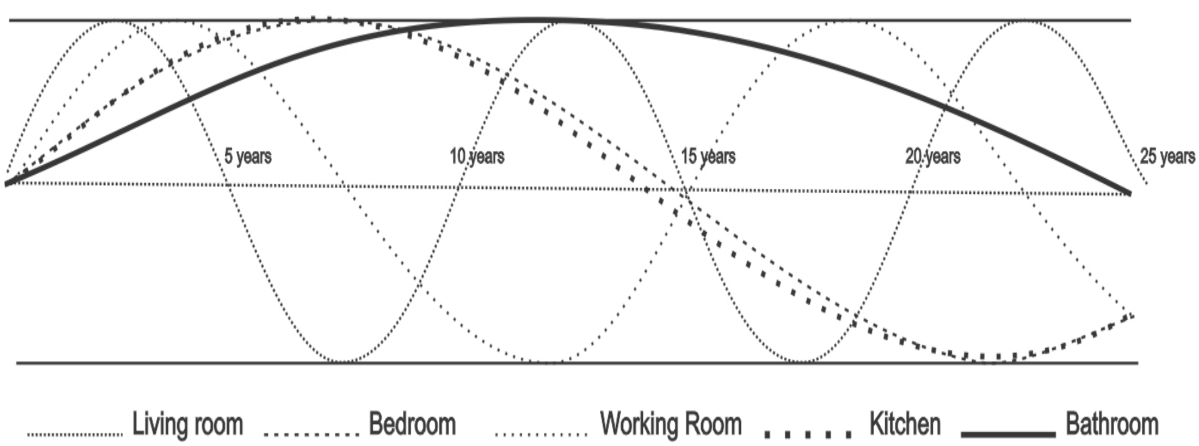

Figure 1.14. Change sequence in a dwelling (Durmisevic, 2006)

This study also projects that in more than 70% of cases, the initial organization of the building no longer meets the occupants' spatial needs. In fact, 30% of families would like to move because they cannot adjust their home to their current requirements (Durmisevic, 2006).

1.4.3 The Single-Family Home as a Dominant Housing Type

This new suburbia development combined mass-production with the use of similar designs and floor plans by developers and builders. In most cases, suburban housing was designed to contain a mother, father, 2.5 children, a dog and additional floor space for the family.

Suburban lots had a frontage as large as 50-foot wide, which was appealing when compared to a 25 to 33 foot lot usually found in the centre of major Canadian cities (Figure 1.15). The typical developments in suburbia were low-density housing, with a combination of single-family detached homes, townhouses and sometimes semi-detached homes (Wolfe, 1998).

Figure 1.15. Don Mills suburbs, Toronto, 1960s (Cruickshank, 2000)

Actually, the townhomes are increasing the densities by 200 to almost 300% compared to the usual 50-foot wide lots. A typical townhome offering a frontage accommodating two 9-foot wide bedrooms can be set on a 25-foot wide lot whereas, whereas a narrow-front one offering a frontage accommodating a 16-foot living room or bedroom can be set on a 18-foot lot; that is the case for the "*Cours du Fleuve*" project in Nuns Island (Montréal).

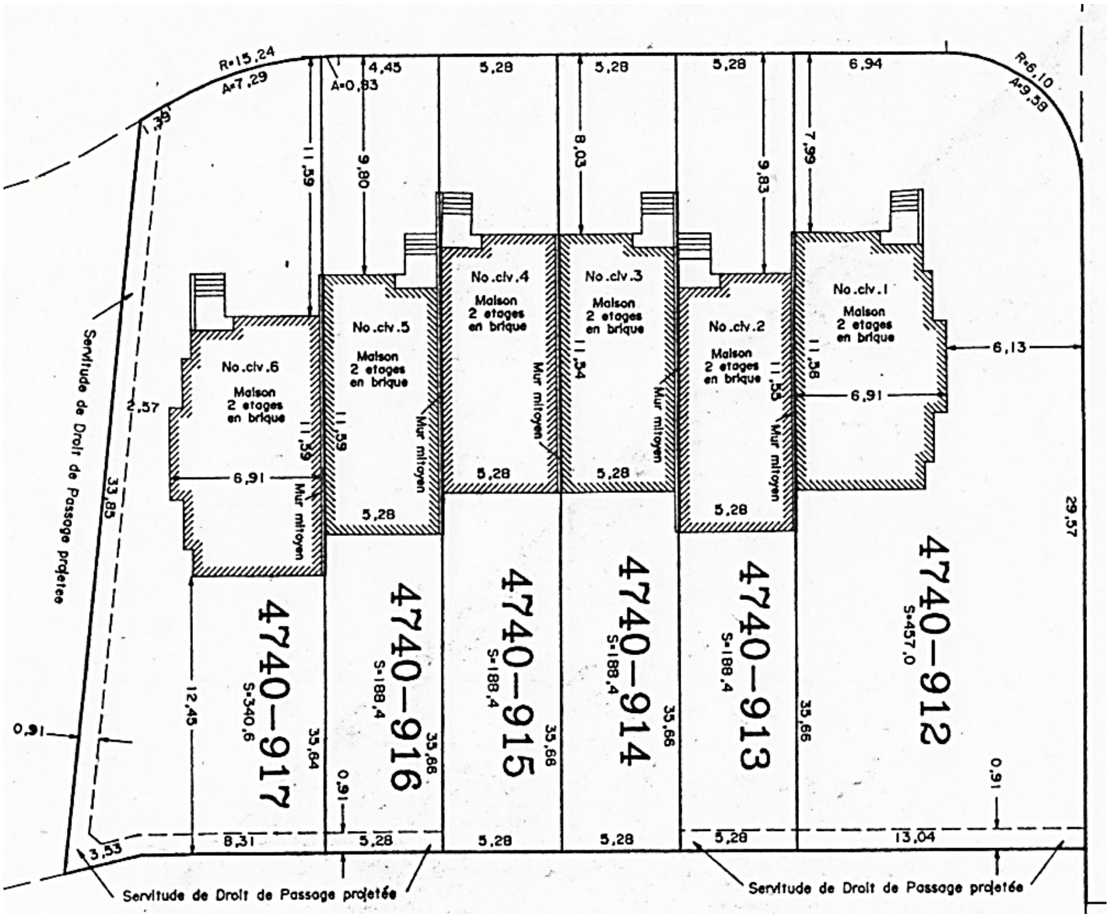

Figure 1.16. A section of the "*Cours du Fleuve*" project in Nuns Island, Montréal

1.4.4 Accessory Unit in Single-Family Homes

It is easy to modify single-family detached dwellings to accommodate emerging needs. The floor area is larger and the basement can be used as additional space for non-traditional activities. Moreover, in single-family detached housing, alternative needs can be met in accessory units (Chapman & Howe, 2010).

According to the CMHC, an accessory unit is defined as a "self-contained dwelling that is accessory in use to the principal dwelling, and which can be located either within the primary dwelling or in an accessory building on the same lot as the primary dwelling." In most cases, basements are accessory units (Figure 1.17) (CMHC, 2016, p.1).

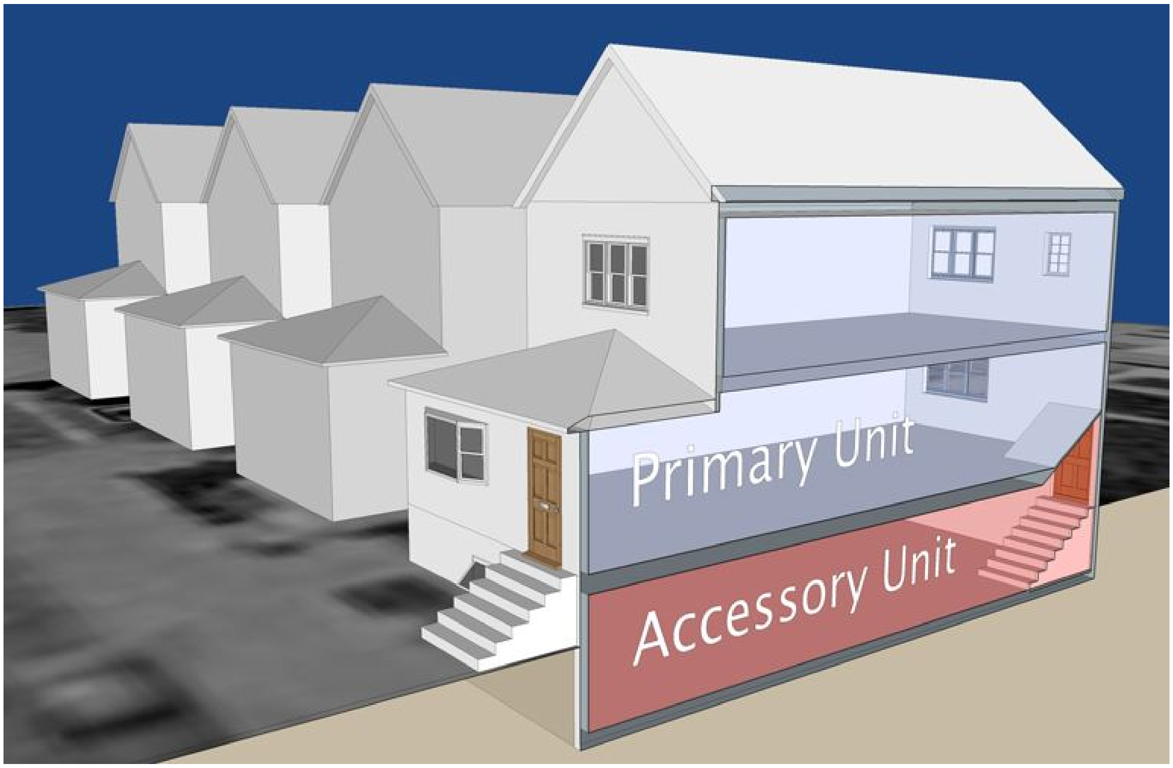

Figure 1.17. Arrangement of an accessory unit in single-detached housing (Lairds, 2013)

According to CMHC, accessory units have more than 50 names in English and 27 in French:

- Names that refer to the unit in relation to the occupant, such as: granny suite, nanny suite, in-law suite, care suite. In French: *logement parental, intergénérationnel* and *espace adapté.*
- Names that refer to the unit in relation to its location, such as: garden suite, garage suite, second house, coach house, accessory building, basement suite and apartment in-house. In French: *logement supplémentaire ou additionnel, pavillon jardin,*

logement accessoire, logement d'appoint, and *logement au sous-sol.*

The most common names used in English are: accessory unit, garden or secondary suite, and auxiliary unit. The most common terms used in French are: logement supplémentaire ou additionnel, logement d'appoint, logement accessoire, logement complémentaire annexe and logement intergénérationnel (CMHC, 2016).

According to a CMHC survey of more than 650 municipalities throughout Canada, the number of municipalities allowing accessory units has increased from 54% in 2006 to 78% in 2014 (CMHC, 2016).

The general by-law provisions for accessory unit differ in each municipality; however, each has at least a few of the following provisions:

- spatial requirements for a specific occupant
- limit on the number of occupants
- owner occupancy requirements for one of the units
- time limitations or temporary use regulations (particularly regarding garden suites)
- discretionary or conditional use provisions
- requirements for special permits, agreements or specific council approval
- restriction by type of building, specific zone or particular type of building in a specific zone
- minimum parking requirements
- architectural integration requirements

- minimum or maximum size requirements

1.4.5 Different Types of Accessory Units in the Single-Family Homes

The basement is the obvious first option whenever an accessory unit is needed to accommodate any emerging activity in a suburban house.

The regular detached house located on a 50-foot wide lot will implies a large basement capable of actually accommodating more than a single emerging need.

Whether that house is detached, semi-detached or attached in a townhome fashion, a split level type will offer a better way to improve the privacy: the accessory unit would be half a level downward whereas the other levels will start half a level upward, as long as there is a direct access to the relevant entrance (figure 1.18).

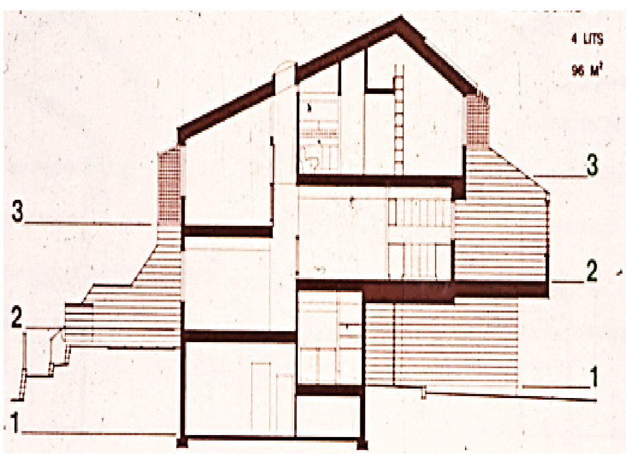

Figure 1.18. LeBreton Flats split-level townhomes, Ottawa

When the entrance of a maisonette house is located laterally, the accessory unit can be located next to it and thereby benefitting from a straight autonomy. It is the case for the "*Modèle maisonette trois modules*" developed for the Quebec Society of manufactured housing" prototype developed by Roger-Bruno Richard in 1979 and published in the brochure "*Habitations: projets d'architectes*" diffused by the Quebec Order of Architects (OAQ) in 1983 (Figure 1.19). The "*pièce polyvalente*" at the right of the entrance is the equivalent to an accessory space.

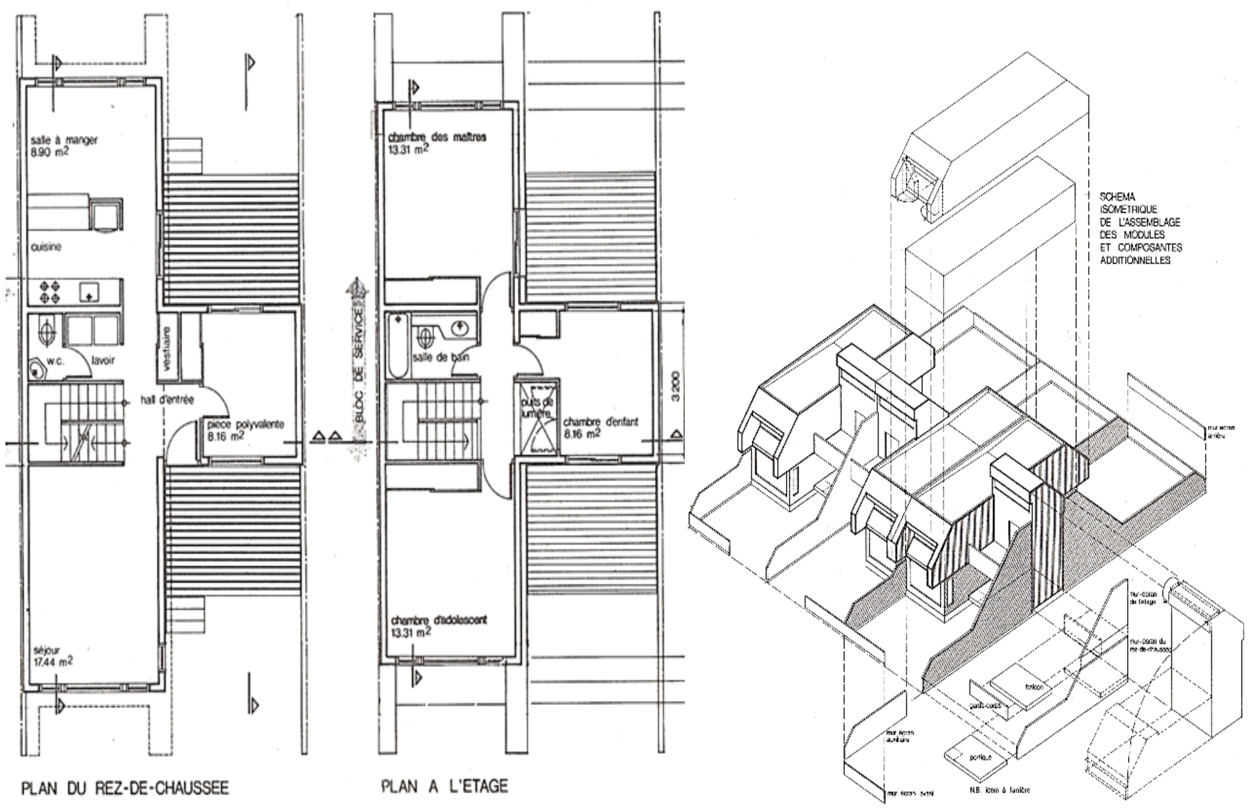

Figure 1.19. *Maisonnette trois modules,* Roger-Bruno Richard

Figure 1.20 shows different locations of accessory units from the basement to the attic, the garage, as well as attached and detached from the dwelling. Furthermore, Figures 1.21 and 1.22 show different usage of accessory units, from an additional bedroom, to an additional unit, or a workstation.

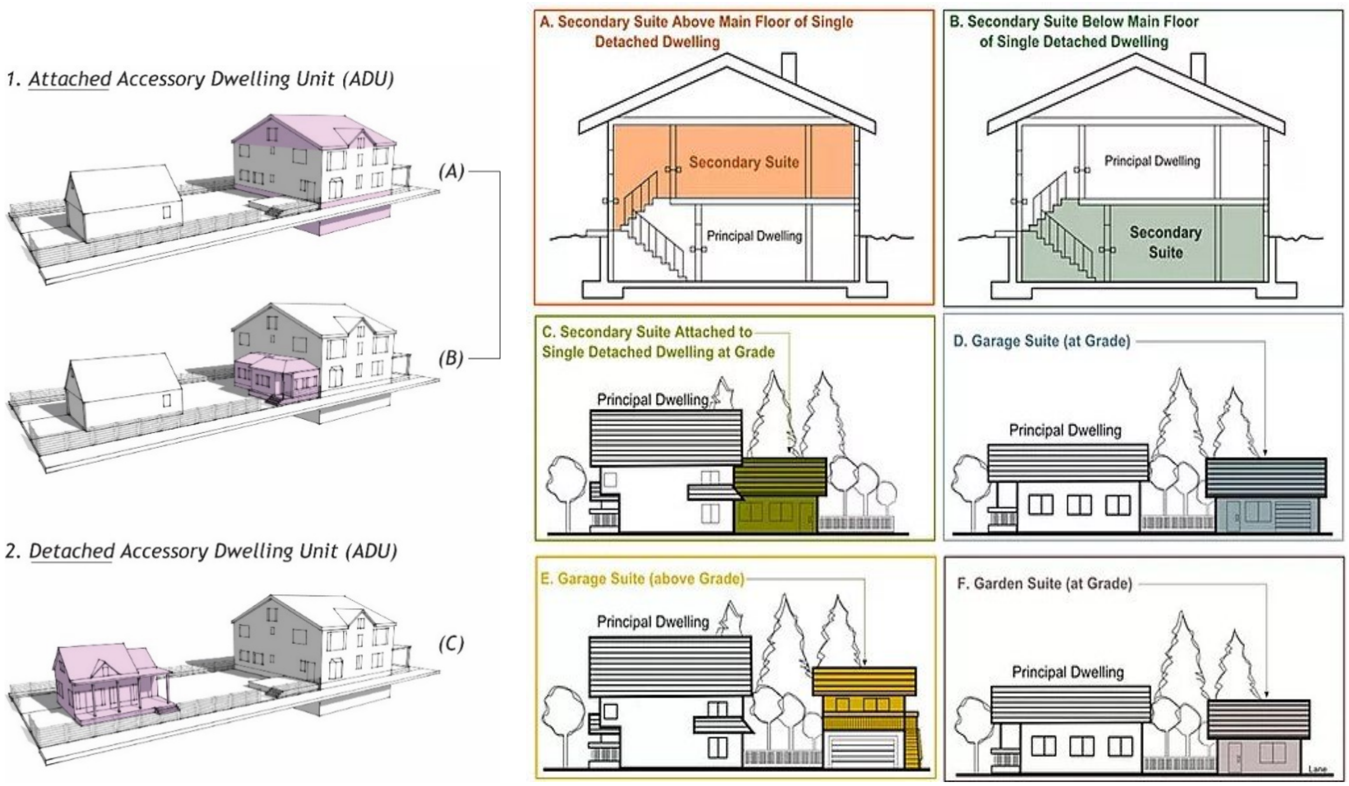

Figure 1.20. Attached/detached accessory unit

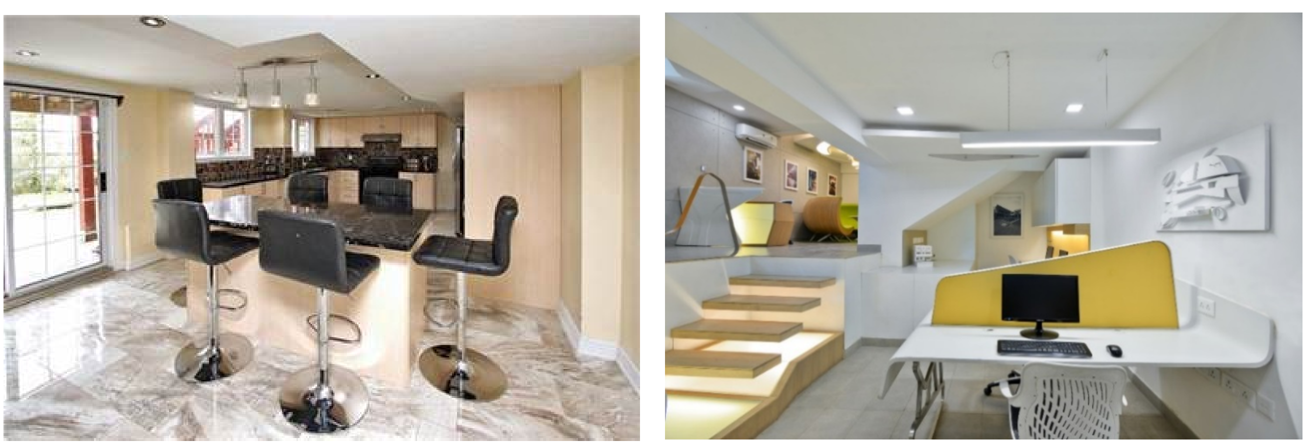

Figure 1.21. Basement used as accessory unit and office (Gellen, 2017)

Figure 1.22. Left: garage converted to living room. Right: attic converted to accessory suite (Gellen, 2017)

Each province and territory has at least one program that helps ease the cost of secondary suites or encourages the province or territory to make secondary suites legal. These programs offer incentives and loans for homeowners who decide to add a secondary suite to their existing dwelling.

1.4.6 Single-Family Housing Entrances

In single-family housing, the capacity of distributing the space into different levels with potential of different entrances makes each level more distinct and accessible. This feature makes single-family home space organization more flexible and capable for future changes (Figure 1.23). However, in most of multi-family housing projects, the space is limited, and the morphology of the floor plan does not easily allow for the introduction of new activities with different characteristics (such as working from home). In multi-family housing projects the space is distributed in a single level, with one entrance, accessing the whole space, making it difficult to distinct the spaces for activities with different characteristics such as working from home.

Figure 1.23. Typical 40' to 50' lot floor plan design (designed by the author, 50' lot).

In a typical two-storey detached single-family home, two or more entrances are given to the dwelling: the front door, the side door, the basement walkout and the rear deck door. Four entrances would lead to four different spaces in the home, at two different levels. Even most of the undersized single-family homes (18 to 30 foot size) in new developments still have three entrances: front door, deck door and the basement walkout door. When it comes to townhouses, they have two to three entracnes: front door, walkout basement, and some of them have a deck door. So, in some ways the separate space for emerging needs can be provided when it is needed.

However, when it comes to multi-family housing, there is usually only a single entrance at one level. Therefore, the distribution of space into different levels from different entrances is not possible. There are exceptions in the multi-family housing types where the floor plan is distributed in more than one level (such as split-levels or maisonnettes), yet they are not common housing types in Canada.

1.5 Emerging Needs in Housing

Lifestyle and life cycle changes in the household lead to the appearance of new activities (e.g. working from home) throughout the household lifespan. For the purpose of this study, we refer to these requirements as emerging needs. Emerging needs have different (and additional) characteristics from the traditional basic activities performed in a home, such as meeting, eating and sleeping.

The following section focuses on two societal factors that have been shown in sub-chapter 1.2 to generate emerging needs in housing: lifestyle and life cycle changes. The first factor examines how the evolving lifestyle of occupants, such as the integration of technology and the growing trend of working from home, alters housing needs (Balta-Ozkan, Davidson, Bicket, & Whitmarsh, 2013)The second factor examines how shifts in the life cycle, such as the prolonged stay of young adults in their parents' homes, can also influence the housing needs of occupants (De Wilde, 2014); Reid, 2013; Smith, Naven, et al., 2013).

1.5.1 Emerging Needs with Respect to Lifestyle & Life Cycle, Different Scenarios of Emerging Needs

The emergence of new technology has dramatically affected people's lifestyles. Acquiring and transferring data is now integral to many careers, especially those in information and communication technology (ICT), and can support a lifestyle that differs from the traditional one of living at home and commuting to the office (Doukidis, Mylonopoulos, & Pouloudi, 2004). According to Femenías (2014), a house's design and the lifestyle behaviours of its occupants are mutually intertwined. Reid (2012) explained how the historical context can influence housing design. He argued that after World War II, changes in demographics, philosophies on raising children, and the culture at large paved the way for housing layouts featuring the emergence of private bedrooms for teenagers. The adoption of such spaces reflected the social, economic, and cultural shifts in that transitional period, undervaluing the relationship between people's lifestyle and their housing choices (M. E. Reid, Lomas-Francis, & Olsson, 2012).

Empirical evidence suggests that housing design should be related to the behaviours and choices of the occupants (Case et al., 2013; Green, Ho-Baillie, & Snaith, 2014; Jansen, Coolen, & Goetgeluk, 2011; Shiller, 2013) (Liu et al., 2011; Niger, 2012; Zinas & Jusan, 2014). For instance, Jansen (2014) found that individuals who live in the city centre tend to value self-direction and prefer housing that is designed innovatively, in a neighbourhood that is a combination of both residential and commercial buildings. Conversely, individuals who live outside the city centre tend to value security and prefer traditionally designed housing in a primarily residential neighbourhood.

Changes in the life cycle also give rise to emerging needs. These changes include the prolonged presence of young adults in the parental household, the declining rate of marriage in favour of cohabitation, and the co-residence of parents and children (Ch'oe, Kim, & Yeung, 2011; Green et al., 2014; Smith et al., 2013). Accommodation of these issues is conditioned on the occupants' financial and social choices. These needs may include a separate bedroom for a teenager, a home office space, or the expansion of the house to accommodate the co-residence of parents (Green et al., 2014; Lister & Harnish, 2011; Nichols, Martindale-Adams, Graney, Zuber, & Burns, 2013).

In addition to the life cycle changes mentioned above (co-residence of teenage or elderly parents), another important scenario for emerging needs is accommodating a permanent caregiver for a person in need (such as a sick person), or a nanny's room, or an elderly parent. Based on the Government of Canada's standards, part of the requirements of employing a live-in caregiver such as a babysitter, or a domestic worker is to provide a standard accommodation based on their guidelines. The description of accommodation must be completed in the application Labour Market Impact Assessment (LIMA) to be assessed and approved by the authorities.

The following schemes are the most common scenarios of emerging needs:

- Workplace at home: an arrangment to work at home, rather than in an office.
- Elderly parents or teenage co-residence: an arrangment where elder parent(s) or tennagers can have some autotomony to live with the main dweller in the same household.
- Nanny suite: a self-contained apartment within a residence (occasionally merely a bedroom with en suite bathroom), designed especially for the use of a live-in nanny.
- Permanent caregiver room: similar to nanny's suite self-contained apartment within residence, designed for a living caregiver.
- Domestic helper suite: live-in domestic helper should be provided with privacy, and basic level of spatial comfort, such as ventilation, natural light, heating and cooling.
- Visitor suite: or guest suite provides a space for family of friend members who come to visit residence.

All of these scenarios have implications for housing design that must be addressed. For example, if elderly parents decide to live with their adult child, how could the household be arranged to preserve the privacy of both parties? Considering solutions for these emerging needs in the early design stage should encourage designers to adopt different housing layouts.

1.5.2 Scenario of Work from Home

The thesis will focus on working from home, as it is the most prevalent and demanding emerging needs in housing. The traditional layout of an apartment—with its bedrooms, bathrooms, and kitchen — cannot accommodate non-traditional activities, which have different spatial requirements than traditional ones (such as eating and sleeping). For instance, to maintain privacy, a home office must be separated from the activities of the other occupants, which is not always easy in a traditionally designed dwelling unit.

In addition, a room can be eligible to be used as an office at home by Canada Revenue Agency (CRA), where part of the mortgage or rent, and utilities expenses can be deducted from the income. According to the CRA as follows:

“2.12 In order to meet the requirements outlined in 2.4(b), the work space must be used:

- exclusively to earn business income; and
- on a regular and continuous basis for meeting clients, customers or patients of the individual in respect of the business.

2.13 A workspace will be used exclusively to earn business income if it is a segregated area, such as a room or rooms that is used in a business and for no other purpose.

2.14 The Act does not specify what is meant by the wording meeting clients, customers or patients, so the CRA looks to the ordinary or dictionary meaning of these words."

In addition to the self-employed, the CRA has a new program for employees to use part of their home for work and deduct 50% of their home expenses; it is called "work-space-in-the-home expenses". The workspace for employees working from home must have the following criteria:

- "The workspace is where you mainly (more than 50% of the time) do your work.
- You use the workspace only to earn your employment income. You also have to use it on a regular and continuous basis for meeting clients, customers, or other people in the course of your employment duties".

On the other hand, working from home has become more of the norm after COVID-19. According to the survey conducted by Gartner Finance, more than 74% of CFOs (chief financial officers) plan on moving at least 5% of their workforce that previously worked on-site to remote positions post COVID-19. Most CFOs revealed that they are taking additional steps in supporting working from home. Another survey, conducted by Global Workplace Analytics, predicted that more than 25% of employees will work from home within the next two years.

Since working from home has the most demanding space arrangement when compared to other scenarios, **the focus of the thesis is on the "*working from home*" as the prototypical issue for designing for emerging needs.** Working from home involves activities which would go beyond the more family-related activities expected to take place in the supplementary space, with the only exception being an artist studio or workshop. Working from home involves carrying tasks requested from clients or employers, hosting clients or advisors and thereby assuring a clear boundary between the family zone and workspace *per se*. (Fan Ng, 2010). Due to the COVID-19 emergence, different organizations such Work Health Organization (WHO), started to publishing series of research and guidelines on preparing the workplace at home. Figure 1.24 is the research guidelines prepared by the British Physiological Society on work from home.

Figure 1.24. British psychological society guidelines on work from home

1.6 The Co-working Movement

Co-working is one of the fastest growing workspace movements since the 1990s. Co-working refers to a work style involving a shared work environment. A co-working space can be defined as "a space with chairs, desks, lighting, power sockets, Wi-Fi access, a pantry with coffee, food, and a fridge" (Vanichvatana, Varapark, & Poontirakul, 2017, p.2). In his book, *Co-working Space Designs*, Kinugasa-tusi discusses, co-working emerged with the aspiration of new start-ups and young companies wanting to share experience and skills, and engage in social networking. Technology played a vital role in such a work environment, bringing flexibility and revolutionizing the way people see the traditional office. These co-working spaces function as 'pockets of energies' distributed across cities with distinct spatial floor plan organization (Kinugasa-Tsui, 2018).

The basic co-working setting provides different services such as a desk, lighting, Wi-Fi, a mailbox, a receptionist, lockers, and a meeting space. In high-end co-working settings, a telephone booth, conference room, restaurant, and minibar are offered to both workers and visitors. Comfort is another important factor; providing natural light, vegetation, ventilation and other creative comfort features are promoted in co-working environments. (Kinugasa-Tsui, 2018).

The co-working concept fits within the framework of the 'sharing economy'. It follows the idea of sharing similar to Uber, Airbnb, Upwork, Bicycle-sharing, Zipcar, etc. According to Kinugasa-Tsui, the 'economic uncertainty', 'technology', and 'community and cities' are the main trends that are driving sustainability in co-working.

1.6.1 Statistics on Co-Working

The number of co-working spaces is expected to reach 20,000 in 2020 and 40,000 by 2024, with a 21.3% growth rate after 2021. Before COVID-19 emergence, 77% of co-working operators that were surveyed planned to open additional locations (Coworking Resources, 2020). The number of co-working space units and people using them are projected in Figures 1.25 & 1.26.

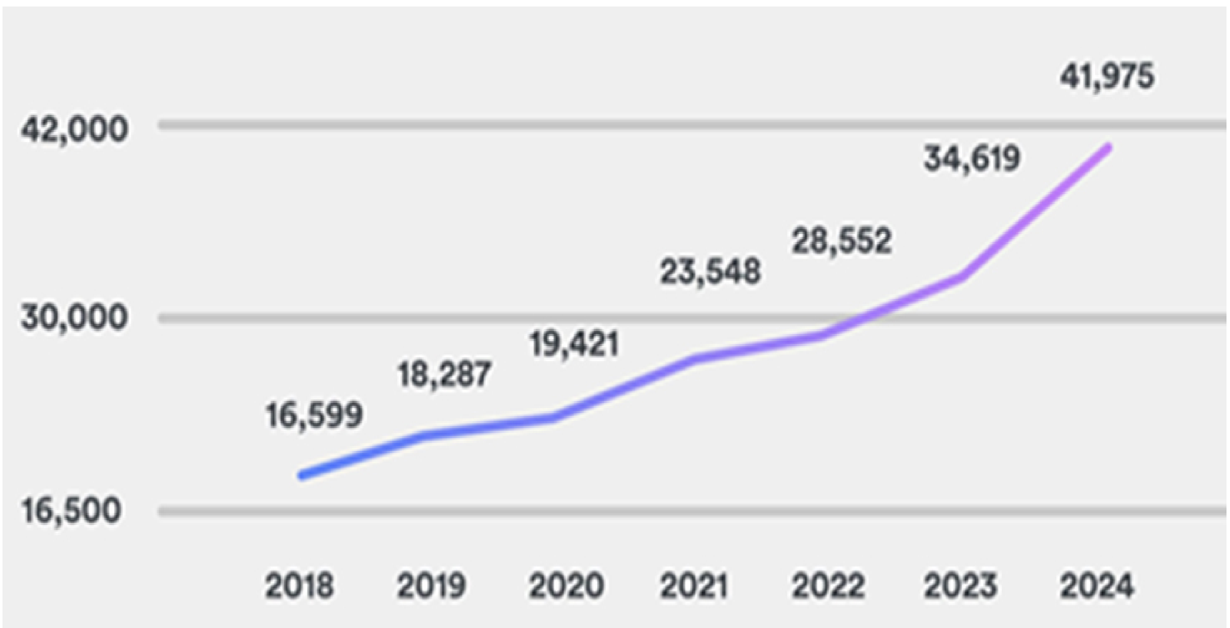

Figure 1.25. Number of co-working spaces worldwide (Coworking Resources, 2020)

Furthermore, it is estimated that more than 5 million people will use co-working by 2024, a 158% increase from 2020 (Coworking Resources, 2020).

In terms of size and capacity, Asia has the highest average capacity with 114 people and South America holds the lowest one with 54 people, with a worldwide average capacity of 83 people. When it comes to capacity, North America has the largest space of 9,799 sq. ft. per space. The United States has the biggest market with 3,700 shared workspaces, while

Canada has 617.

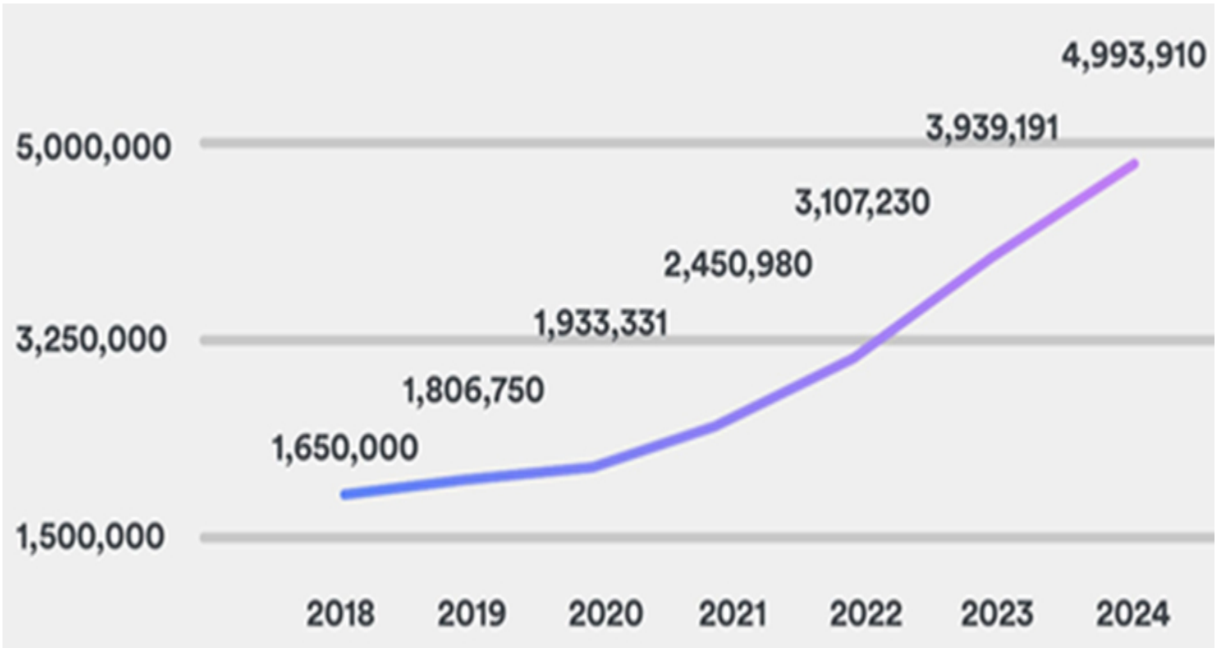

Figure 1.26. Number of people using co-working spaces worldwide (Coworking Resources, 2020)

1.6.2 Canadian Co-Working Expansion

According to a research carried out by Colliers' Study International on co-working in Canada, co-working office spaces are revolutionizing the way businesses approach the traditional office and their workplace strategy. In the past 2 years, 2.4 million sq. ft. of new flexible office space was delivered, accounting for 130 new locations. The Toronto market has the largest share of co-working arrangements, with 40.8% of the country's total inventory (Figure 1.27) (Levy, 2019).

Region	Flexible Office Inventory (SF)	Total Office Inventory (SF)	Proportion to National Flex Inventory	Market Saturation	Q4 2019 Vacancy Rate
Greater Toronto Area	2,678,286	252,466,565	40.8%	1.1%	4.0%
Greater Vancouver Area	1,368,197	71,434,296	20.8%	1.9%	2.9%
Greater Montreal Area	836,621	87,901,538	12.7%	1.0%	8.1%
Greater Calgary Area	783,605	73,031,376	11.9%	1.1%	23.0%
Waterloo Region	253,254	12,968,636	3.9%	2.0%	13.8%
Greater Ottawa Area	243,989	40,566,465	3.7%	0.6%	6.1%
Victoria	108,991	29,867,097	1.7%	0.4%	15.7%
Greater Edmonton Area	83,960	16,570,063	1.3%	0.5%	11.6%
Winnipeg	65,246	5,242,321	1.0%	1.2%	3.5%
Kelowna	59,559	8,816,819	0.9%	0.7%	5.1%
Saskatoon	57,309	5,954,349	0.9%	1.0%	13.3%
Regina	29,754	5,134,190	0.5%	0.6%	12.1%
Total	**6,568,771**	**609,953,715**	**100.0%**	**1.1%**	

Figure 1.27. Proportion vs. market size (Levy, 2019)

According to this research, three main types of co-working options exist in Canada, with their average monthly rent presented in Figure 1.28.

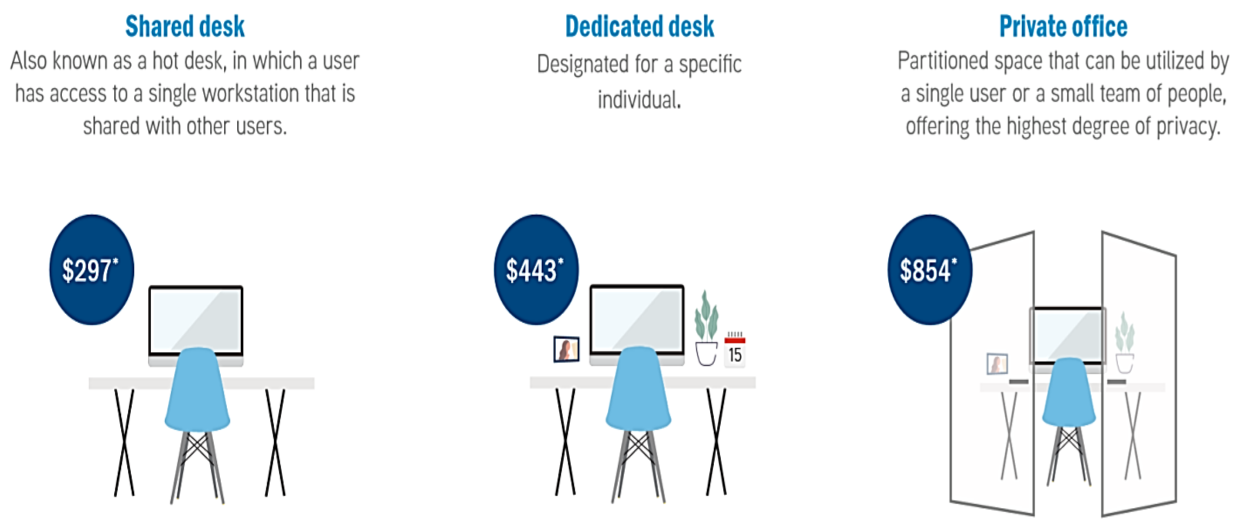

Figure 1.28. Three main types of co-working spaces with their average monthly rent nationwide (Levy, 2019)

1.6.3 Different Types of Co-working Arrangement

There are different types of co-working arrangements worldwide. Different names and ways of classifications are employed to categorise co-working spaces. The most common terminology and arraignments are being used in North American context are presented here.

1.6.3.1 Hot-Desk

According to the Oxford English Dictionary, hot-desking is "the practice in an office of giving desks to workers when they are required, rather than giving each worker their own desk". The 'desk' attributes to work space are being shared with different office workers, as opposed to a traditional office where each worker has a particular spot and space. The primary objective of hot-desking is to minimize costs through space-saving. Hot-desking is more valuable in cities where the real-estate prices are high (Roth & Mirchandani, 2016).

Hot-desking is mostly used for employees with flexible schedules, where they can work remotely and do not need to be physically in the office all the time (Figure 1.29). Hot-desking has great advantages for start-ups as they get flexible rent terms and a professional network establishment, they share experience and skills, and they connect users belong to the professional community. The disadvantages of hot-desking are a lack of privacy, unavailability, and inability to customize personal space (Roth & Mirchandani, 2016).

Figure 1.29. 1275 Avenue des-Canadiens-de-Montréal

1.6.3.2 Dedicated-Desk

Dedicated-desk is reserved for a certain individual, where the worker can add personality to the desk. Unlike the hot-desk it has to be arranged ahead of time, and mostly the minimum amount of time for a desk assignment is longer than hot-desk, depending on the policies of the co-working office (Figure 1.30) (Halvitigala, Antoniades, & Eves, 2018).

The dedicated-desk could be in a collective open space, in a “landscaped” screened – kitchen – bathroom – bedrooms layouts.

Figure 1.30. Dedicated-desk, Place Ville Marie, Montréal

1.6.3.3 Green-Desk

Such office spaces can be rented for different durations of time. The user has complete sound and visual privacy from the other users. The user also can benefit from different office amenities, such as a secretary, meeting rooms, a printer, etc. (Levy, 2019).

These offices can be used for group of co-workers who need to work together or have a meeting or it can be rented for short amount of time to meet a client, as little as one hour. Once the full office is not needed, the virtual offices, meeting, and conference rooms can be used. It best suites people who do not need office on regular or full basis, but once in a while mainly to meet clients.

The Green Desk option is quite available in most large cities in Canada. In Montreal, the *Centre d'affaires* of Nuns Island is offering a full series of Green Desk services and so is the Decision-1 business center on the 20th Floor of the prestigious downtown 1 Place Ville-Marie building (Figure 1.31).

Figure 1.31. Place Ville Marie wework conference room, Montreal

1.6.3.4 Co-working in Condominium

With the opportunity to work from home becoming more common over the last decade, many developers have started to incorporate co-working space as an amenity in condominium projects. It becomes selling point for condominium projects to have such spaces with different names such as “study area”, “work zone” for residents. In many cases they offer different facilities such as WiFi, kitchenette and bathroom along within the work area for the residents.

Figure 1.32. Mercer condo, Toronto

1.6.3.5 Office at Home

As mentioned in the previous sub-chapters, working at home is the prevailing emerging need in multi-family buildings and the Office at Home type is addressing that issue, even though it does not directly imply co-working per se. Actually it could be considered as an "office away from the formal office" and could be included in the "Agile Office" (i.e. moving the laptop anywhere) option of co-working which is popular in some countries.

The criteria will be detailed further on in the present thesis will cover all the amenities an Office at Home does require.

The co-working arrangement options become even more relevant when the space for "working from home" has to be given to other emerging needs that do not benefit from the equivalent options. Otherwise two spaces for two different emerging needs may be required.

1.7 Spatial Planning in Early Design Stage to Accommodate for Emerging Needs

According to Van Assche, Beunen, Duineveld, and de Jong (2013), spatial planning focuses on the “ways in which people shape and govern spaces and takes into account social, economic, and environmental issues” (p. 2). The floor planning is directing and, up to a certain point, conditioning the activities taking place: it become the “container” of those activities and should then be favourable to the “content”.

1.7.1 Design for the Whole Life Cycle

Buildings should be designed in a way which could plan for the entire service life of its inhabitants. The sustainability considerations must not only encompass the materials incorporated, but also the potential use of the building over its entire life cycle, culminating in its disassembly or reconfiguration, and its ultimate disposal. Thus, a thorough assessment of the environmental and economic impact of the building design and its use is paramount. There are certain methodologies that can be used for this life cycle consideration in the early design stages of a building. The primary tools that can be used are (Norris, 2001):

- LCA – Life Cycle Assessment,
- LCC – Life Cycle Cost.

LCA assesses the various expected phases of the life cycle of the building. LCC assesses the expected costs incurred during the entire life cycle of the building (Figures 1.33 & 1.34).

The key to the life cycle assessment methods is the **level of predictability** when it comes to building design. The building's expected deterioration of physical and service expectations has to be assessed (Zhang, 1999). These methods can thus provide a more thorough picture of all environmental, economic, and quality of life benefits of the project (Norris, 2001). The assessment starts from the beginning of the project in all levels, materials life cycle, design life cycle, construction life cycle, building systems life cycle, etc.

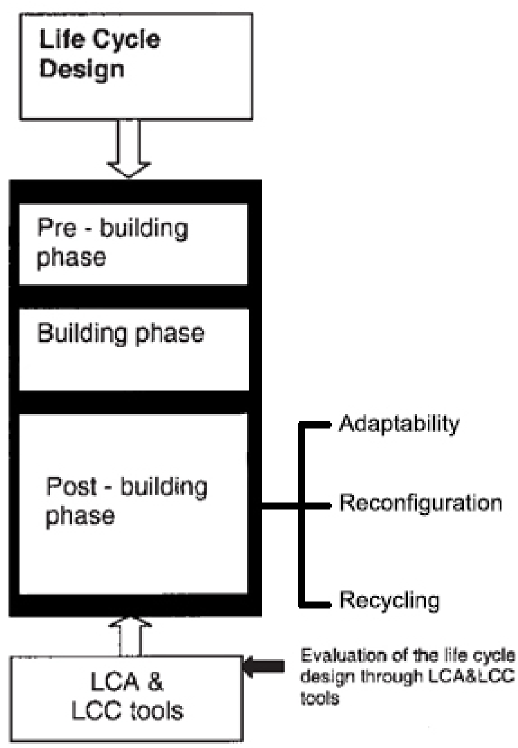

Figure 1.33. Integration of sustainability into life cycle design (Durmisevic, 2006)

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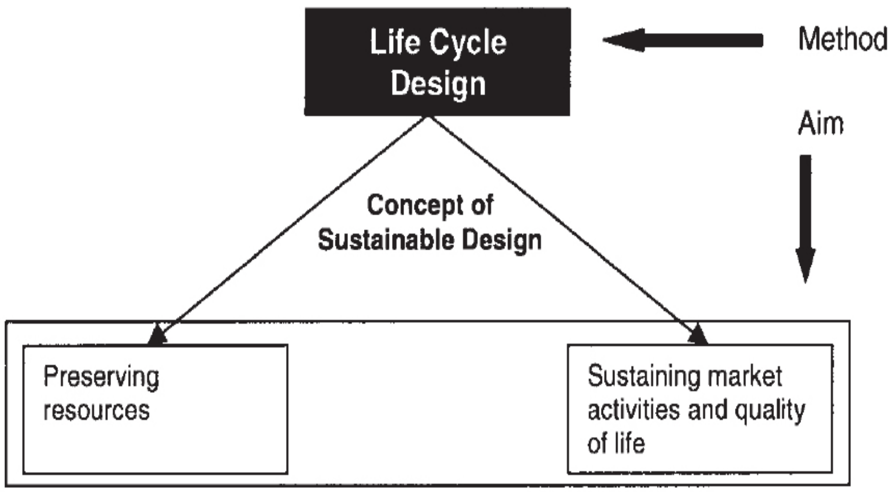

Figure 1.34. Conceptual Diagram of Sustainable Design (Durmisevic, 2006; Norris, 2001)

Investors normally consider the financial risks of any construction, based on problems incurred during pre-construction and construction. These problems include labour issues, bad weather, faults in design or construction, availability of materials and timetables for completion (Clift, 2003). Long-term investors are, however, now beginning to assess the operational life cycle of any construction, taking into account all the operational phases of the building. However, future costs can be very difficult to equate. This can be due to insufficient understanding of all the phases in the life of a building, and therefore not taking into account all the interventions that may be necessary in the life of the building (Clift, 2003).

According to Kohler, in his book *A Life Cycle Approach to Buildings*, there are four life cycle phases associated with buildings (Figure 1.35):

- New building: begins with the intention of the client and ends with the commissioning and handover of the building.
- Usage: includes use, operation and maintenance, begins with commissioning and acceptance of the building and ends with the intention to carry out (periodic) renewal.
- Renewal: includes a conversation regarding partial or full renewal. There could be several renewal and usage phases.
- Demolition and disposal: begins with the intention to stop using the building and to demolish it, and ends with the complete transfer of building materials for subsequent uses (reuse, recycling, power generation, landfill, etc.).

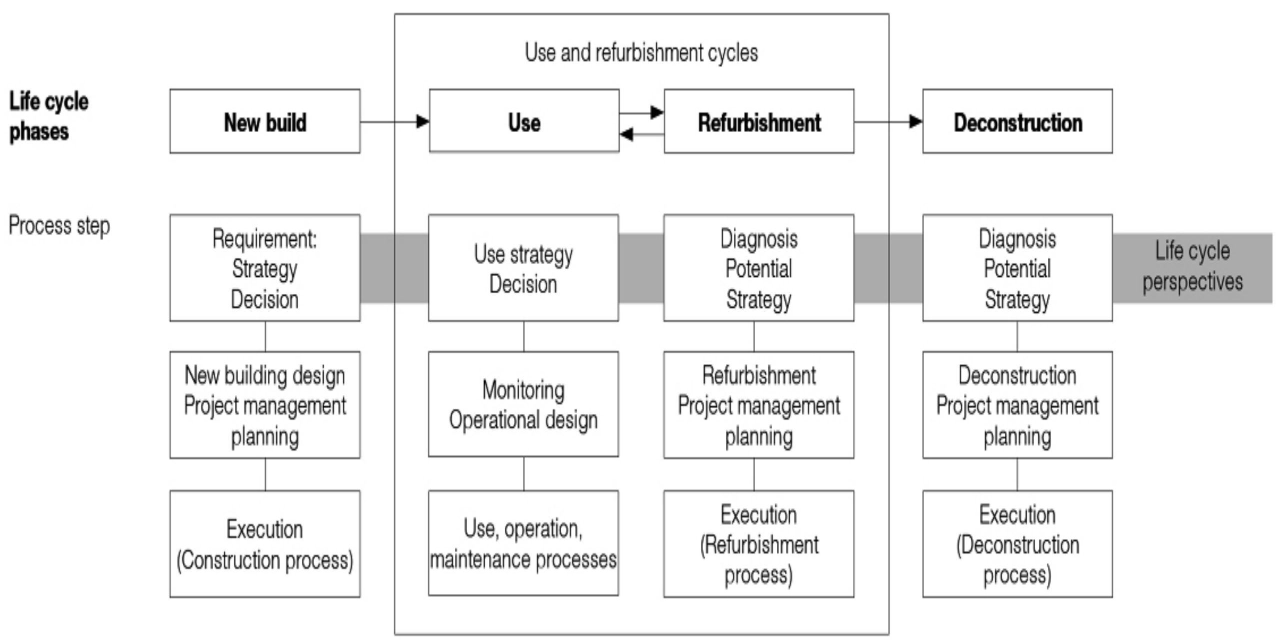

Figure 1.35. Lifecycle phases and process steps (Kohler, König, Kreissig, & Lützkendorf, 2010)

1.7.2 Design Process in Early Stage

The early design stage in buildings is considered by contrasting and multidisciplinary objectives. It is in this stage that designers contemplate the largest number of design alternatives and make decisions for the building's future. Cost, building performance, and energy efficiency are all determined in the early stage of design. In this research, the term "early design stage" refers to the **beginning process** of briefing and the architectural planning of the building (Echenagucia, Capozzoli, Cascone, & Sassone, 2015). Suitable early design would lead to a longer life span, which is the focus of this research.

Decisions made in the early stages of design have significant impact on the cost of design changes and the efficiency of design effort. They also have the biggest impact on energy demand. Therefore, design for energy efficiency is best achieved in the early design stage (Figure 1.36 & 1.37) (Hollberg, Lichtenheld, Klüber, & Ruth, 2018).

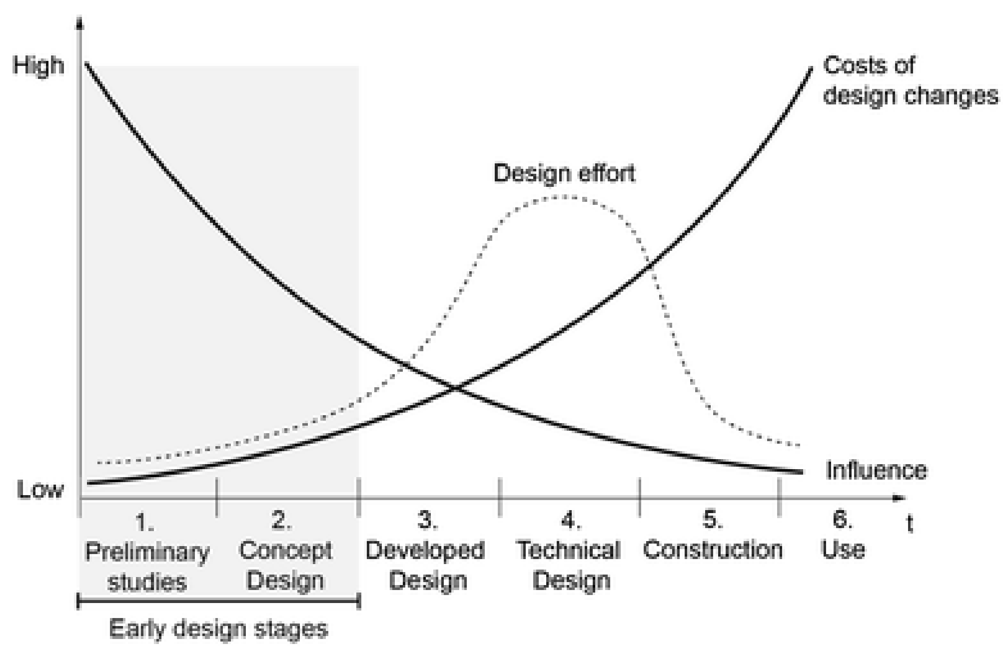

Figure 1.36. Cost of design changes and efficiency of design efforts on project in different stages of project

(Hollberg et al., 2018)

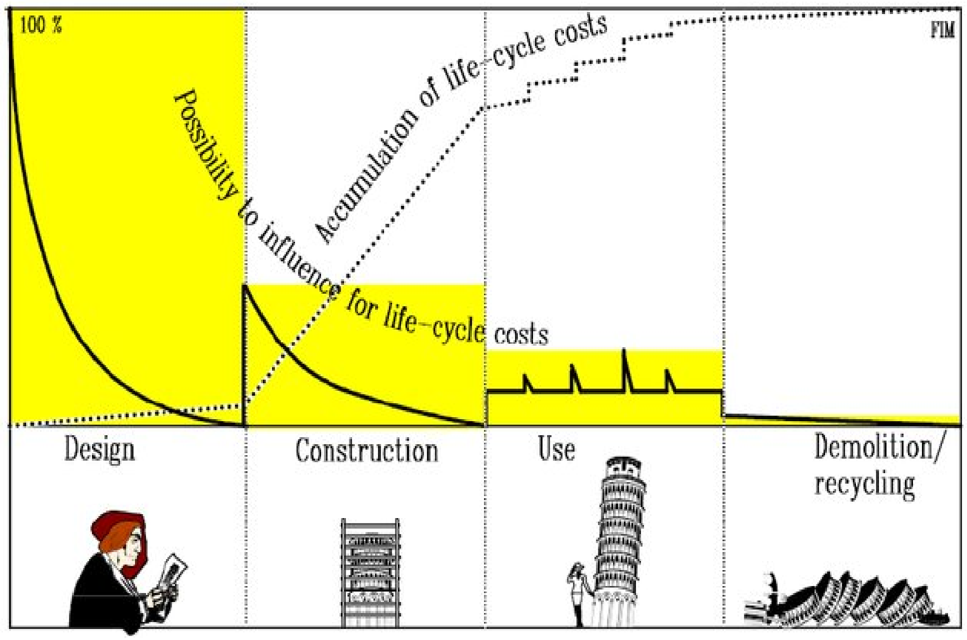

Figure 1.37. Design freedom in different service life of building (Hollberg et al., 2018)

1.8 Chapter 1 Findings (Research Problem)

The emerging activities have different spatial requirements than the conventional ones. For instance, to maintain privacy, a home office must be separated from the activities of the other occupants, which is not always easy in a traditionally designed dwelling unit. The focus of the thesis is on the "worklace at home" as the prototypical issue in designing for emerging needs. Working from home involves activities which would go beyond the more family-related activities expected to take place in the supplementary space.

There are several "Co-Working" options available outside the dwelling unit itself. These options become even more relevant as they offer a solution when spaces used for "working from home" have to give way to other emerging needs that don't normally benefit from equivalent options; otherwise two supplementary spaces might be required.

So, the question becomes: how to generate the appropriate planning guidelines to accommodate the emerging needs? Moreover, to address the changing physical needs of the occupants, the floor plan must be adaptable. Over time, occupants may wish to modify their dwelling unit to accommodate various changes in their lifestyle and life cycle, including new and unexpected emerging needs.

1.9 Sequence of Chapters

The thesis consists of seven chapters. Chapter one explained the issue of emerging needs in multi-family housing and how the new life cycle and lifestyle will bring about such a need in housing. Further, it elaborates on accommodating such needs to improve the sustainability in housing design, reducing the construction waste, delay the building's obsolescence and avoid undesired moving. Chapter two will introduce supplementary space as a solution to deal with the issue of emerging needs in housing. By first going through literature, the current study show such a space already unintentionally exists in practice and theory. It further emphasizes that such a space can be incorporated in early design stages. In chapter two, research and design questions will be proposed, and research through design (RTD) will be selected as methodology; systematic approach to propose supplementary space. Chapter three will select criteria from three different literature sources for proposing supplementary space for accommodating the scenario of working from home. Chapter four elaborates on the principles of adaptable housing as the main solutions for the issue of change in housing. Chapter five creates a model based on the criteria and adaptable housing principles to propose design guidelines for supplementary spaces (design solution). Chapter six responds to the research question through elaborating on proposing design for disassembly (DfD) for supplementary spaces. Chapter seven will draw conclusions, future research topics and other scenarios based on the model created. The model created in chapter five can be used as a tool to deal with other emerging needs scenarios in housing, where specific criteria and solutions for each scenario can be deduced by the user towards proposing supplementary space for other emerging needs activities.

2 Supplementary Space and the Systems Approach

The development of the supplementary space will use a research through design (RTD) model, a deductive methodology (systems approach) and an intuitive methodology (scenario planning). The answer to the design question is a generic model in the form of floor plan guidelines, and the answer to the research question is incorporating a Design for Deconstruction (DfD) approach in order to offer adpatability without demolition.

To identify the relevant criteria, this study applies the system approach, deductive methodology starting from existing knowledge and using it to generate new knowledge to meet a specific objective. The scenario-buffered technique attempts to create strategies that will enable the building to give a series of alternatives for future occupancy.

2.1 Supplementary Space

In his article “teleworkers’ home office: an extension of office corporate?”, based on both Canadian and American research context, Fan Ng emphasizes the need for an **extra space at home** when it comes to working from home (Fan Ng, 2012). Another survey has shown that more than 57% of people who telecommute would like to have a separate room toward the perimeter of the home (Senbel, 1995). The study proposes one or more **additional adaptable spaces** that can change their function based on the changing needs of the household. This new adaptable space accommodates undetermined requirements, facilitating activities other than those typically occurring in a traditional dwelling (eating, sleeping, entertaining), such as working from home. Because these new activities are fundamentally different from the traditional activities of the household, a new entity to deal with them is required.

Supplementary space is an area in the unit that the occupants can use dynamically, based on their emerging requirements. For example, this space can be converted into an office, a young adult’s room, or an aged parent’s domain. Because it must be able to serve various purposes, the supplementary space must meet certain appropriate criteria. According to the Fan Ng article (mentioned above) such a space must be **distinct** from the rest of the dwelling. Depending on the size of the home and the activities being accommodated, other criteria could be defined for the supplementary space, such as having its own services, perhaps a bathroom, and even a separate entrance. It is better for the space to be located close to the main circulation level of the building (e.g. along the corridor in multi-family housing) as the Fan Ng articles suggests, which will be further elaborated in the next chapters.

2.1.1 Supplementary Space in Literature

It is pertinent to note that a supplementary space already exists in some projects, although the designers have not explicitly identified it as one of their desired outcomes. In their book, *Flexible Housing*, Schnieder and Till define Slack Space:

> "This is space provided by the designer, the occupation of which is not fully determined. It is space that something happens in, but exactly what that something might be is not programmed. Slack space is not just any space, but areas that are anticipatory of potential occupation. Externally slack space is found on flat roofs that can be built upon, courtyards that can be filled in or a communal stairwell with landings big enough for occupation by its users. Internally it might be found in an alcove that can be later enclosed or have furniture built into it, a balcony that can be glazed and turned into an additional room or those nooks that are good to have but one does not quite know what for" (Till & Schneider, 2005, p. 134).

A fine example of slack space is provided in the Wohnanlage *Genter Strasse* terrace housing designed by Otto Steidle. The architect incorporated flexibility through an excess space from the beginning of project, which could be claimed by the user over the time, either on the outside which could be filled in an exterior non-filled frame or inside by filling one-and-a-half or two-storey spaces. The distinction between load-bearing and non-loadbearing walls easily allows alternation according to users' needs (Figures 2.1 &2.2). Since its construction, the volumes, interior, and uses have changed considerably (Till & Schneider, 2005).

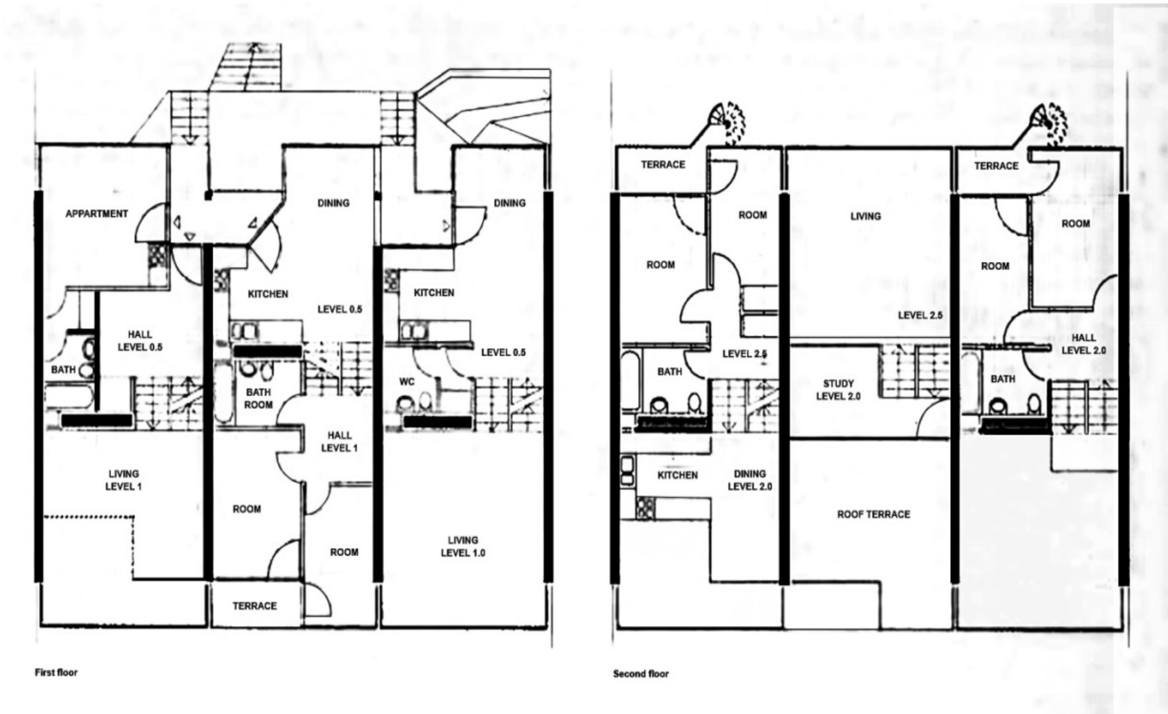

Figure 2.1. Wohnanlage Genter Strasse. Munich. Otto Steidle, 1972

Figure 2.2. Wohnanlage Genter Strasse exterior infill

One notable example of the supplementary space application is the Shinonome Canal Court in Tokyo, which is a large-scale development of 2,000 dwellings in combination with offices, commercial facilities and parking. The development consists of six large blocks around a central court in the Tokyo waterfront area. Each block was designed by a team of architects, including Riken Yamamoto and Toyo Ito, offering a range of accommodation from one-bedroom apartments (500 sq.ft.) to family dwellings of 1500 sq.ft. in size. The project brought a new style of home office called SOHO to Tokyo. A SOHO residential unit can be used as an office, a showroom or a studio. In the Yamamoto design, the larger units come with an 'F-room' (foyer room) which can be accessed directly from the public corridors (Figure 2.3). The F-room can be used as a home office. The walls, which are shared with the corridor, can be partially glazed. The F-rooms can be individual rooms, attached or non-attached to the dwelling. Most have a separate entrance to preserve the privacy of the rest of the dwelling. F-rooms are flexible and can be used for work or other needs in the future.

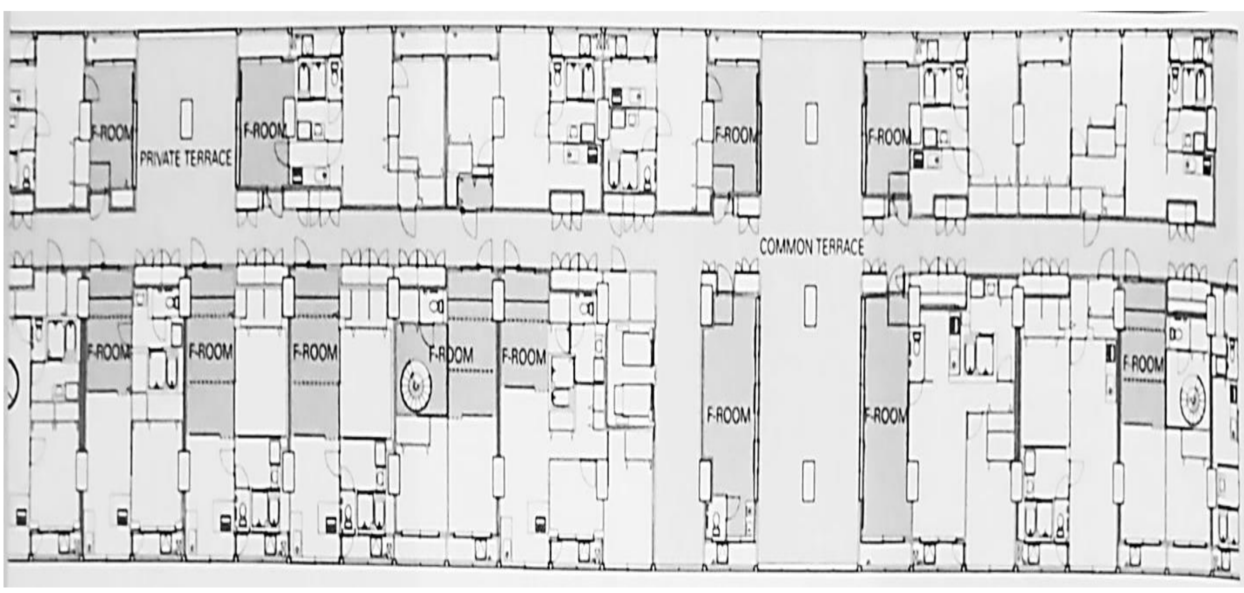

Figure 2.3. F-room in typical floor plan, Shinonome, 2003, Yamamoto (Leupen, Heijne, & Zwol, 2005)

The Azimieh Residential project is another example of allocating a specific area for supplementary space in a mid-rise residential project. Designed by the author, Azimieh Residential is a six-storey apartment building in Tehran, Iran. The architect was approached by the client to design a three-bedroom apartment where one of the bedrooms could serve as a guest room or an office with separate access. The suggestion was to allocate the third bedroom beside the main circulation, where the visitor does not intrude the privacy of the rest of dwelling (Figure 2.4). In an informal interview with the owner, the room was partially used as the guest room, and during the COVID-19 situation, it became a home-office.

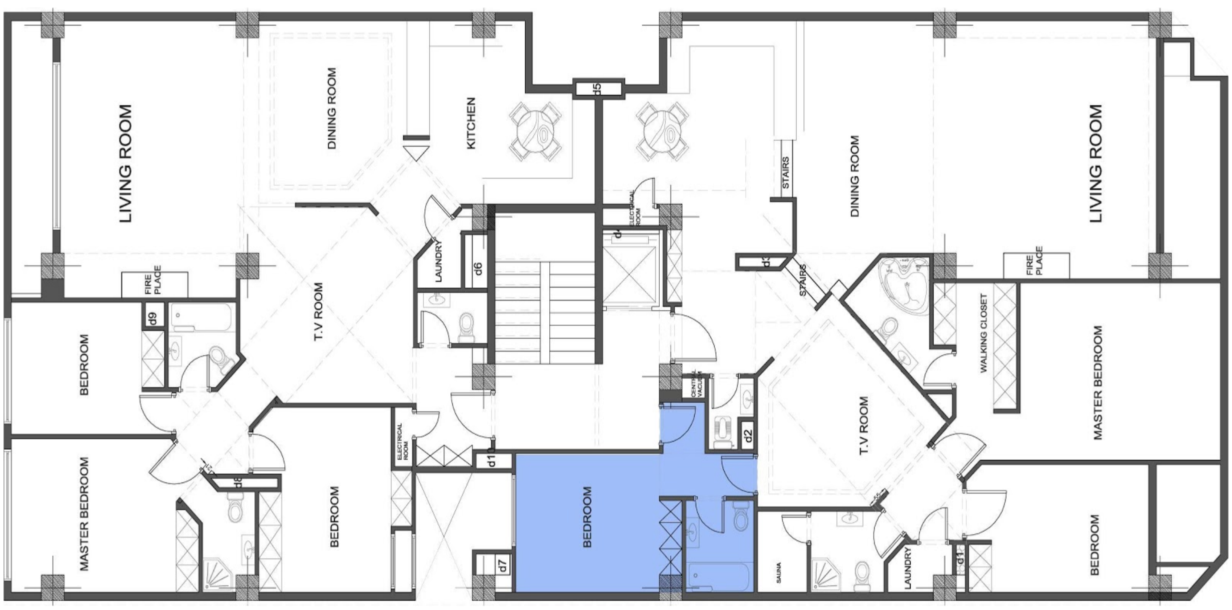

Figure 2.4. Azimieh residential project. Tehran, Iran. Designed by Sam Moshaver, 2015

2.1.2 Research Objective: Guidelines for Designing Supplementary Space

The present research focuses on the characteristics of supplementary space which must be considered in floor planning. Supplementary space can be used for different scenarios mentioned previously, with **working from home being the most common and demanding** emerging need in housing (as mentioned in the last chapter). Therefore, this research will focus primarily on accommodating that activity. Extracting the criteria of working at home, proposing a consequent model, and developing design guidelines will be the focus of this research. The same procedure can be used for other scenarios, where each scenario's criteria, consequence model and design guidelines could be generated. Supplementary space can be applied to all of these scenarios, where proposing design guidelines for each scenario will take place through research and design procedures. Once the supplementary space is defined as a workspace (in this research), modifying it to meet other needs, such as serving as a teenager's or parent's room, will be easier. The delivery of a supplementary space occurs in two stages:

- In the first stage, the architect incorporates supplementary space in the initial design process of floor planning.
- The second stage is the development of technical solutions, to respond to the features and modifications required to meet the user's needs.

2.2 Developing Methodology of Research

Traditionally the design of floor plans happens through practice, embracing 'evidence-based design' approaches. These approaches are based on other disciplines (sociology, psychology, environments) and formulating the design in a case-specific formula. 'Evidence-based design' formed the majority of efforts in research related to architectural design (Foqué, 2011).

However, descriptive knowledge of a status quo is not sufficient to support design decisions that target the future conditions of buildings. There is a need to develop more **knowledge** when designing for new states of buildings and on how to assess them. Furthermore, more recently (late 20th century) there has been a need to generate knowledge that goes beyond the support of case-specific design through the work of Christopher Alexander (*A Pattern Language*) and Constance Perin (*With Man Wind*). Designers in practice often find it difficult to translate 'evidence' from other disciplines into practical application, especially when knowledge is very abstract (Eliasson, 2000; Kantrowitz, 1985; Nassauer & Opdam, 2008). Additionally, time constraints or simply the nature of assignments can make it hard for design professionals to find relevant evidence that can inform their designs. Consequently, this lack of evidence also makes it hard to assess design results on a reliable basis.

The following sections will elaborate on the discourse of *design inquiry* and its framework. The framework of design inquiry leads to research through design (RTD) as one of the common methodologies in design research.

2.2.1 Background of Design Inquiry and its Framework

By searching through literature, there are no commonly accepted meanings of the terms "design" and "design literature" among design researchers (Saikaly, 2005). However, researchers agree that design is "concerned with the making and doing aspects of human activity, distinct from sciences and humanities" (Saikaly, 2005). From a methodological standpoint in his book, *The Science of the Artificial*, Herbert Simon defines design as:

> "Courses of action aimed at changing existing situations into preferred ones. The intellectual activity that produces material artifacts is no different

> fundamentally from the one that prescribes remedies for a sick patient or the one that devises a new sales plan for a company or a social welfare policy for a state." (Simon, 2019, p.63)

In his book, he further distinguishes between natural science and design as follows: "The natural sciences are concerned with how things are. Design, on the other hand…is concerned with how things ought to be" (Simon, 2019, p.68). In his book *Notes on the Synthesis of Form*, Christopher Alexander distinguished between designers and scientists: "Scientists try to identify the components of existing structures; designers try to shape the components of new structures" (Alexander, 1964, p.47).

Two theoreticians who touch on this issue in an interesting way are Nigel Cross and Bruce Archer, who describe design as "the area of human experience, skill and understanding that reflects man's concern with the appreciation and adaptation of his surroundings in the light of his material and spiritual needs", distinct from science and humanities (Dowlen & Ledsome, 2006, p.3). Archer also describes the different ways of collecting knowledge in design as compared with sciences and humanities. In the sciences, observation, measurement, and testing, and in the humanities interpretive knowledge, criticism, and evaluation are the main ways of acquiring knowledge. In design, knowledge is collected by sensibility, invention, validation, and implementation. In his book *designedly ways of knowing,* Nigel Cross defines the design research related to both design process and design products as follow:

> "Designers tackle 'ill-defined problems;'
>
> Their mode of problem-solving is 'solution-focused;'

> Their mode of thinking is ‘constructive;’
>
> They use ‘codes’ that translate abstract requirements into concrete objects;
>
> They use these codes to both ‘read’ and ‘write’ in ‘object languages;” (Cross, 2006, p.65)

As explained earlier, scientific thinking tests the hypothesis in the form of an explanatory model. Design thinking, on the other hand, creates many hypotheses to contextually respond to the issue. The testing is done through choosing the most optimal result. In his book, *Building Knowledge in Architecture,* Richard Foqué distinguishes design testing as follows:

> “In scientific inquiry, testing is based on verification. The results should be objective, repeatable, and universal. In design inquiry, testing is based on both verification and appreciation” (Foqué, 2010, p.42).

According to Foqué, the framework of assumptions and premises on which decisions are being made in design inquiry should be made explicit. His book further elaborates on the design inquiry process as follows:

> “This is not to say that it should be a general metaphysical analysis, but it should make transparent how the specific design beliefs are determining the normative knowledge about the physical world and how this physical world should be organized. It refers to pragmatic thinking, where it reflects the unity of the process of learning and experience, of conceptual thought and situational consciousness.” (p.124)

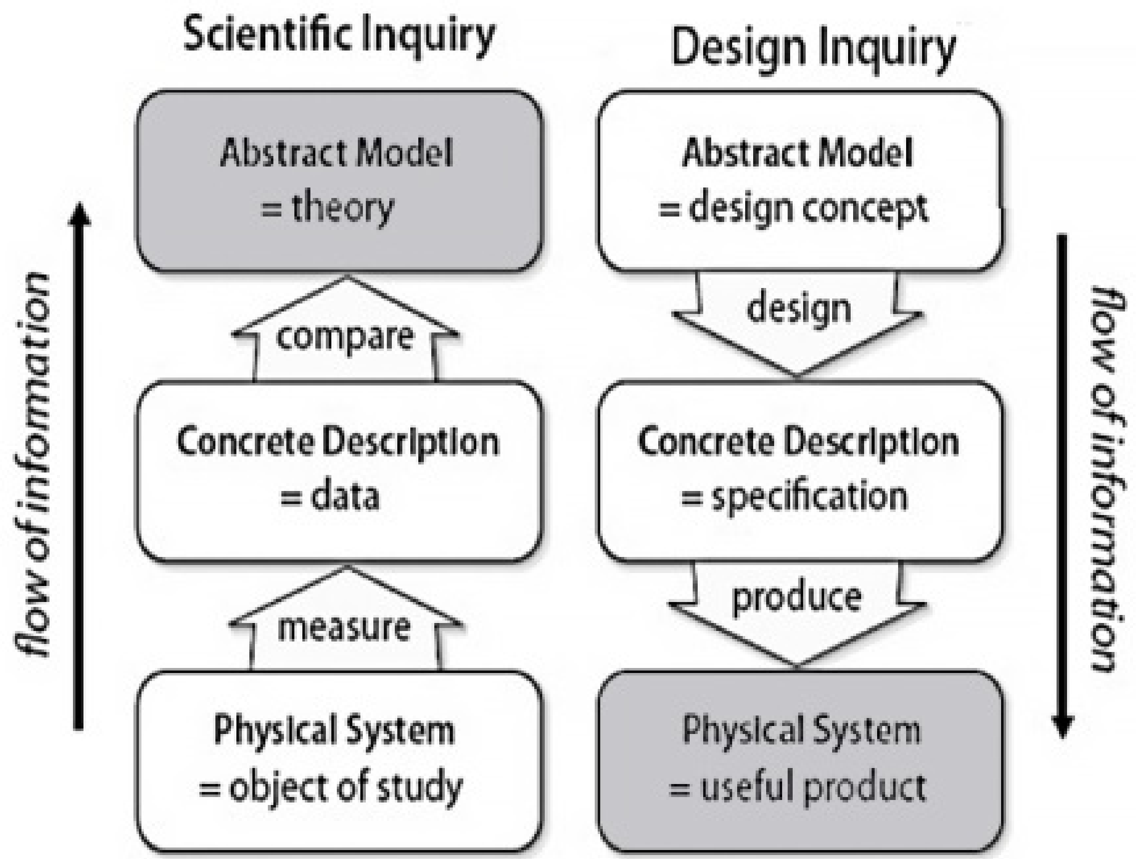

Figure 2.5. The antiparallel structures of scientific inquiry versus design inquiry

In design inquiry, the hypothesis is tested based on the context and a specific situation, where an interrelated approach is taken to locate the outcome(s) and evaluate them within said context (Figure 2.5). The evaluation is rationalized based on both the subjective values and objective perceptible facts. This is where the creativity of the researcher comes into account.

2.2.2 Research through Design

Design research, due to the relevance of people, processes, and products, deals with an inseparable mix of purposes and subject matters. Findeli's approach of Research Through Design (RTD) builds upon Frayling's differentiation between research "for"," about", and “through” design, which is discussed below. It also builds upon Cross’ argument regarding “designerly ways of knowing” and Archer’s early definitions of design research. Both Cross’ argument and Archer’s definitions are also discussed below, each in its respective historical context. Findeli defines design research as follows:

> “Design research is a systematic search and production of knowledge related to general human ecology considered from a designer way of thinking, i. e. a project-oriented perspective.” (Findeli, 2010, p. 287)

The approach that he proposes, RTD, seeks to answer a research question through the inquiry of a design question (Findeli et al., 2008, p. 86). In Findeli’s work, two different methodological descriptions of RTD can be found. In one description, a design question is transformed into a research question as a first step (Figure 2.6). The other description starts with the research question, which is then transformed into a design question (Figure 2.6). In both descriptions, the third step is the finding of a **design answer**, from which, in the fourth step, a research answer is extracted. Hence, it may be assumed that one may start with either a design question or a research question – depending on the starting conditions – as long as a design answer is found, which can then contribute to a research answer. Thus, Findeli’s approach can be viewed as belonging to the general field of RTD, which is concerned with “designerly” ways of research (Saikaly, 2005). According to Bardzell et al. (2012, p. 288), designing is often considered to be the central activity within such “constructive design research”. Findeli’s approach emphasises the interplay of **practice** and **theory**, as well as the interplay of design and research.

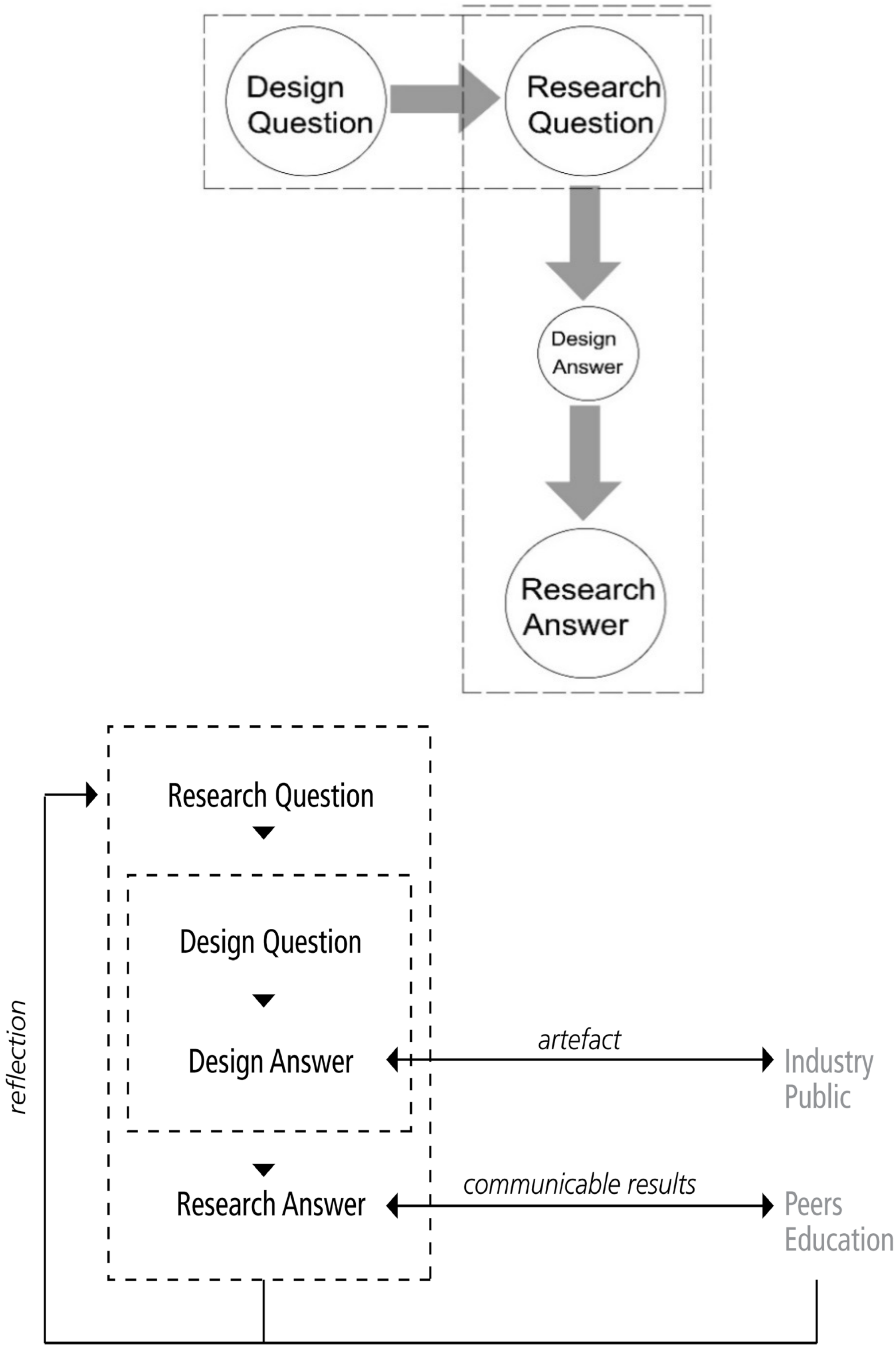

Figure 2.6. .Two types of RTD, proposed by Findeli (after Findeli, 2010)

Oya Ataly Frank, in her article "what should be the criteria for a doctorate in architectural design", elaborates as follows:

> "In fact many architects claim to perform research when designing a building. However, there is a fundamental difference if the research is executed in ad-hoc and understructued manner or in a systematic, thorough, and 'scientific' manner. RtD objective is not design of a building but an issue investigated by means of designing- and somehow related to it" (Figure 2.7) (Nilsson, Dunin-Woyseth, & Janssens, 2017, p.58).

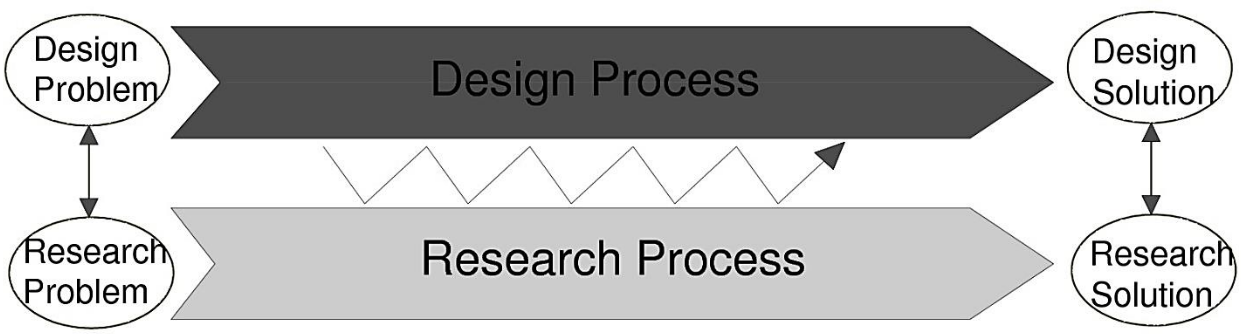

Figure 2.7. Research through design process (after Nilsson et al., 2017)

She further makes distinction between design and research outcomes as follow:

> "The distinction is relevant because a designed object cannot be considered as the 'main outcome' of research. Research must always lead to knowledge—it is knowledge that is the principal outcome of academic research. A design may be the carrier—or, as Nigel Cross puts it—the 'source' of knowledge. Outcomes of research cannot be the design of an object" (Nilsson et al., 2017, p.56).

2.2.3 Selection of the First Description of Findeli's Approach

Findeli's first approach description is chosen for this study. The study starts with the design question: How to incorporate supplementary space in the early design stage of multi-family housing? It then leads to the research question of how to propose a theoretical model for supplementary space to synthesis the criteria? (Figure 2.8). The design answer is in the context of research question, proposing **generic model** (guidelines for supplementary space). The research answer is the ultimate response to incorporating a supplementary space as well as incorporating DFD (Design for Disassembly) in housing.

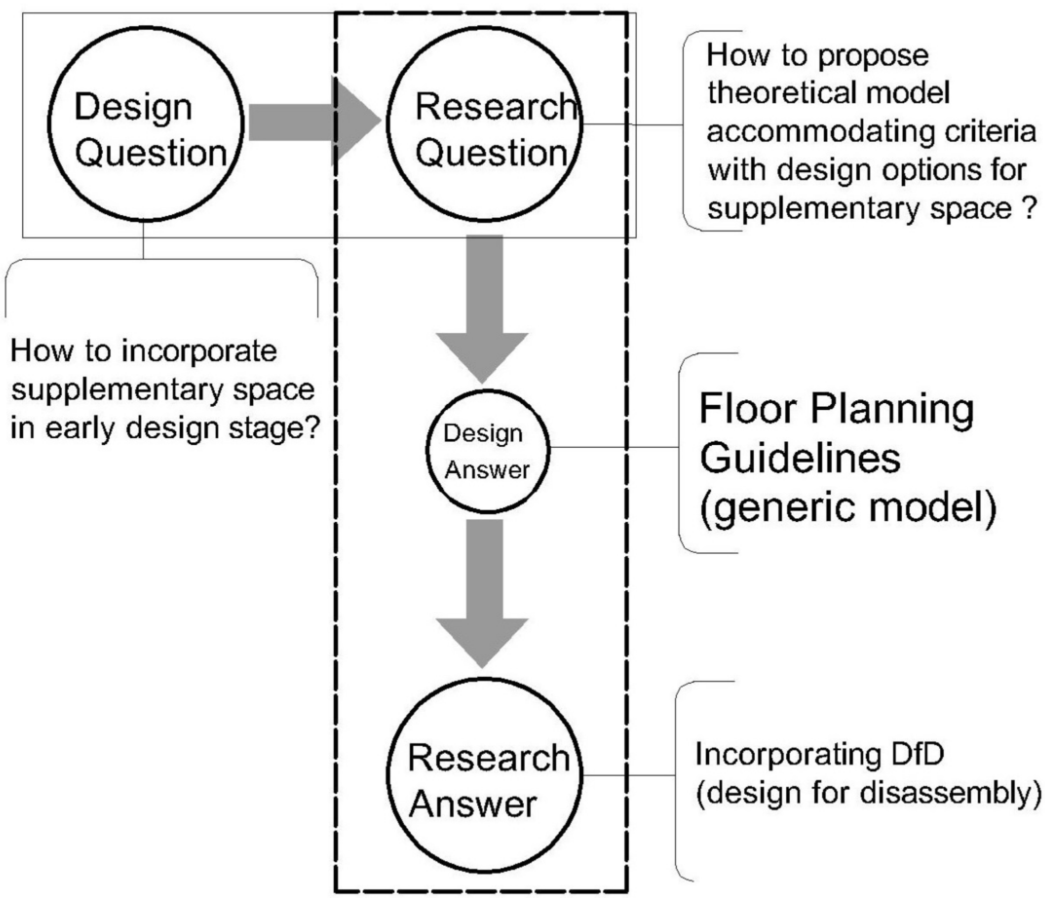

Figure 2.8. Research framework based on Findeli approach

2.3 Scenario Design (Intuitive Methodology)

According to Nielsen (1994), scenario-buffered design is a broad term for the application of different design techniques to life cycle planning of a product. That planning helps to extend the lifespan of the product system (de Bont, den Ouden, Schifferstein, Smulders, & van der Voort, 2013). He further suggests that scenarios have two purposes during the early design process:

- A scenario is a thinking tool to envision different future uses of the product system.
- It is also a contextual reference to evaluate the solutions (Nielsen, 1994).

The first purpose of creating scenarios is to generate a thinking tool that allows the designer to imagine possible future uses of the space. The designer considers the potential need for different design products based on various assumptions. Furthermore, scenarios can create different problem platforms, which help the designer to come up with different solutions for each problem (de Bont et al., 2013).

The second purpose of scenarios is the evaluation of design solutions. The scenario works as a virtual environment that represents the future of the product system, allowing the designer to decide how it will be used. It is important for the designer to create a valid scenario that represents the possible future of the situation (de Bont et al., 2013; Nielsen, 1994).

2.3.1 Scenario Planning to Deal with Uncertainty in Design

According to Chermack (2011), scenario planning is a discipline that seeks to predict the future and is normally used by organizations in their business planning strategies. A business scenario is evaluated in terms of financial, political, transport, land use, and marketing components to judge whether it can adapt to a given environment in the future. Through these examinations, the investigators attempt to create a picture of how well their plans will work over a certain timeframe. The discipline has become increasingly significant in analysing unpredictable environments for future market segmentation and business positioning (Chermack, 2011).

Godet and Roubelat (2000) define scenario planning as a framework that projects highly flexible plans for the future. They maintain that the tool is **vital in emerging situations where the outcome is difficult to define** (Figure 2.9). Some organizations, such as Royal Dutch Shell, the pioneer of this technique, have applied it with great success in the midst of economic crisis coupled with shrinking oil prices, whereas their competitors, who did not implement said technique, suffered (Godet & Roubelat, 2000; Schacter, Addis, & Buckner, 2008).

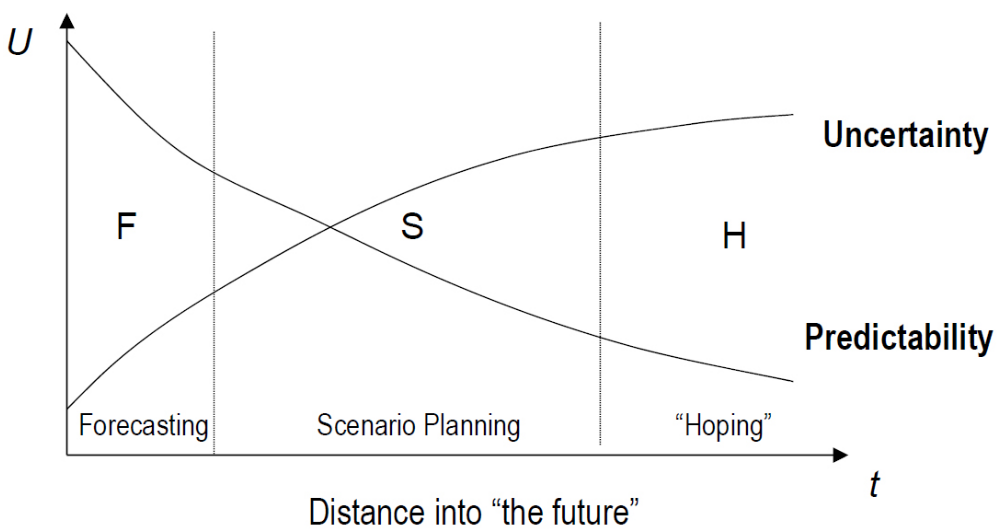

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Figure 2.9. Relationship of hope and uncertainty (Van der Heijden, 2011)

In environmental design, scenarios have several characteristics that make them a helpful tool for dealing with future uncertainty. Accommodating these characteristics is mainly deduced during the early decision-making stage for different emerging situations (scenarios). Steane and Steemers (2013), in their book *Environmental Diversity and Architecture,* list them as:

- Breeding plans and developments that will provide a gateway to exploring the future and shape desired outcomes.
- Thinking more broadly about the future, for finding compelling answers to design scenarios.
- Creating a context in which decisions will be made based on prior information.
- Developing solution(s) for issues that might affect the whole system within one scenario (Steane & Steemers, 2013).

Chermack (2011) argues that scenarios should not be confused with decisions themselves but should rather be seen as indicators of whether to proceed with undertaking a decision or considering a different one. The scenarios are tools for providing information to decision-makers, who then choose whether to act on this input based on their own ideas about the future and on the internal operations of their environmental context (Chermack, 2011; Wege, 2009).

Several sources can be used to inspire scenario generation. Nielsen (1995) differentiates between sources that are based on empirical observations and those based on the designer's ideas, meaning that scenarios can be built to reflect either the world as it is now or the world as it may evolve. Lifestyle, for instance, can be observed empirically (Blomberg, Garland, & Ives, 2003). Carroll (2000) also provides scenario generation sources, including participatory design, the reuse of prior analyses, scenario typologies, technology-based, scenarios theory-based scenarios, and transformations. User involvement is another source of inspiration. This involvement can take the form of either empirical observations, in which most users play a less active role, or participatory design and scenario generation, in which users are more active.

2.3.2 Scenario-Buffered Planning

In building design, a similar approach to that of product design must be taken, in which the architect determines the cycles the building is about to face. The choice of materials, layout, construction, etc. is anticipated based on the service life of the building. The fact that a building is a complex entity, composed of thousands of components with different performance levels and requirements, imposes great risk on the designer. Even after using rational design methodology, predicting the building's eventual fate will be fraught with uncertainty (Steane & Steemers, 2013). The way to accommodate this is to reduce the risk by constructing a building that can readily cope with a wide range of unforeseen future situations.

Programming enables designers to determine the optimal function of a building to project its future usage. During the programming phase, the most used method is to first identify the applicable user groups correctly, in order to identify the primary needs. Next, designers turn the information into spatial drawings describing data in terms of quality and quantity (Brooks et al., 2009). Finally, they write down the concise design to be used by the team. The scenario-buffered technique attempts to create strategies that will enable the building to continue to be of service. This is distinguishable from the task of visualizing the probable future of the structure.

Another function of scenario-buffered design is to give users a series of alternatives for future occupancy. Designers may deliberately leave a section of the work uncompleted or completed slightly rather than finishing the whole building to the same level of completion. For example, the “Base Building” approach on the office building market, allows the user to finish the space based on their evolving needs. Or in another example, a teenager’s bedroom may eventually be converted into an office (Palladio, 2014). This also enables users to select the suitable equipment to be used.

The creation of adaptable scenarios is an alternative way to incorporate change into the design layout (Kester, Ruskin, Lee, & Anderson, 2007). Scenario-buffered design, as well as the other programming methods, depends heavily on a projection of many distinct and probable outcomes. The diversified lifetime method is a strategy through which buildings may accommodate change via physical reconfiguration.

2.4 Systems Approach (Deductive Methodology)

The deductive solving approach is based on the conditions facilitating achieve research objective. It starts from existing knowledge and leads to **new knowledge**, or an additional provision to meet the objective (Wilson, 2014). Interrogating the objective in the early stages of the design process is the goal of the systems approach. The systems approach is a step-by-step procedure that allows the designer to identify the needs and criteria leading to the generation of the optimal solution to any given problem

2.4.1 The Concept of Systems

There are myriads of general system definitions. One that is particularly clear can be found in Maier and Rechtin: “A system is [a] collection of different things that together produce results unachievable by themselves alone. The value added by systems is in the **interrelationships** of their elements” (Maier, 2011, p.27). According to Meadows, “a system is a set of elements or parts that is coherently organized and interconnected in a pattern or structure that produces a characteristic set of behaviors, often classified as its function or purpose” (Meadows, 2008, p.188).

A system is constituted by elements and things interrelating in a complicated manner. The pieces of elements that generate the environment are referred to as things. People in this case are perceived to be goal-oriented, seeking objectives by pursuing goals. A system can exist at the level of a city, a region, a town, a building, or a single space within a building. Depending on the level, a system on a smaller scale can be viewed as a sub-system or component (Markus, 1972).

2.4.2 General Systems Theory

In the twentieth century, Karl Ludwig von Bertalanffy theorized that advancements in engineering and computer science were on their way to mending the disconnection that over-specialization in certain technological fields had produced. Over-specialization was also a problem within his own specialty of biology, and this realization led him to become a pioneer of the general systems theory. This theory states that specific scientific disciplines should be encompassed within a system that applies to multiple areas of knowledge. Vibæk stated in his book (2014), *Architectural Systems Structures: Integrating Design Complexity in Industrialized Construction:*

> “It turns out that there are general aspects, correspondences and

> isomorphisms common to "system." This is the domain of a general system theory. General system theory is scientific exploration of "wholes" and "wholeness" which, not so long ago, were considered to be metaphysical notions transcending the boundaries of science". (Vibæk, 2014, p.63)

According to Bertalanffy, "a system is exchanging with its environment, presenting import and export, building up and breaking down of its material components" (von Bertalanffy, 2003, p.34). Systems theory is a method for understanding phenomena in different disciplines. It is described as "the trans-disciplinary study of the abstract organization of phenomena, independent of their substance, type, or spatial or temporal scale of existence" (Dori, 2002, p.7). Systems theory focuses on the relations of parts (e.g. organs, muscles, and cells), rather than on studying each part by itself. It examines how all the components interact with one another. The behaviour of the system is "independent of the properties of the elements. This is often referred to as holistic" (Ansari, 2004, p.1).

2.4.3 Open and Closed Systems

Systems theory is divided into two different categories: closed systems, which stem from
2.4.3
the study of classical physics, and open systems, which are derived from biology. The modern version of closed system theory, cybernetics, was discovered by Norbert Wiener (a philosopher and mathematician), while the open system theory was proposed by biologist Van Bertalanffy.

Open systems allow interactions between internal elements and the environment. An open system is defined as a "system in exchange of matter with its environment, presenting import and export, building-up and breaking-down of its material components" (Figure

2.11). Closed systems, on the other hand, are isolated from the environment. For example, equilibrium thermodynamics is a field of study where the closed system applies (Figure 2.10).

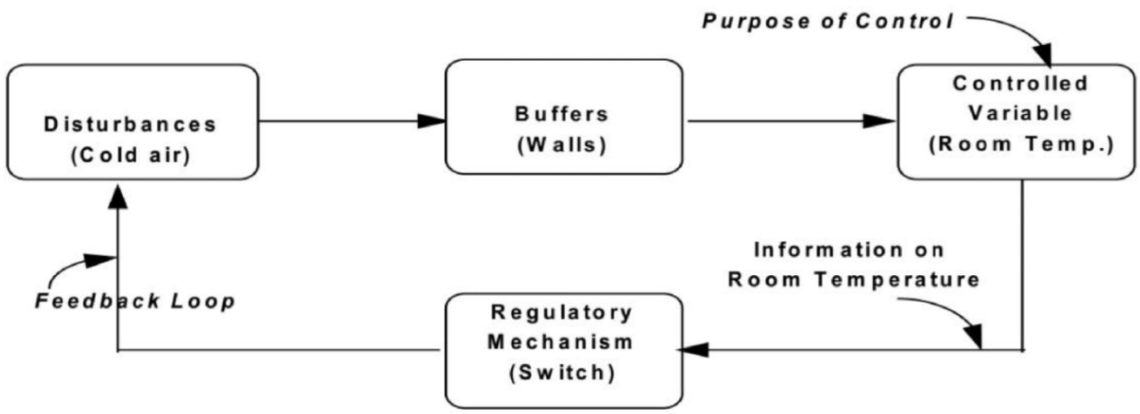

Figure 2.10. Closed system, a typical thermodynamics loop model (Ansari, 2014)

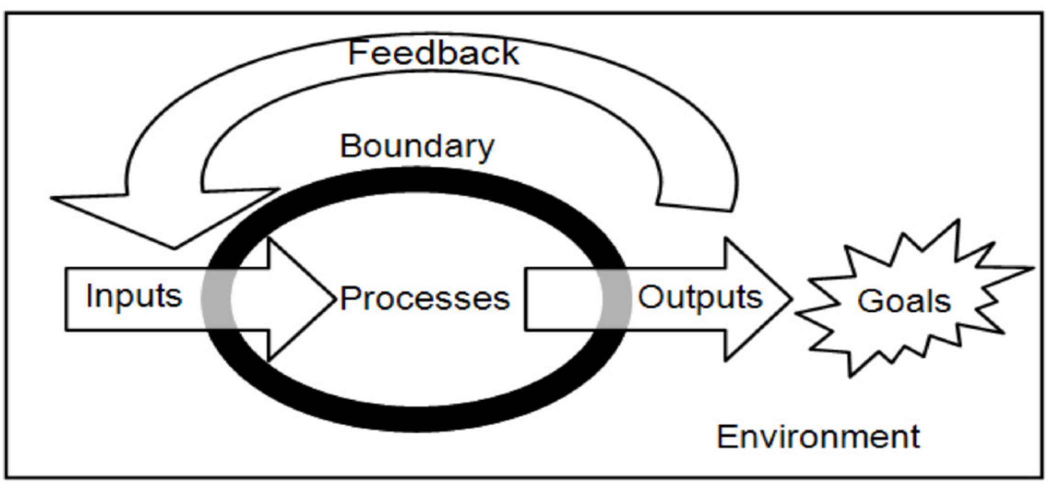

Figure 2.11. Simple open system of environment (Ansari, 2014)

In open systems, due to the unpredictable nature of the environment and the delicacy of the life cycle, the ability to adjust small mistakes without negatively impacting the big picture was greatly reduced. Furthermore, closed systems are not goal-oriented phenomenon. Instead, the aim is to maintain an existing system, whereas, in open systems, there is a goal which must be achieved through the utilization of system. According to the book

Architectural Systems Structure:

> "Architectural design is ultimately defined by the conscious or intuitive choices of the architect as an integration of architectural concept and the various demands, potentials and vision of project- resulting in an ill or loosely defined design problem expressed as the building itself. Architectural design can as the combination of concept and process leading to a final product, tentatively seen as an open system of respectively information (concept/thought), energy (process) and material (product/matter) that evolves from idea or concept towards a dynamic but steady state- the 'final' building' expressed physically through the applied building materials. The idea of architectural design is the goal or finality- but the ways to reach that goal can be manifold." (Vibæk, 2014, p.65)

The existence of different stakeholders (occupants with different interests) in the unit, and a goal-oriented purpose of reaching space for emerging needs, makes supplementary space a field of study that applies to open systems. In designing for supplementary space, there must be an interaction between internal elements and the environment (the other occupants). For example, the issue of privacy and noise in supplementary space affects the other occupants in the unit, so the location of supplementary space, and the goal of not intruding on the privacy of users makes supplementary space an open system.

2.4.4 Design-Decision Process

In environmental design and architecture, the design-decision process is a recognized means of solving problems. Its procedure consists of five steps (Andresen, 2000), as shown on Figure 2.12.

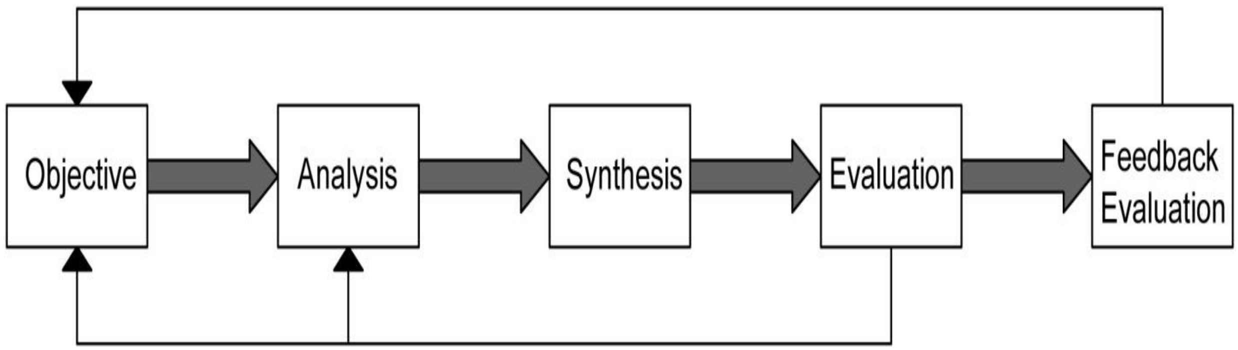

Figure 2.12. Design decision-making process (Andresen, 2000)

The first phase is to identify the objective, the nature of the problem, and the goals that must ultimately be achieved. The second phase is to collect the information extracted from the objective, formulate the data into criteria, and divide the criteria into sub-criteria (implications), similar to a shopping list. By analogy, when a shopper brings a list, they do not forget what to buy and do not purchase anything irrelevant. The third phase, synthesis, is the formulation of options to meet the criteria and the selection of the most compatible and highest-performing solutions (optimisation). Next comes decision making and simulating (testing) the optimal solution. The last step is to evaluate the optimal solution already tested in the simulation phase, measuring whether it fulfills the criteria, and calling for feedback from the objective (Andresen, 2000).

According to Markus, the feedback decision-making loop "divides up the total time into phases which develop from the general and abstract to the detailed and concrete." Based on his model, the design decision-making process has three phases:

- Analysis (understanding the problem): This phase is about gathering all the information extrapolated from the objectives, criteria, requirements, and previous experiences on the issue.

- Synthesis (producing a design solution): Based on the criteria and information, the designer identifies solutions to the sub-problems and interfaces them into the total design problem. The aim is to first individually offer solutions to sub-problems, then generate a single overall solution.
- Implementation (evaluation): The performance of the solution is established through representation and measurement. In this phase, the solutions are modeled; the model might be verbal, mathematical, or visual. The evaluation, which can be done using various validation methods, determines whether the solution is approved (Voordt, 2005).

In designing for supplementary space, the options are tested against the context and its specific situation. The evaluation is rationalized based on both the subjective values and objective perceptible facts. This is where the architect's creativity comes into play. For instance, locating the supplementary space in a way that does not intrude on the rest of the occupants is a subjective solution based on the designer's intuition. On the other hand, the acoustics of the space is an objective criterion that can be tested by machine and designed for accordingly.

2.4.5 Selection and Application of Systems Approach as Deductive Methodology

The deductive, problem-solving methodology allows the designer to provide a suitable solution by interrogating the objective in the early stages of the design process. The systems approach is a step-by-step procedure that allows the designer to identify goals, needs, criteria, and optimal solutions to any given problem (Figure 2.13). This approach calls for a rational methodology wherein the objectives and criteria are investigated by the designer to identify relevant solutions (Figure 2.13).

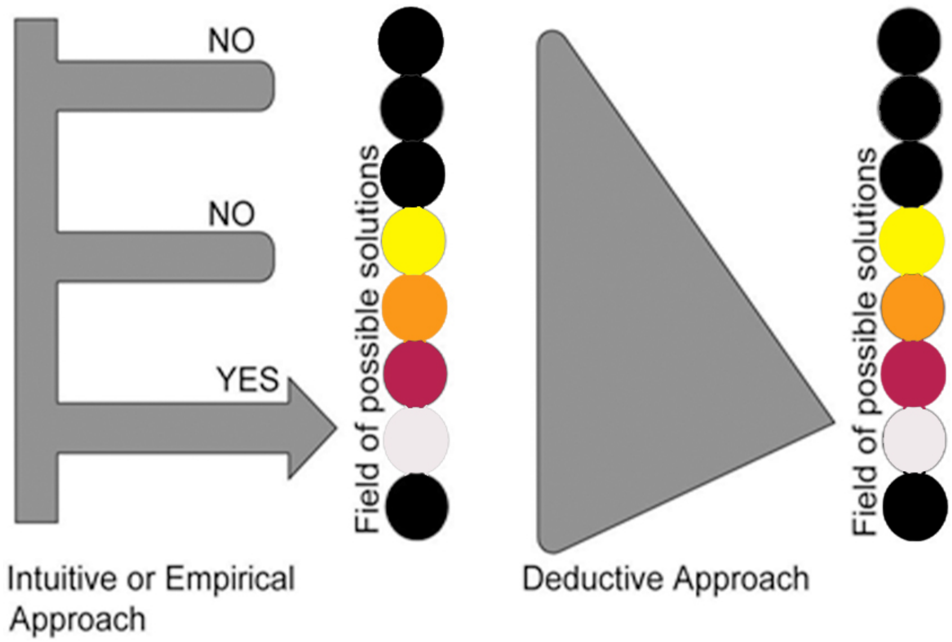

Figure 2.13. Strategic difference between the intuitive/empirical and deductive approaches (R. B. Richard, 2007)

This approach calls for a rational methodology wherein the objectives and criteria are investigated by the designer to identify relevant solutions.

2.4.6 Systems Approach Sequence

The systems approach is similar to design decision-making, because both extrapolates from the objective. According to Richard (2007), the systems approach can be applied to architectural design. First, "the process search(es) for functional indications on WHAT to build and after for technical indications on HOW to materialise it." The result will be a generic model that can be applied to developing the supplementary space for different housing types.

The seven stages of the systems approach will be explained briefly hereafter. In the next chapter, the supplementary space will be generated based on these stages (Figure 2.14).

1. **Functional Criteria**: These are the user's needs, similar to a shopping list. In the book, *A Pattern Language,* Alexander (2008) offers a suitable collection of architectural criteria.

2. **Incubation**: After the full list of criteria is created, the designer must organize and formulate them into a set of common goals.

3. **Generic Model:** The aim of the model is to "vectorize" all the criteria into different sub-systems; the outcome is similar to the preliminary sketch generated in the intuitive approach. This will show what the final solution could be.

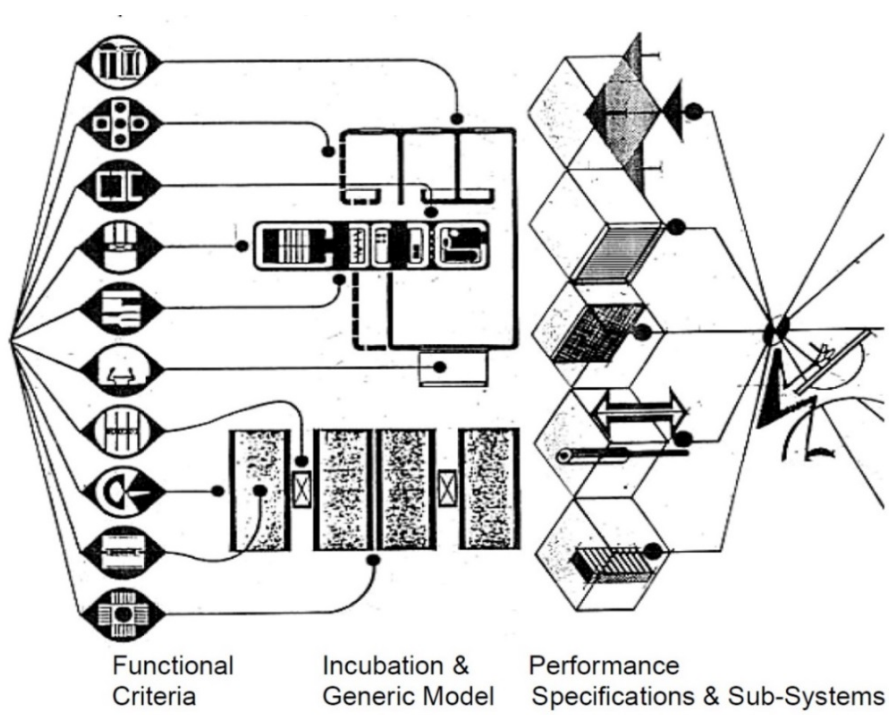

Figure 2.14. Functional analysis and synthesis (Richard, 2007)

4. **Performance Specifications:** To analyse the solutions, their performance must be measured. This allows us to see how the products perform rather than what they need to be. Performance specifications will be used to identify the suitable technologies (options) by the designer to fulfill the objective. For instance, the specifications for the beam are its size, span, and resistance to live and dead load.

5. **Sub-Systems:** The specifications are usually grouped into sets corresponding to the main function of the building; these are known as sub-systems. Typically, the building has five sub-systems: structure, envelope, partitions, services, and equipment; the finishes could be considered as a sixth one.

6. **Compatibility Matrix:** The best method to study the compatibility of one sub-system with the others is to create a matrix. A successful set of compatible sub-systems is called a possible path. At least three complete solutions should be evaluated from all the possible paths to recognize the optimal one.

7. **Simulation:** The solutions should be tested using a physical or virtual model. This stage involves **feedback and evaluation** to verify whether the solution meets the demands.

Application of RtD as the methodology, with respect to scenario planning and the systems approach, is presented in Figure 2.15. Scenario planning creates the context for research (such as working from home) and the systems approach is used as a tool to synthesize the criteria in order to reach the objective.

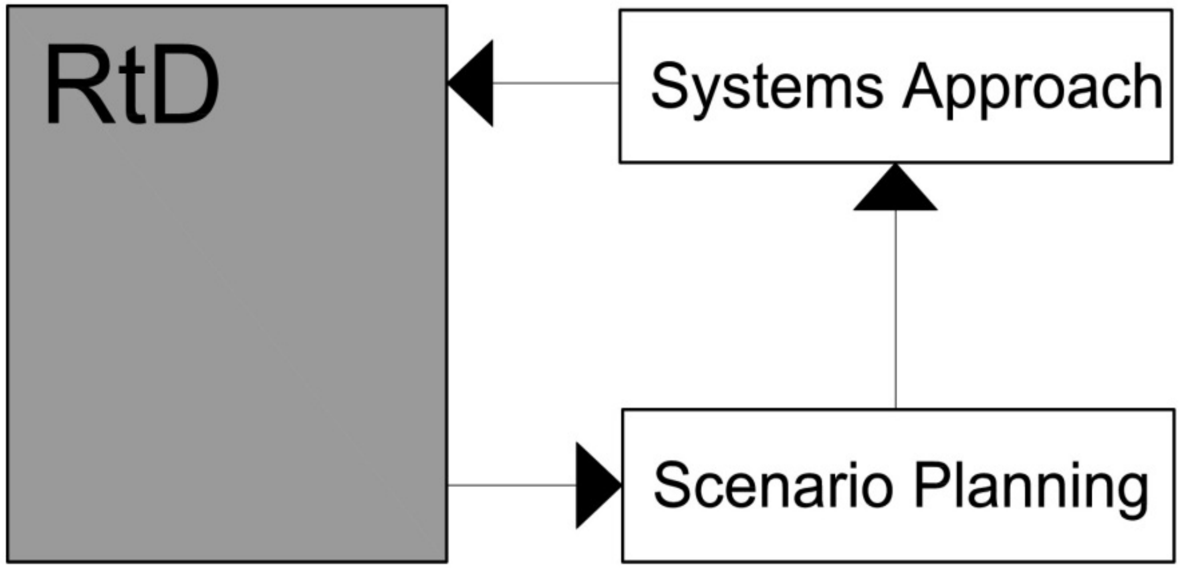

Figure 2.15. Scenario planning and systems approach with relation to RtD

2.5 Knowledge Model

Models are one of the most fundamental tools used to solve problems in architectural research. A generic model is an abstract, simplified version of the real world. Models are created to easily understand, perceive, and contextualize problems, and subsequently help to better solve them. Indeed, "a model for a scientist is a way in which human thought processes can be amplified" (Churchman, Whitton, Claridge, & Theng, 1984). A model assists architects in translating thoughts into an image of reality. The complexity of the model depends on the objectives, goals, and processes being deployed in it.

Knowledge models have been categorized differently in literature. In general, they are classified based on the disciplines in which they are used, such as management and business, artificial intelligence, and environmental science. These models are mostly associated with various design methods since their aim is to "articulate" the methodology.

Knowledge modelling is the schematic representation of an information system.

According to Mylopoulos, “knowledge modeling is the activity of formally describing some aspects of the physical and social world around us for purposes of understanding and communication” (Kwon, 2011). A knowledge model **itemizes** the **options** and **criteria** in a way that allows each one to be studied individually. There are two background approaches that help with the structure of the model: classification theory and decomposition theory.

Classification theory: In his article, “Classification Theory and the Number of Non-Isomorphic Models”, Brad Hart notes that:

> “The goal of classification theory is to discover lines between classes that have structure theory and those that do not. The results of classification theory for a particular class can be variously viewed as evidence for or against the existence of a structure theory for that class. A secondary issue in classification theory is the selection of the classes to examine” (Hart, 1993, p.1074).
>
> Figure 2.16 shows the application of classification theory in the mathematical theory of graphs. Such an approach can be taken with respect to building criteria and components where classification of related group criteria and components with each helps achieving the objective. For instance, classification of building systems to structure, envelope, services, partitions, and equipment was inspired from the classification theory. Where building components are grouped into distinct category based on their role.

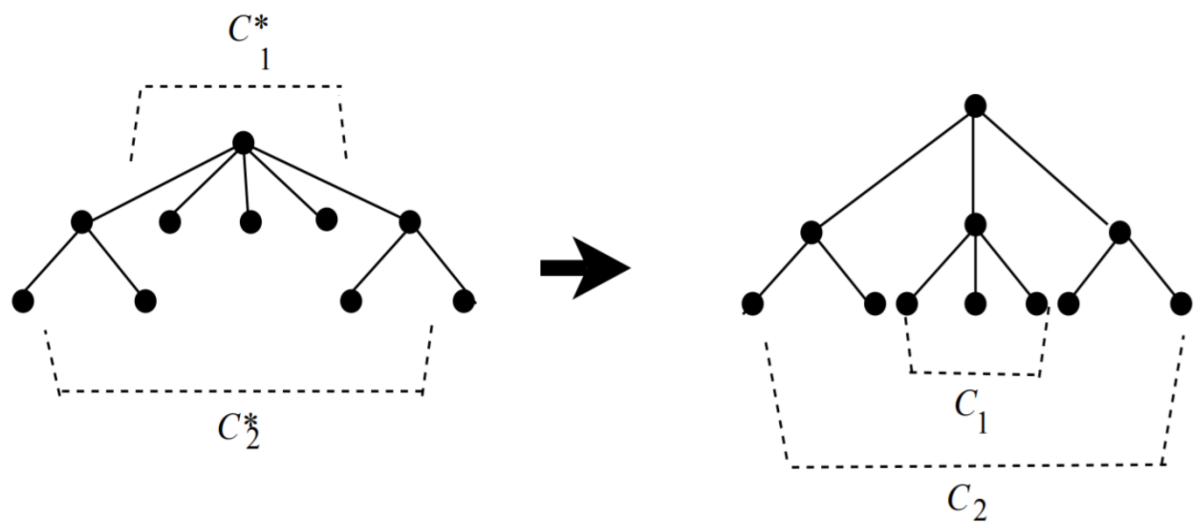

Figure 2.16. Mathematical theory of graph classification (Mirkin, 2013)

Decomposition Theory: This theory shows that every component of a system can be decomposed into smaller components, which can then be studied. The aim of decomposition theory is to present complex structure as simpler components (Figure 2.17). The simpler components achieved, can be translated to the form (Bratteli & Robinson, 2012).

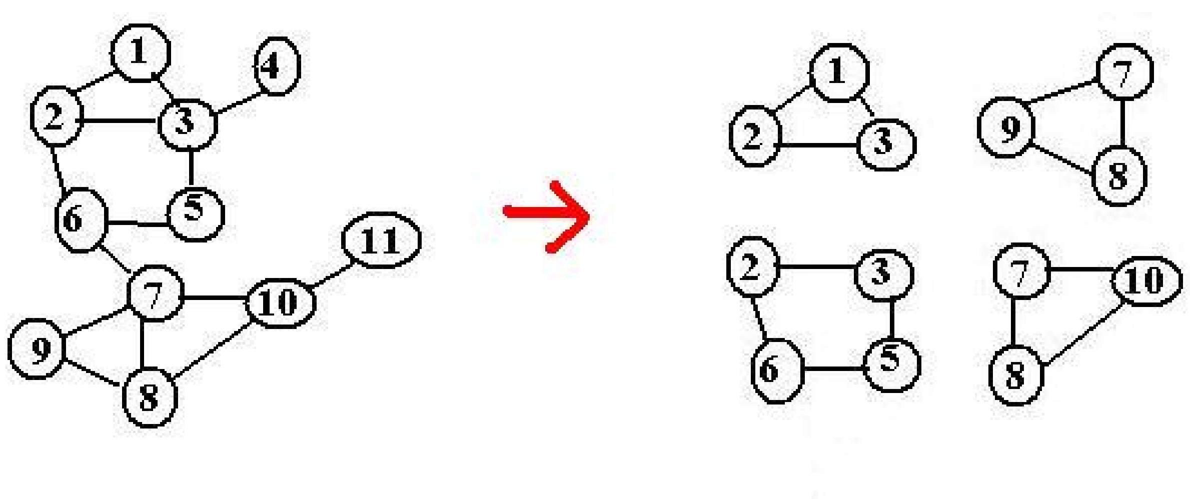

Figure 2.17. Example of graph decomposition theory (Gusfield, Bansal, Bafna, & Song, 2007)

Decomposition theory is used to breaking down building systems to manageable building elements. For example structure system can be broken down to building elements_ post, beam, slab, foundation, etc. Each building element can be modified/designed separately within the framework of its system.

In the 1980s, both approaches were used to generate mathematical knowledge models. Later, these theories inspired design and business knowledge models and eventually were used in other disciplines. The combination of classification theory and decomposition theory creates the foundation of domain models widely used in design researches (Figure 2.18) (which will be explained in the next section).

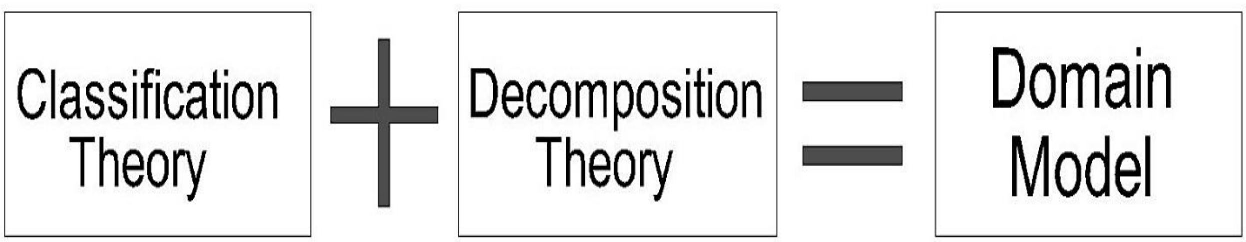

Figure 2.18. Creation of domain model

2.5.1 3D Domain Model

In their article "The Core of Domain Model", Oosterm describes the domain model as such:

> "A domain model is a type of knowledge model that incorporates representations of behaviour and data at the same time. It includes the various entities, their attributes and relationships, plus the constraints governing the conceptual integrity of the structural model elements

comprising that problem domain." (van Oosterom et al., 2006, p.632)

A domain model may also incorporate several conceptual views, where each view is pertinent to a particular subject area of the domain or to a subset of the domain model that is of interest to a stakeholder. As demonstrated in the Figure 2.19, it often represents database entities, using simple diagramming techniques to illustrate one-to-one, one-to-many, and many-to-many relationships within the system (Al-Kamha, Embley, & Liddle, 2008). The 3D domain model was chosen as a knowledge model for the supplementary space, and it will be discussed in more detail in chapter 5.

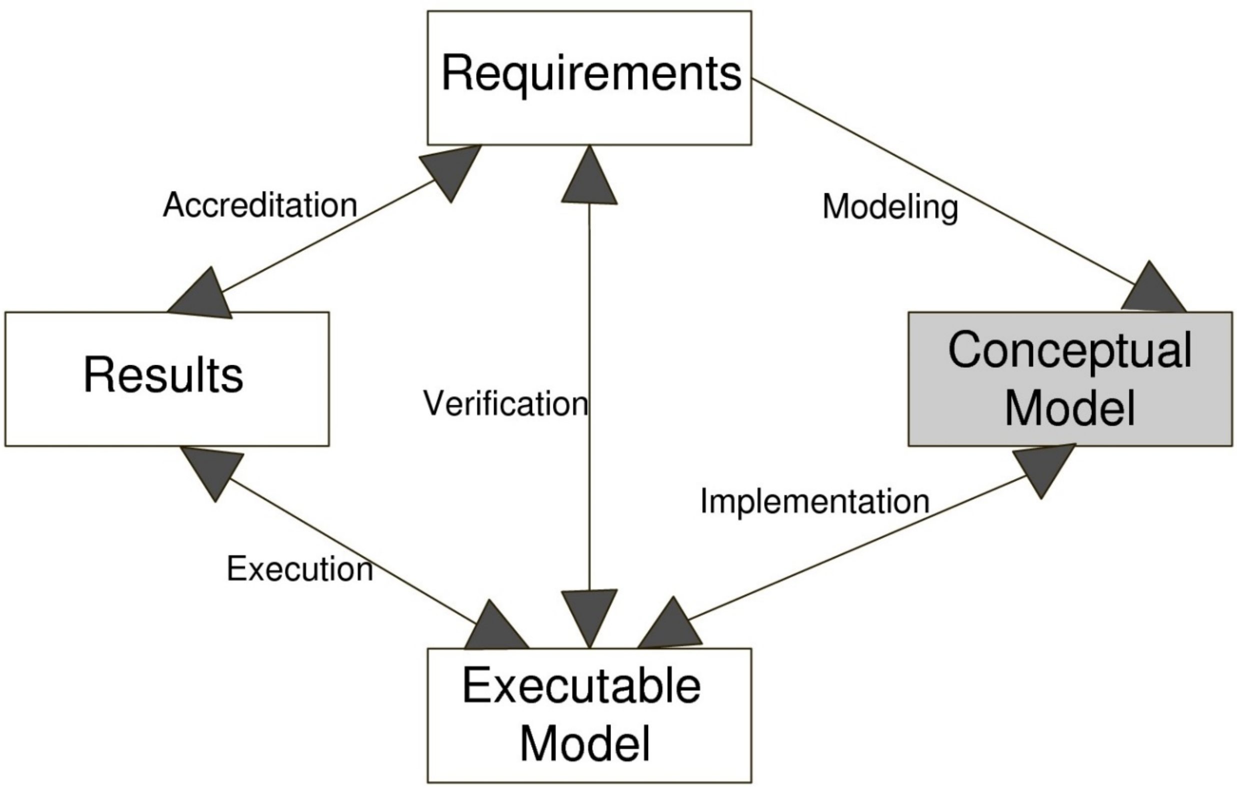

Figure 2.19. Modeling and simulation of fundamental theoretical underpinnings and practical domains (after Wei & Hong, 2003)

2.5.2 Different Types of Models: Descriptive and Prescriptive

A descriptive model is a model which usually offers solutions in the early stages of the design process. Yet, it still follows the analysis and evaluation of the development phases. The process of this model type is empirical; it uses previous experiences, common sense, and rules of thumb. In this model type, the solution is not guaranteed. The solution might be proved to be wrong later in the process, where the designer must come up with a new solution and goes through the process again. French proposed the following sequence for this model type: analysis of the problem, conceptual solutions, preliminary design solutions, and detailing. French suggests:

> "The Analysis of the problem is a small but important part of the overall process. The input is a statement of the problem and this can have three elements:
>
> - A statement of the design problem
> - Limitations placed upon the solution, e.g. codes of practice, statuary requirements, customers' standards, date of completion, etc.
> - The criterion of excellence to be worked to." (Figure 2.21)(Cross & Roy, 2008, p.29)

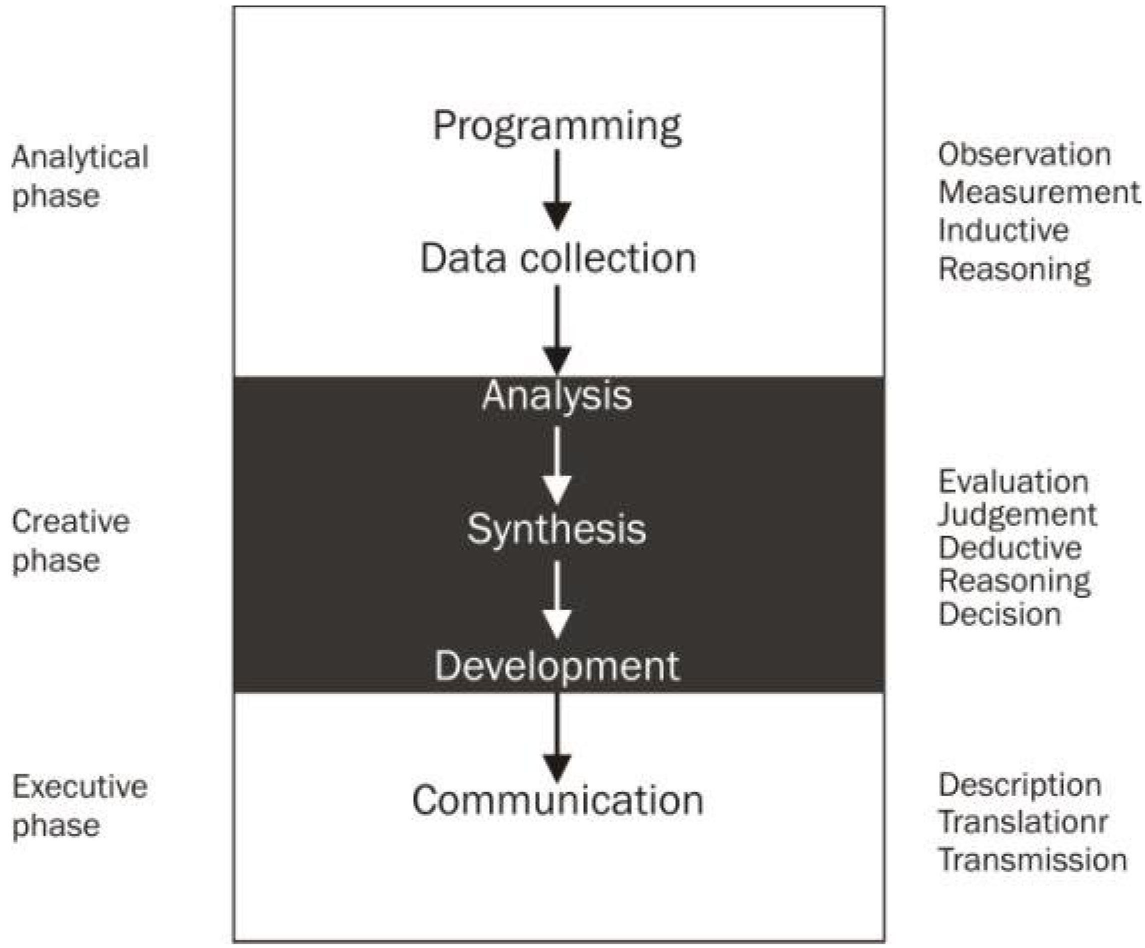

Figure 2.20. Archer model of design process (after Cross & Roy, 2008)

Prescriptive models have an analytical process of solving the problem, and mostly use an algorithmic, systematic approach. They mostly create a unique design methodology, which varies in one case to another. The aim is to investigate the problem as much as it is best understood, and based on the complete understating of the problem, the solution is proposed. The methodology of this model has the basic structure of: analysis, synthesis, and solution (Cross & Roy, 2008). There is a more detailed, prescriptive model suggested by Archer in Figure 2.20.

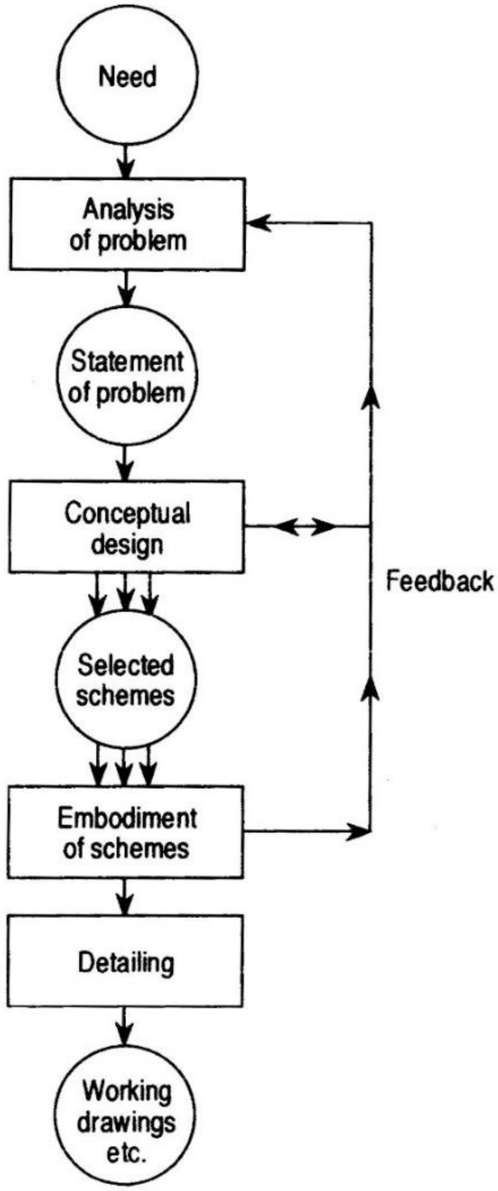

Figure 2.21. French model of design process (Cross & Roy, 2008)

2.5.3 Designing for Supplementary Space: Knowledge Model Leading to Physical Model

Based on their characteristics, models can be divided into physical and conceptual types. Physical models are objects such as maps, photographs, building prototypes, and drawings. Conceptual models are formulated as abstractions of the problem and the context. They are usually presented symbolically, such as the economic, chemical, and mathematical models used to represent the relationship of the elements involved. The conventional design process, wherein the architect designs a space based on programming, generates a physical model in the form of a series of drawings.

In the decision-design process, in which the architect selects the option that best meets the criteria, a conceptual model is produced (Figure 2.22).

Designing a supplementary space starts by combining all of the criteria to generate a synthesis for the stakeholders, which will become the conceptual model. Then, this model is translated into sub-systems and implemented in the real world. The design strategies are floor plan strategies (extracted from adaptable housing principles) which, through responding to conceptual model, lead to a graphical (physical) model.

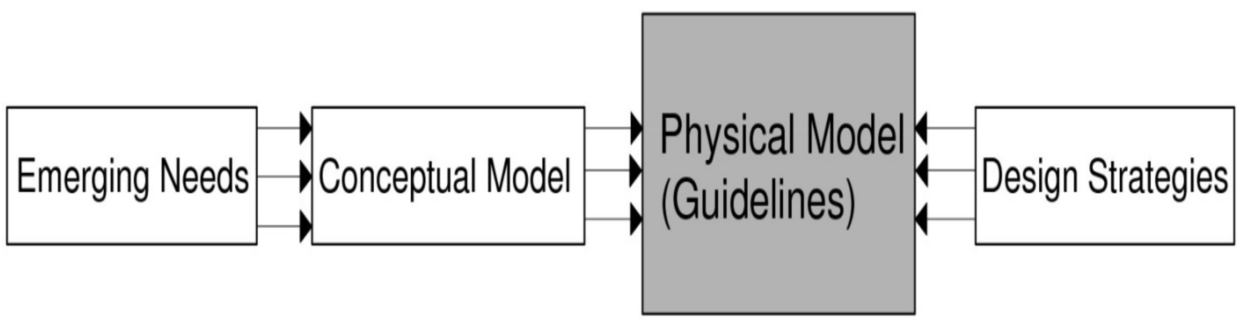

Figure 2.22. Conceptual to practical model

2.6 Schematic Diagram of the Systems Approach Sequence Applied to the Generation of the Supplementary Space z

Developing guidelines for designing a supplementary space is the objective of this research, as explained in this chapter. The extrapolation of the criteria will be described in chapter three. Chapter four will elaborate on options through open building and adaptable housing. Chapter four incorporates the criteria into a generic model. The feasibility of the supplementary space model can be validated by some of the construction and building systems suggested in chapter six. The following diagram (on the next page) proposes a map of the systems approach applied to the present research (Figure 2.23).

2.7 Chapter 2 Findings

RTD is the method used to design the supplemenatry space, where the designers' skills will be envisioned. The intuitive scenario-buffered technique attempts to create strategies that will enable the building to give a series of alternatives for future occupancy. To identify the relevant criteria, this study applies the system approach: deductive methodology starting from existing knowledge and using it to generate new knowledge to meet a specific objective.

Thereafter, the knowledge model becomes a conceptual framework which is translated into a physical model, generating a tool that can be applied to different scenarios in the future. The further development of the generic model involves a five step design-decision process: objective, analysis, synthesis, evaluation, feedback evaluation.

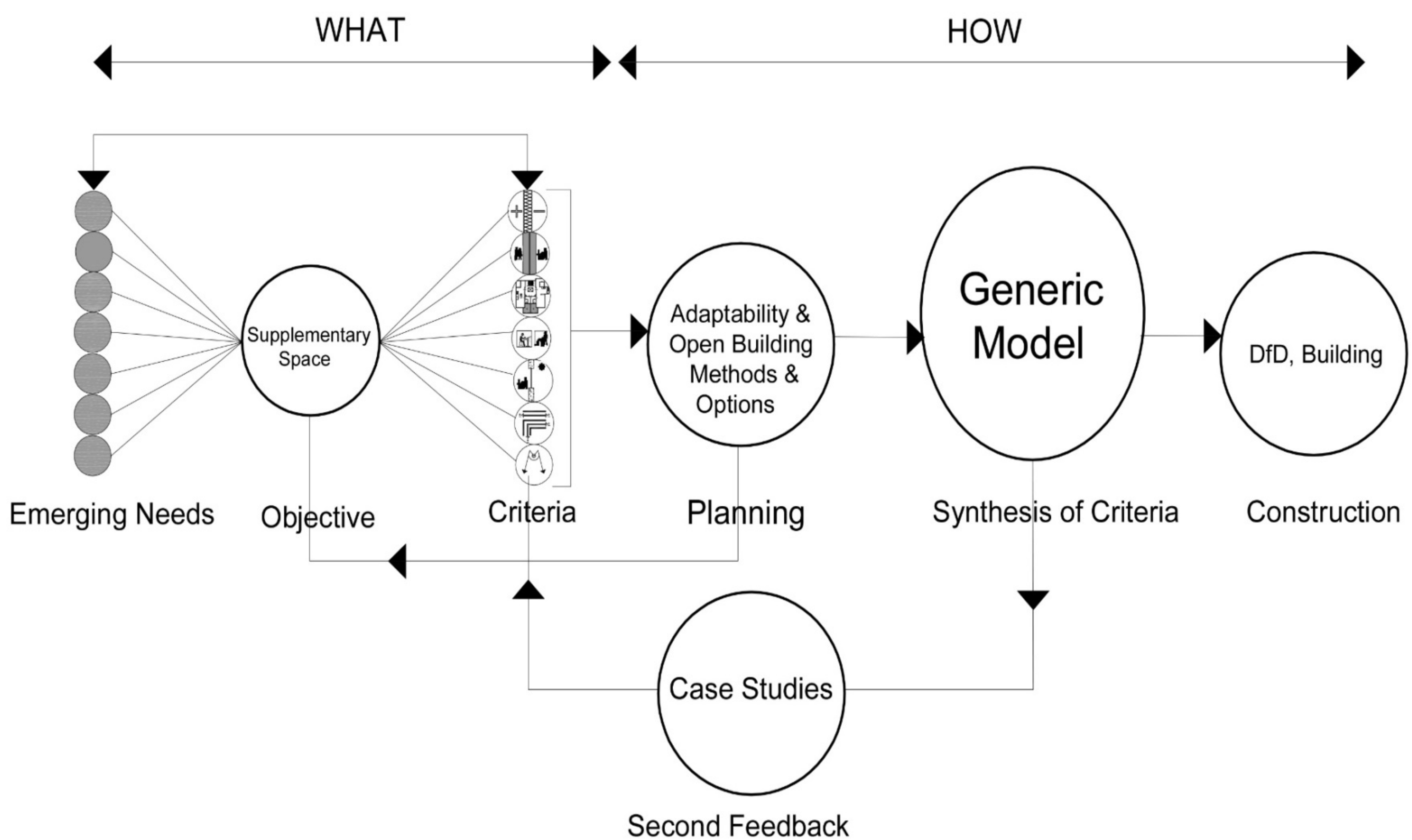

Figure 2.23.Map of research

3 Extrapolating Criteria for Supplementary Space

The first stage of the systems approach is to extrapolate all the specific criteria from the objective corresponding to the purpose of the supplementary space (Figure 3.1). Working from home being the most demanding one to fulfill, the focus will be on stipulating the criteria for a home office.

There are six sets of criteria sources: CHMC criteria of well-being in housing, environmental comfort of workplace, Canada Revenue Agency (CRA) criteria on work at home, general criteria of housing, pattern language and WELL building standards. Privacy is recognised as the main criterion, for users of the supplementary space as well as for the other occupants of the dwelling unit.

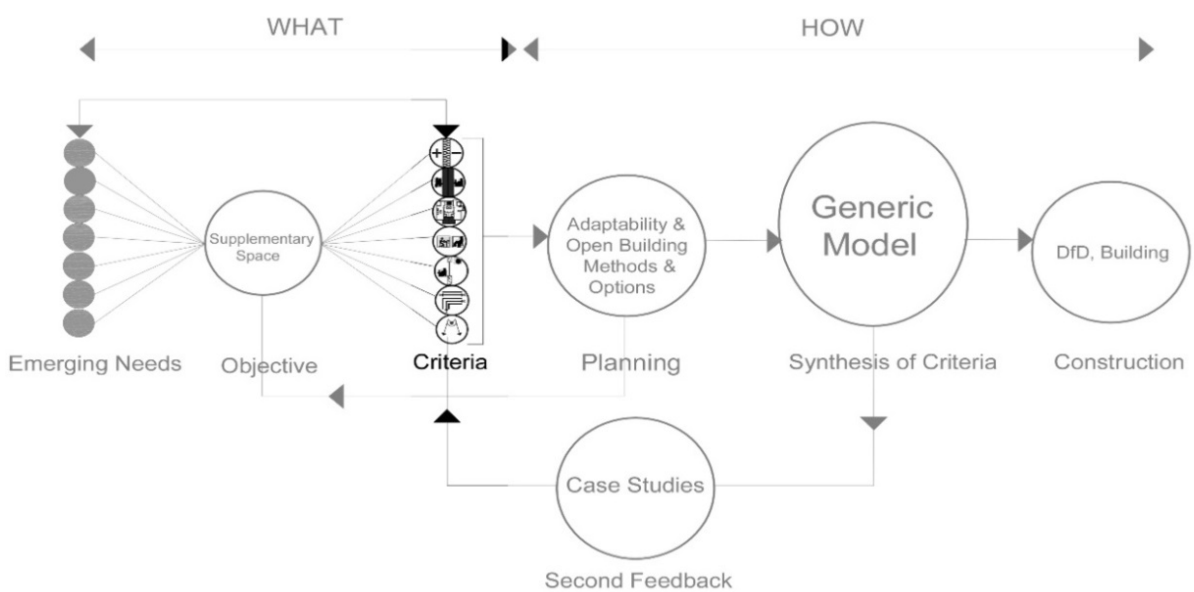

Figure 3.1. Map or Research

The different definitions of live-work units are introduced and the most appropriate scenario configuration will be selected for the live-work unit and the list of criteria will be extrapolated acordingly.

3.1 Scenario-Building

Scenario-building can be described as a story which is based on the analysis and understanding of current and historic trends and events. It includes a description of possible future situations. The development of sets of narrative **scenarios** helps to identify possible pathways towards a vision of the future (S. Roth, Greber, & Osterwalder, 2016). There are different approaches for scenario-building when it comes to design research. In the context of the present study, scenario-building will be envisioned through the following steps:

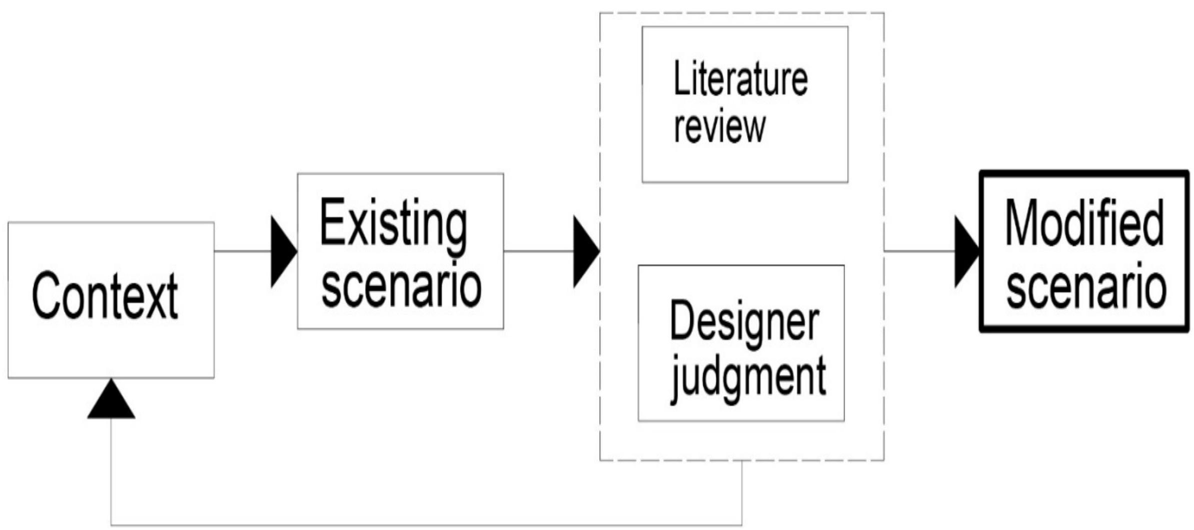

Figure 3.2. Scenario-Building for Supplementary Space

3.1.1 Defining Live-Work, as the Main Scenario

The following sub-chapters aim to further clarify live-work terminology using short and comprehensible lexicon. Live-work can have both residential and commercial purposes. The term live-work can have different meanings for different individuals, including designers, developers, planners, users, and regulators. Consequently, there could be be ten different answers when asking fifteen people to define live-work, with all such responses being correct, since various types of live-work scenarios exist.

Table 3.1. Live-work types (after Dolan, 2012)

Use-intensity types	Determined by work-use intensity and dominance of residence versus work *activity*
Work-Proximity types	Determined by the *form* of the unit, specifically how the workspace and the residence activities are physically arranged in relation to each other
Project types	Determined by the *scale*, urban intensity, and transect location of the project

The term live-work has a simple overarching definition, namely as a building, unit, or compound in where, a majority of the time, the same people carry out residential and work activities. Furthermore, live-work may be a part of a wider live-work neighborhood in some cases. For example: if the living space is located within five minutes (by foot) from the working space. Secondly, if most of the needs of the live-workers are fulfilled within a ten minute walk from their workplace or home.

In his book *Live-Work Planning and Design*, Thomas Dolan classifies live-work units based on use-intensity types, proximity types and project types (Table 3.1). The live-work types mentioned in Table 3.1 were elaborated into more categories in Figure 3.3.

(Table 3.1).

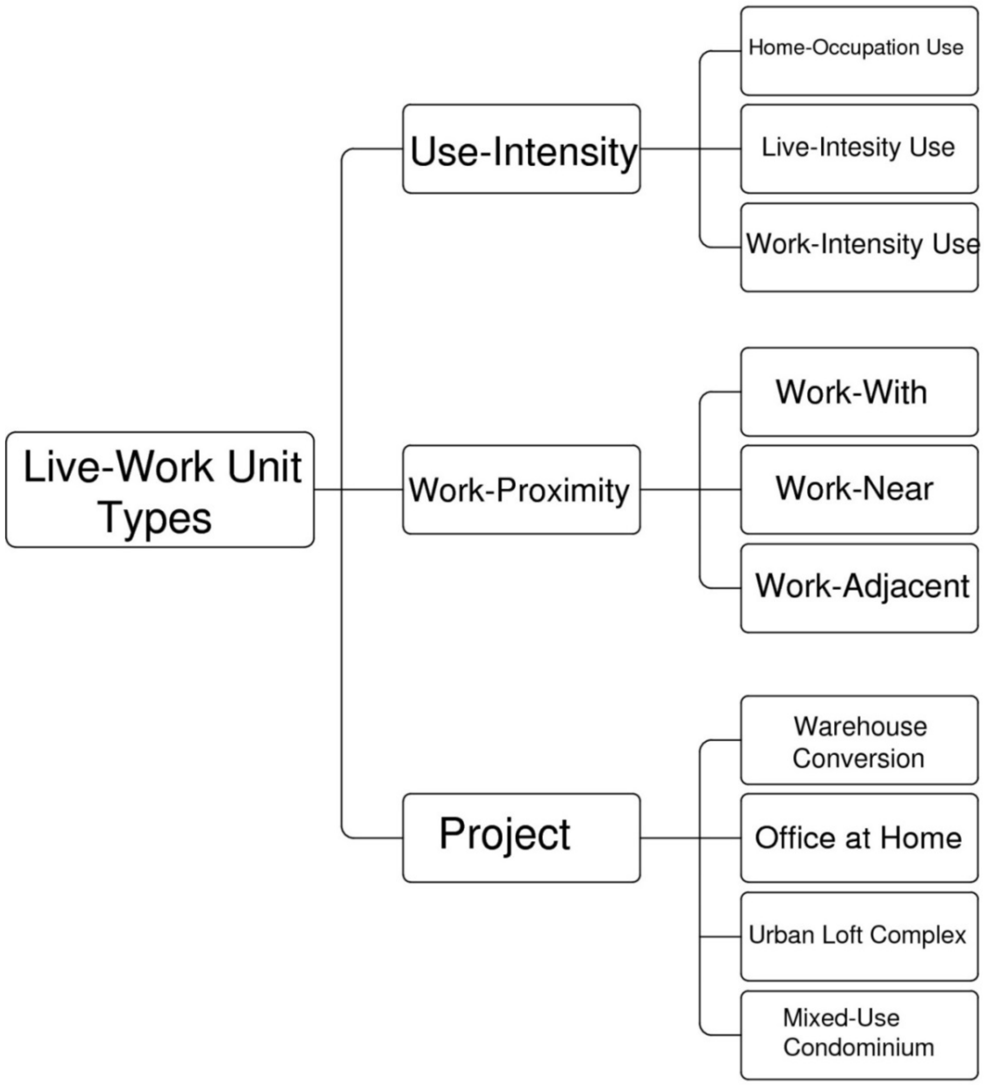

Figure 3.3. Live-Work classifications (after Dolan, 2012)

3.1.2 Use-Intensity Types

The easiest way to distinguish live-work units is by separating them into types according to their work-intensity, or in other words, the dominance of work activity over residential purposes. Such categories may include home occupation; live-work intensity use types (Table 3.2).

Table 3.2. Live work-Intensity Use Types (after Dolan, 2012)

Home occupation use	Work occurs within a residence
Live-intensity use	Work occurs within a unit; residential activity intensity surpasses the work
Work-intensity use	Residence occurs within or adjacent to a commercial space: therefore, the work use is dominant

3.1.2.1 Home Occupation Use

In a number of jurisdictions**,** *home occupation* is a phrase used to give residents permission to conduct small-scale work activities from home. Such an arrangement is typically what people imagine when hearing the phrase 'working from home' or 'home office'. Home occupation, in its very definition, occurs at a place of residence, which does not necessarily demonstrate a workspace like an office or a workshop. Work-use intensity is restricted to a home occupation (Dolan, 2012).

Physical Configuration and Use

It is possible to set up a home occupation that is dedicated to solitary work activity, including visits from clients for appointments, and may even include hiring some employees. A dedicated workspace for home occupation (Figure 3.4) could be a purpose-built home office, studio, or workshop situated in the residential unit or building. On the other hand, it could be situated in an outbuilding (like a shed or converted garage). A "granny annex" overlooking an alley-facing garage is a popular type of home workspace. Such annexes can also serve as an office or studio when not in use for residential purposes

(Hollies, 2015).

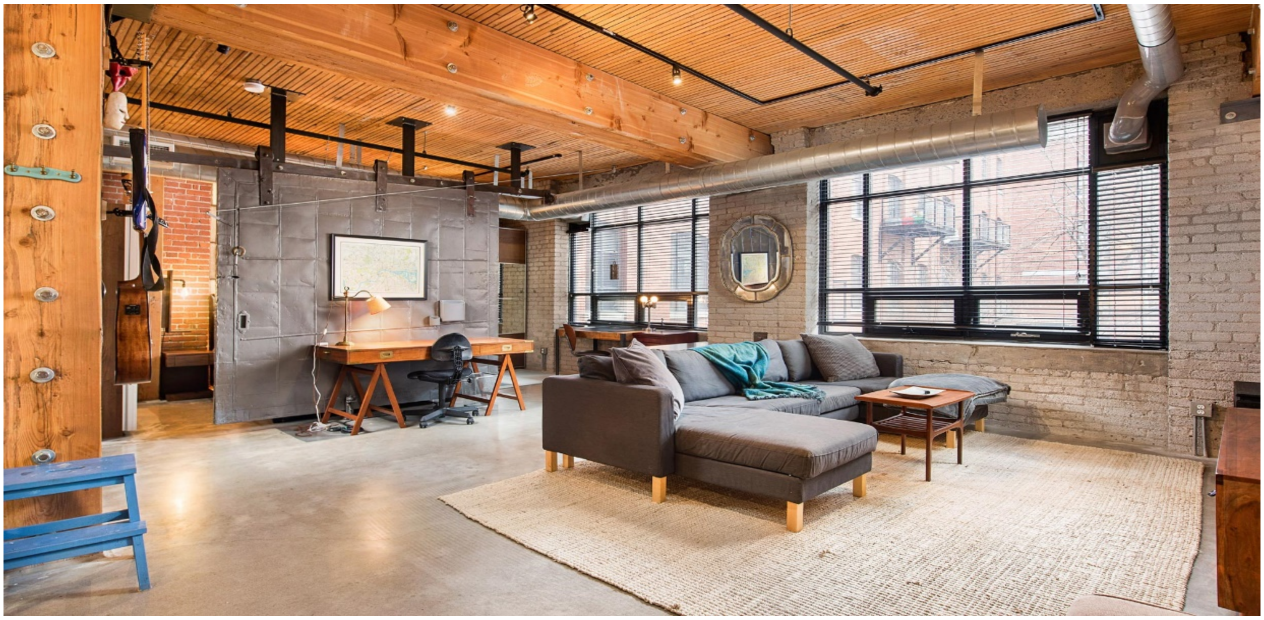

Figure 3.4 Broadview Live-Work units, Toronto ("Broadview residents", 2017)

Location

Home-working may take place in any residence or accessory building located on the same property in which one resides, with working activities continuously being secondary to the building's main function. Thus, irrespective of the location and permissions of residences, home occupation may take place, and this has been further facilitated through inexpensive small-office automation and online communications (Hollies, 2015).

3.1.2.2 Live-Intensity Use

The term live-intensity is commonly employed when referring to a unit in which the peaceful expectations of local neighbors are more important than the work-related purposes of the property. Therefore, anyone who carries out work activities from the property must be respectful of any noises, smells and other effects that could be caused.

The key purpose of live-intensity unit is residential (Figure 3.5). Work remains secondary to this function, or equally important if the workspace is slightly separated from living space. Both walk-in trades and a small number of workers are allowed, however this means that accessibility measures and issues of public accommodation must be considered. Often, clients are permitted to visit on an appointment-only basis, and despite workers being allowed, there are usually strict limitations on numbers. Work-use intensity is considered a restricted type of live-intensity use (Hollies, 2015).

Figure 3.5. Ava luxury residents, live-work units, Toronto. The unit is primary for living (Ava residence, 2019)

Physical Configuration and Use

The most important part of live-intensity use is flexibility, even more than for home occupation orwork/live types. One typically presumes that the higher importance of work versus residence within a live/work building fluctuates, and thus it is most effective to use a mixed type of live/workspace situated within the unit or property. Although it is possible for live-intensity units to be present in townhouses, there is a crucial difference to consider. Given the likelihood of lower-intensity work activities being carried out, it is not likely that there will be a separation. It is possible for live-intensity units to be set up in any type of space and location. They may be anywhere within the unit, building, or same property (Hollies, 2015).

The Urban Loft is a popular type of live-intensity set-up. This could be used to refer to a single high-ceilinged area whithin a converted building, or on several levels within a purpose-built property constructed from the ground up. Often, this appears as a townhouse. As the most flexible form of live-work, such a property may be predominantly residential, work or an equal balance of both. This may cause the work-to-residence balance to fluctuate from week to week, month to month or year to year. A dining area may have a dual purpose and also act as a conference room, a workspace may be used for a party or a previous work area could be subsequently transformed into a child's room.

Location

There has been a great deal of inconsistency with jurisdictions that have differentiated between live- work and work-live with regards to determining whether live/work is a commercial or residential type. Most of the time, a live/work unit will be situated within the middle range of urban intensity, i.e. in any place except the lowest-density residential areas and moderate/high-intensity industrial areas.

Urban loft conversions are the most common type of purpose-built live-work settings. Furthermore, former commercial buildings and warehouses situated within redundant commercial areas are the most common types of renovated live-work settings.

3.1.2.3 Work-Intensity Use

In work-intensity units, work needs are considered more important than residential needs (Figure 3.6). It is possible that the work may result in smells, noises, and other effects, and employees and walk-in trades are permitted (Figure 3.6). The work-intensity unit's key purpose is to enable commercial or industrial work activity, with the residential needs being secondary. Typically, employees and walk-in trades are allowed in these places, with accessibility measures needed most of the time. For example: public accessibility and transportation for disabled people.

Physical Configuration and Use

Work-intensity units are built to facilitate work activity and walk-in trades. There is usually a dedicated workspace situated on the ground floor of the property, a space which tends to be set apart from the residence via a wall, ceiling, or floor (live-near). The workspace may also be a completely separate space or building (live-nearby). Normally, the residential part of the building is not as big as the workspace and is often located on a different level of the building, or perhaps even in a different building but still within the same premises.

A storefront is a popular example of a work-intensity building. This is a historical kind of urban building that facilitates living above the store. In such cases, people may enter the building via a ground-floor space, often with a storefront, meaning they do not have to go through the residence. The latter tends to be located above or behind the workspace. This type of premises is known as “housing over retail” and is often regarded as a mixed-use building.

Figure 3.6. Work/Live unit where the primary focus is on work (Dolan, 2012)

Location

The majority of jurisdictions differentiate between work-intensity properties and other property types according to the extent of work that takes place. Such units are often located in areas that allow for commercial, industrial, or mixed uses. Renovated work-intensity arrangements often take place in former warehouses and commercial buildings. Very few new work/live properties have been constructed, with the exception of those outlined above (Dolan, 2012).

3.1.3 Work-Proximity Types

Three key proximity types exist, namely work-with, work-near, and work-adjacent. Such terminologies define the unit's form, with a particular focus on the physical arrangement of the work and residential spaces (Table 3.3).

3.1.3.1 Work-With Proximity

Figure 3.7 shows a type of property that exists completely within one room or has a "common atmosphere." This space is often imagined as a typical artist loft. The work-with unit tends to have a kitchen/dining area, bathroom, sleeping area and workspace all within one room. This allows for high flexibility. Moreover, there are hardly any interior partitions, which mean it can be configured in various ways. The amount of space set aside for residential and work purposes is determined by the specific needs of the current occupant and will change over time (usually 1/3 working space and 2/3 living space).

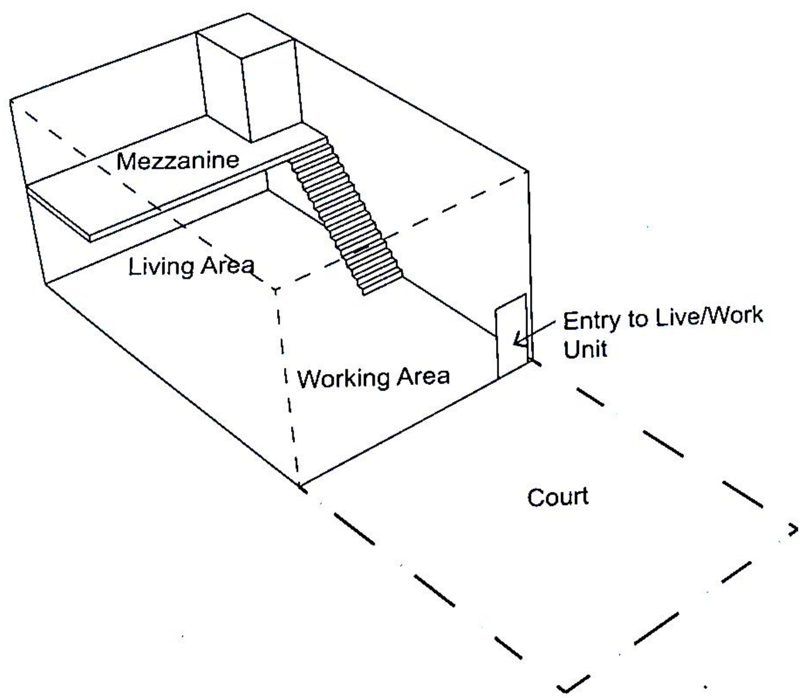

Figure 3.7. Work-With Proximity Type (after Dolan, 2012)

This type of work-with property tends to be developed within a single-level high-ceilinged space with few partitions, or in a two-level building with a workspace, sleeping area and bathroom (Figure 3.8). These rooms are typically located on the mezzanine level and open onto the work area, while the kitchen/dining space is often located below the mezzanine. The space set aside for each purpose will be largely determined by the heights of the ceilings.

Figure 3.8. Work-with unit. Etobicoke live-work unit, Toronto (Etobicoke units, 2018)

3.1.3.2 Work-Near Proximity

Figure 3.10 shows an example of work-near units. They have some form of separation between the living and working spaces and can still fulfill the needs of people who consider live-work to be important. There can be different forms of work-near units, however the property is typically made up of a workspace located on the main floor (Figure 3.9) and a living area above (Dolan, 2012).

As shown in Figure 3.9, a typical work-near unit is separated by a floor/ceiling, which could be fire-rated based on the risks generated from the work taking place. The workspace in rooms other than the living area can also serve as a type of work-near unit. If the partition is a wall, it may be glazed, fire-rated, or neither. Some jurisdictions enforce that all live-work units are work-near and require partitions with a fire-rated assembly to be placed. The living area tends to look like an apartment or a townhouse.

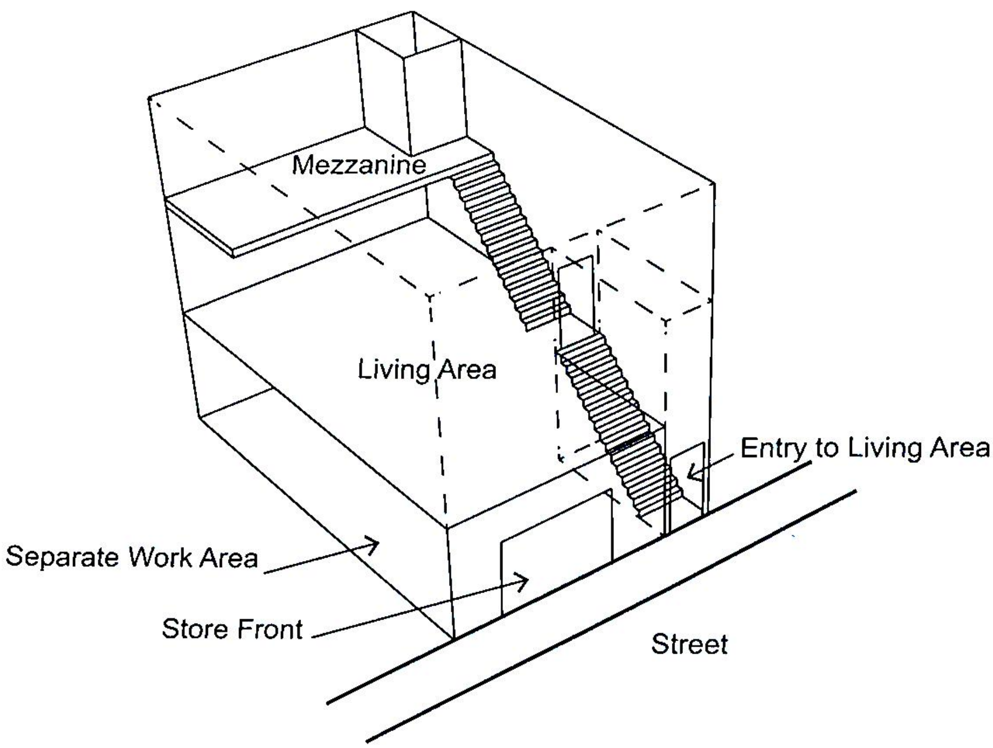

Figure 3.9. Work-Near Proximity Type (after Dolan, 2012)

The separation implemented in work-near units often reduces any exposure to dangerous materials or high-impact work activity, which means that work can be carried out within impacting roommates or family members. It can also serve to create some distance. Typically, the residents of the work-near unit access the workspace via a door or staircase.

This type of separation can really help in establishing a work-life balance (Figure 3.10.). The flexibility of work-near units varies according to the different live-work units, although is always high. Such flexibility enables the occupant to separate their living space from the work area, or even to lease both spaces more easily.

Figure 3.10. Work-Near Proximity Type. Working and Living Spaces are in two different Levels (after Dolan, 2012)

3.1.3.3 Work-Adjacent Proximity

This type of set-up, as shown in Figure 3.11, separates the living and workspaces via a short walkway, which may be in the form of a courtyard or the path to a converted garage. The walkway may also be a staircase (interior or exterior) located within the same premises. It may also be possible to use the term to describe workspaces not situated on the same premises but only a short walk away (this, however, will not be used in the present thesis). Although work-adjacent set-ups often seem to be mixed-use, the classification of live-work unit can allow them to be located in areas in which a residential or a commercial space in isolation is not allowed (Figure 3.12).

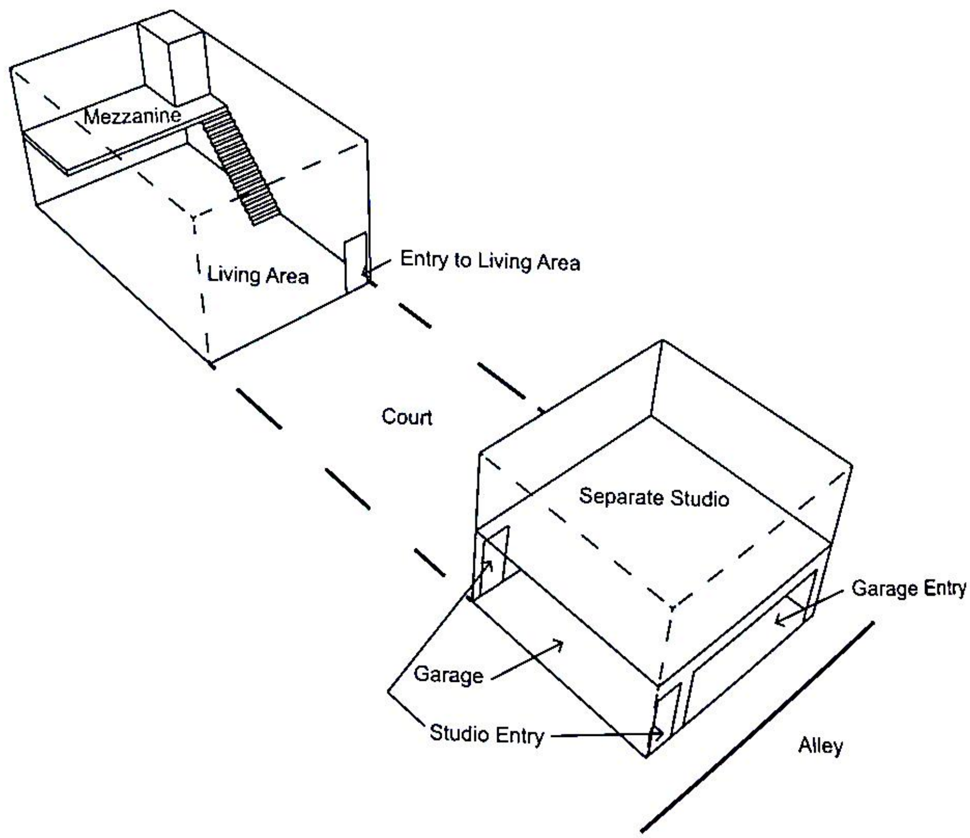

Figure 3.11. Work-adjacent proximity type (after Dolan, 2012)

Figure 3.12. DuEast condos, Toronto. Co-working amenities facilities (DuEast Boutique, 2018)

3.1.4 Live-Work Project Types

There can be many different types of live-work projects, the most popular of which will be discussed in Table 3.3.

Table 3.3. . Live-Work Project Types (after Dolan, 2012)

PROJECT TYPE	DESCRIPTION
Warehouse Conversion	Conversion of an existing commercial building to multiple live-work units, often called lofts.
Office at Project	Home occupation in or on the same property as a residence of any kind.
Urban Loft Complex	"Lifestyle" lofts in a new building or a renovated commercial building.
Mixed-Use Office Condominium	Mixed-use retail/commercial, office, residential complex, providing shared offices for residents

3.1.4.1 Warehouse Conversion District

The most common types of live-with units are converted warehouses, a majority of which are single-level buildings. However, in cases where ceilings exceed fifteen feet in height, mezzanines tend to be added.

The most popular configuration for warehouse conversions is a double-loaded corridor. Here, the living spaces tend to be near the corridor and the work area is typically close to big windows located around the edge of the property (Figure 3.13). Warehouse conversions tend to be work-live or live-work units, and over time, the former can develop into the latter. Given that warehouse conversions tend to be permitted as commercial spaces, they are almost never defined as having residential spaces.

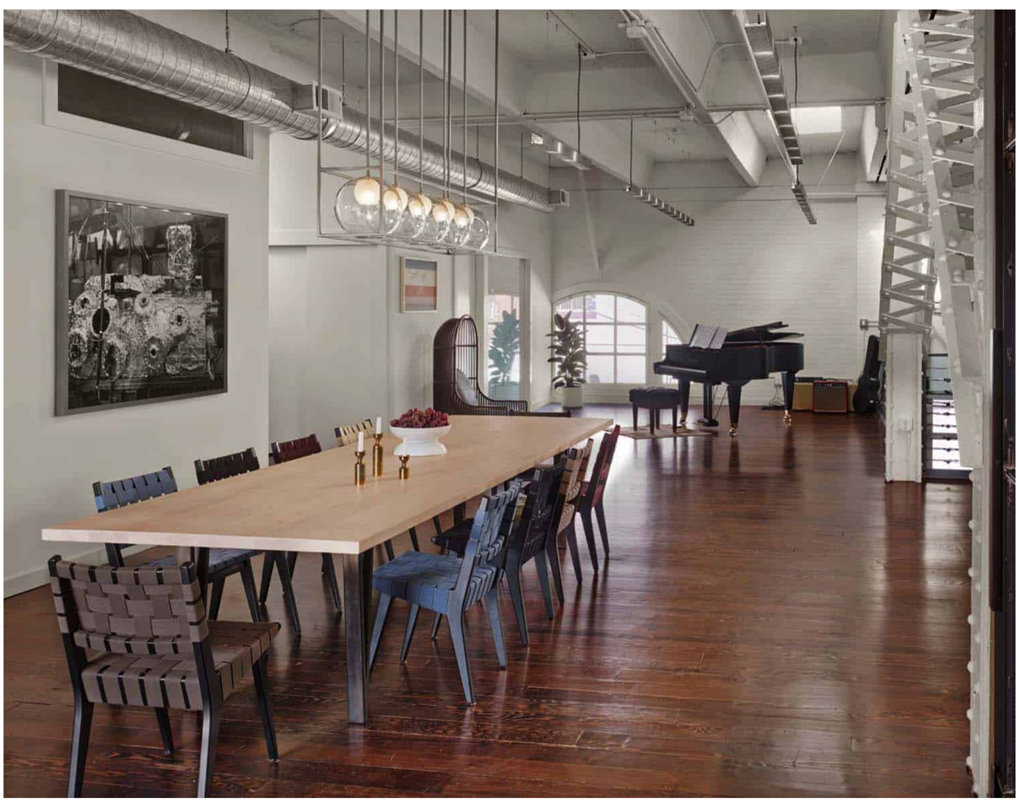

Figure 3.13. Junction condos, Toronto. Warehouse conversion (Junction Condos, 2019)

3.1.4.2 Office-at-Home Project

An **office-at-home** project set-up is almost always configured within an existing residence, with the former bedroom, recreation area, garage and outbuildings being used. On the other hand, it may be redesigned as a purpose-built property (Figure 3.14).

Figure 3.14. Yorkville condos, Toronto. Part of unit is dedicated to office (Yorkville Condos, 2019)

Office-at-home projects are becoming recognised as a key part of new residential construction. Rooms situated near the main door (or accessible via a separate entrance) can have separate phone/data lines and their own bathroom that can be used without needing to go into the main residence. Building for office-at-home uses enables visits to be made to the property by clients without interfering with the residence, and thus this develops a live-near unit, in which the workspace is located in the most public part of the building (Dolan, 2012).

Similar to home occupation, the office-at-home projects tend to be the main activity, since it often represents the mainstreaming of live-work units. The popularity of this type of building has largely grown due to the increase in cheap, small-office automation and the internet.

3.1.4.3 Urban Loft Complex Project

Since urban lofts began to emerge as common urban real estate "products," the growing availability of cheap home-office automation and advancements to the Internet lead to the emergence of a flurry of home-based businesses. Simultaneously, all types of developers displayed a heightened interest in transforming existing buildings into live-work spaces. This led to the development of loft conversions (Figure 3.15).

Figure 3.15. Liberty Village Condos, Toronto. Storage warehouse converted to live-work (Liberty Market Tower, 2018)

3.1.4.4 Mixed-Use Office Condominium

Mixed-use office condominium is a new phenomenon which combines shopping, office and residential within the same complex. This type consists of shops at ground-level, offices from level two to ten, and residential from ± level ten onwards. One of the most successful examples of such live-unit types is the Hullmark Centre in Toronto, which consists of 198 offices from two to twelve floors with the capacity of combining offices, and 38 levels residential floors from level twelve to fifty. The offices can be used for medical and professional offices, with the capability of receiving clients. The priority for rental offices is given to the residents of the building (Figure 3.16).

Figure 3.16. Hullmark Complex, Toronto (Hullmark Complex, 2017)

3.1.5 Choosing the Live-Work Type for Supplementary Space, Modified Scenario

Based on the discussion in the previous sub-chapters, supplementary space for live-work units can be categorized as the **live-intensity use** type, since the residential use is primary, and work is secondary. For the proximity types, since the supplementary space will be within the dwelling, the **work-with proximity** type is the best fit. When it comes to live-work project types, the supplementary space would fall into the **office-at home** project type (Figure 3.17).

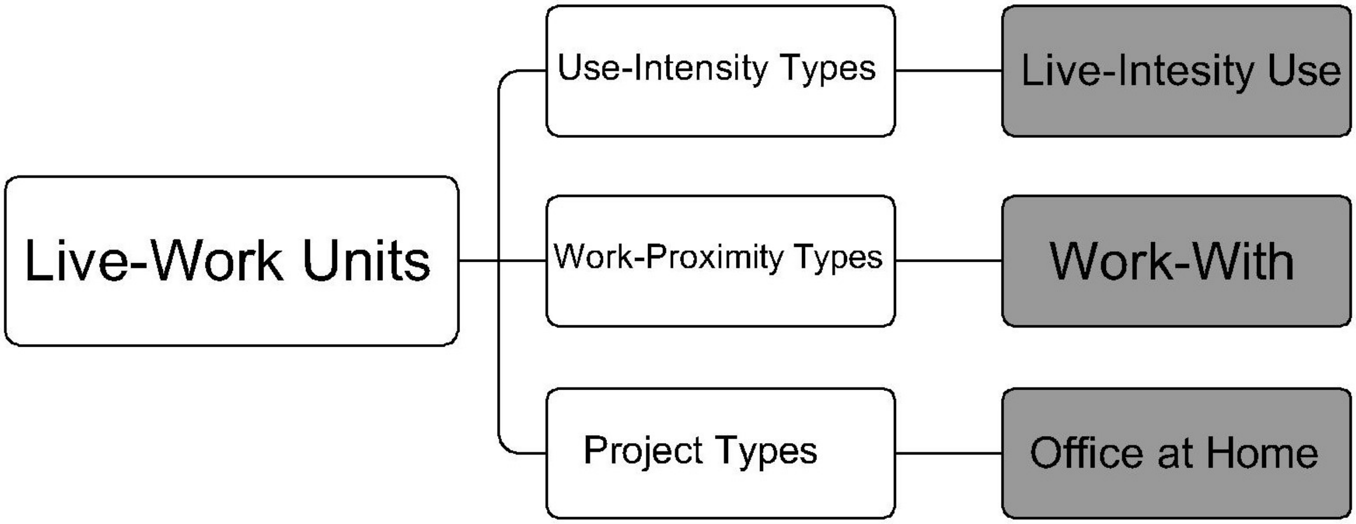

Figure 3.17. Live-work classification selection for supplementary space, new scenario

3.2 Stakeholders

Stakeholders are individuals and organizations involved directly or indirectly in the system; as such, their interests and roles must be considered (Hajialikhani, 2008). Although the theory of stakeholder organizations was first developed in business and management studies, its procedures have been taken up by other disciplines as a **systematic problem-solving tool**. Identifying stakeholders makes problem-solving easier for the designer, in responding to the priority and importance of the criteria of each stakeholder (Figure 3.18).

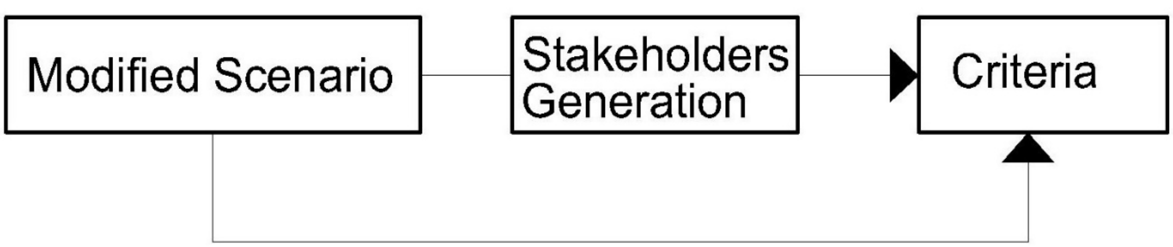

Figure 3.18. Scenario-stakeholder-criteria path

Stakeholders can be either direct or indirect. Direct stakeholders are those whose actions immediately affect the project, while indirect stakeholders influence it tangentially (such as banks, developers, and environmental designers). Therefore, the first step is to identify the direct stakeholders and their requirements to gauge their influence on the entire system. In the housing delivery process, there are three major categories of stakeholders according to Dunn et. al (2006) (Table 3.5):

1- Controlling agencies

- Government (federal or provincial): The government promotes and regulates housing policies and safety through financial incentives, codes (NBC, QBC), and standards.
- Municipal: Using local legislation, the municipal government translates its policies into master plans, by-laws, and a system of incentives.
- Financial or lending institutions: Banks, trust companies, etc. lend the initiator or the user the financial means (under certain conditions) for the execution of a project or the purchase of a unit.

2- Stakeholders in the supply process

- Initiator: This person or organization, known as the developer or builder, conceptualizes and realizes a project. He/she can be a private or public entity, depending on his/her source of finance and objectives. He/she can be directly involved or can rely on a representative (such as a project manager).
- Design decision-maker: This is the party involved in the design of a project, such as

the architect, engineer, etc.

- Project executor: This party is involved in the actual building of the project such as general contractor or sub-contractor.
- Manufacturers/suppliers: These organizations manufacture and supply the construction components and materials.
- Real estate agencies: These entities represent the parties involved in buying or selling.

3- Stakeholders in the demand process

  - User: The party using the "final product" can be a specific person or class of users.

Table 3.4. Stakeholder categories in housing (Dunn, Hayes, Hulchanski, Hwang, & Potvin, 2006)

Government (Federal or Prov)	Financial or lending institution		Evaluate future use situations	
Factors for supply process	Initiator	Design decision maker	Product executor	Manufactures/ suppliers
Factors in the demand process	User			

3.2.1 Stakeholder-Centered vs User-Centered Stakeholder Approach

Stakeholder-centered design considers all the people who will interact with the building over its lifetime, including intended and unintended users. Therefore, the designer must first understand who these stakeholders are and address their needs to keep the chain intact.

The user-centered approach emphasizes the users of the system more than other stakeholders. In this type of design, the goal is to satisfy this group. Besides considering users' goal, a design must incorporate the perspective of other unintended users to achieve the main goal of the project (Figure 3.19).

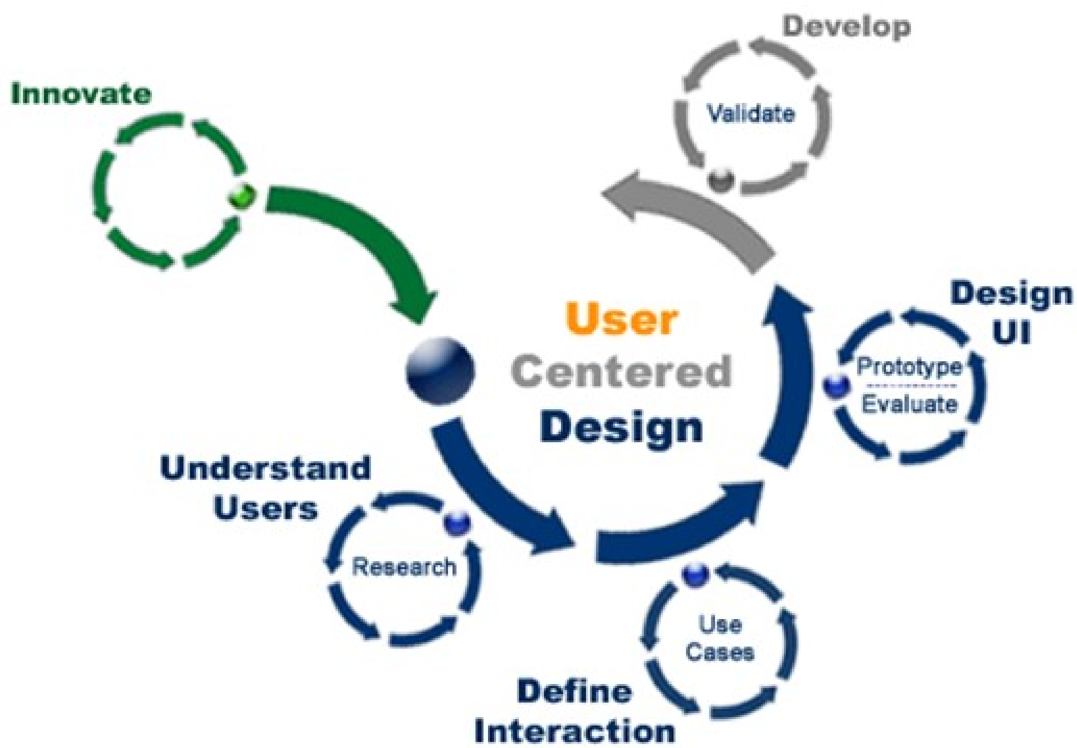

Figure 3.19. User-centered design (Abras, Maloney-Krichmar, & Preece, 2004)

Since the participatory approach is being selected for the present thesis, the user-centered stakeholder approach is taken for this study. A user stakeholder is anyone who is directly or indirectly involved with the supplementary space:

- The user of the supplementary space

- The other residents of the household
- Visitors to the supplementary space

3.3 Criteria Sources

The criteria for the supplementary space will be examined from four perspectives: factors of well-being in housing, environmental comfort in the workspace, the general criteria of housing, and WELL building standards. The factors of well-being are taken from the **CMHC guidelines**, which set the general qualifications for housing such as safety, health, and comfort.

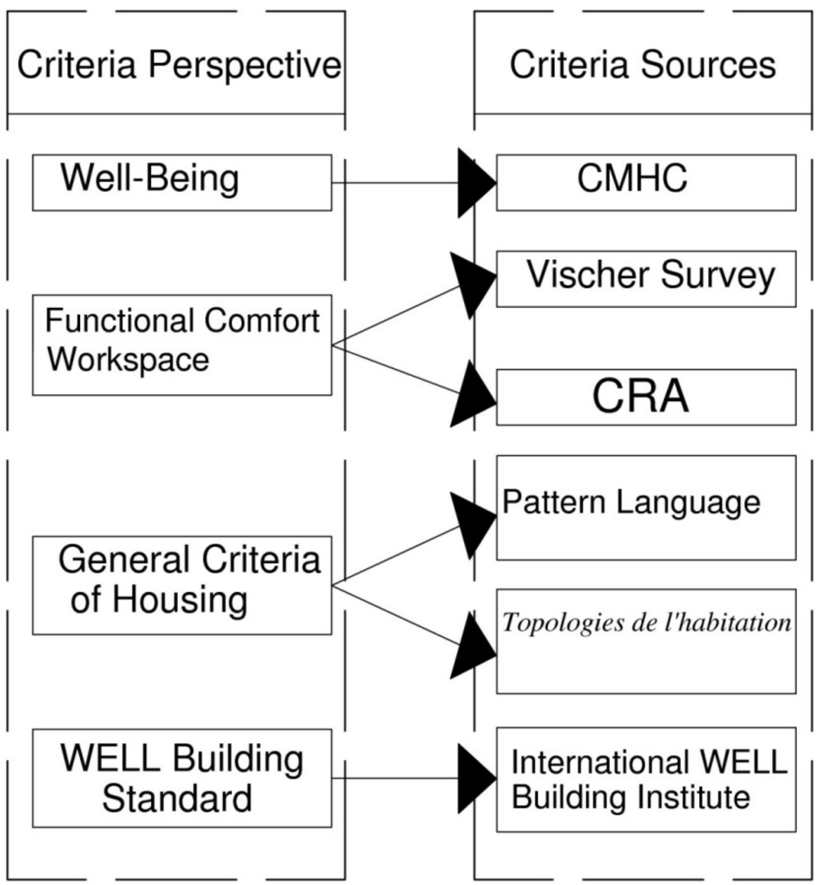

Figure 3.20. Criteria perspective and sources

The environmental comfort criteria for the workplace are extracted from the **environmental survey** in Canadian offices by Jacqueline C. Vischer. The general criteria of housing comes from **Pattern Language** by Christopher Alexander and ***Topologies de Habitation*** prepared by Professor Roger B. Richard at *Université de Montréal*. Finally, the **WELL Building Standard**, developed by the International WELL Building Institute**,** is a performance-based system for measuring and clarifying features of the built environment with respect to human health (Figure 3.20).

3.3.1 Criteria of Well-Being in Housing (CMHC)

The CMHC (2009) identifies several issues that it considers to be important indicators of housing livability: economic vitality, well-being, and environmental issues (CMHC, 2009). To target the most relevant part of the objective, only the well-being of incorporating workspace within living space will be considered.

Although the term 'well-being' is used often, there is no agreed upon definition and it is regularly used as an all-encompassing concept to describe the quality of people's lives. For example, terms such as happiness, quality of life, and life satisfaction have been used interchangeably to mean well-being. Each term represents elements of well-being but individually do not reflect everything that well-being entails. Many of those who have attempted to define well-being see it as a dynamic process. New Economic Foundation (NEF) described well-being as the dynamic process that gives people a sense of how their lives are going, through the interaction between their circumstances, activities, and psychological resources or 'mental capital' (Voice, 2015).

The framework of *well-being* in a built environment is divided into various groups according to reports by the CMHC and the Department for Environment, Food and Rural Affairs in the UK (Maxwell, Henderson, McColy, & Harper, 2011), (CMHC, 2009) as follows:

- Health comfort
- Quality of the environment
- Safety and security
- Personal activities
- Social connections and relationships

Although these groups sometimes overlap, the emphasis of this research is on *health and comfort* and the *quality of the environment,* both of which can be further subdivided. The World Health Organization's working definition of well-being is the realization of one's physical, emotional, social, mental, and spiritual potential. Because the supplementary space is part of the dwelling, it must meet the criteria that pertain to all units. It also is a workplace, should fulfill the specific criteria for any office. The criteria of well-being in an office consists of as follows (Mallory-Hill, 2004):

- Building integrity
- Spatial requirement
- Acoustics
- Visual comfort
- Thermal comfort

- Air quality

As mentioned earlier, this research focuses on working at home. Designers can leverage the same criteria selection process for other functions of supplementary spaces, such as a teenager's bedroom, a parent's room, etc.

3.3.2 Criteria of Workspace: Physical, Psychological, and Functional Comfort

In her article, "the Concept of Environmental Comfort in Workplace Performance" (2008), Jacqueline C. Vischer develops the idea of environmental comfort as a crucial factor to designing suitable workspaces. She explains how the workers desire more than just safety and health requirements to be met in their offices. In her article comfort is defined as the environmental support that building users need to conduct their business. The psychological elements of employees' environmental satisfaction are connected, through comfort, to specific outcome measures, including organisational productivity and task performance. The relationship among the three levels of environmental comfort is depicted in Figure 3.21. All levels must be considered for a thorough understanding of comfort in this context, although each level can be measured individually. Physical comfort is a fundamental human need, which suggests that a lack of it renders an environment unlivable. To conduct activities and tasks in their workspaces, users must fulfill their relevant functional needs as they pertain to the next level of comfort.

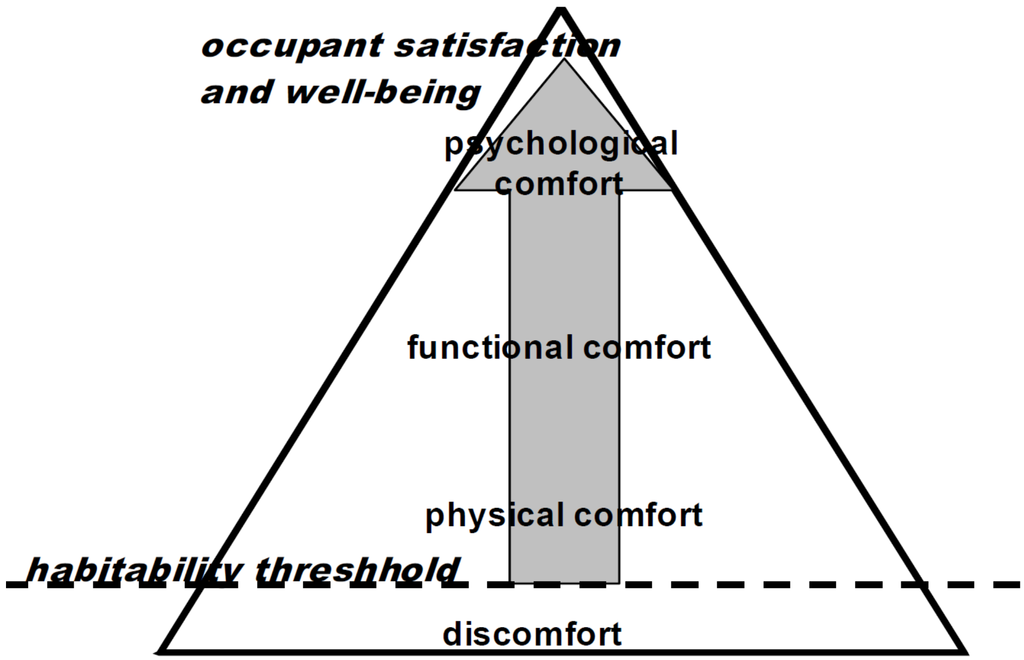

Figure 3.21. Ranges of environmental comfort, from basic habitability to optimal well-being (J. C. Vischer, 2012)

Physical Comfort: The essential liveability factor for a building is found at the base of the triangle. It is ensured by appropriate building design that can meet health and safety standards. In the workplace, health and safety regulations seek to prevent unacceptable conditions such as excessively noisy, cold, or hot environments. The physical comfort of workers must be assured, given its direct impact on performance. In addition to the influence of interior workspace conditions, the user is also negatively affected by shortcomings or disruptions in building services such as bathrooms, cleaning, and maintenance.

Psychological Comfort: This is located at the top of the triangle. Despite the impact of occupational and industrial psychology, the measurement of this criterion is relatively new in the workplace. Psychological comfort is the link between psychosocial aspects and the environmental design, as well as the management of workspaces via the concepts of control, privacy, and territoriality. One of the principal factors that increases workers' psychological comfort is a sense of privacy.

Functional Comfort: This is located at the midpoint between users' basic need for physical comfort and psychological well-being. It measures the impact of effective workspaces on users' task performance instead of on their satisfaction, although there is an overlap between the two notions. Table 3.6 depicts how a 'comfortable' or task-supportive office lifts the worker's energy and enables him/her to improve his/her concentration. Suitable lighting for screen-related work or low, background light levels are examples of a task-supportive workspace. 'Uncomfortable' workspaces that detract from task performance are also shown; this environment depletes the user's energy struggling with environmental challenges that hinder optimal work outcomes and lowers user's energy levels to perform tasks.

3.3.2.1 Environmental Comfort Survey

In 2001, a major Canadian insurance company began a three-year study of its new "universal footprint" initiative in office planning (H. Vischer, Granneman, Linskens, Schulz, & Bogerd, 2003). Functional comfort was analyzed through responses on 53 environmental scales, five of which indicated comfortable and one uncomfortable workspace. The occupants' responses suggest that, overall, they were comfortable in their workspaces, apart from acoustic conditions and privacy. Three thousand new workstations were sequentially installed in all company buildings. Older furniture in various configurations of 2.4m by 2.4m and 2.4m by 3m were replaced by new workstations that were 2.1m by 2.1 m. 520 users were surveyed, and their responses were grouped according to 13 dimensions of functional support, as shown in Table 3.6 (the score is on a scale of one to five).

Table 3.5. Dimensions of functional comfort (based on the survey) (J. C. Vischer, 2007)

	FUNCTIONAL COMFORT DIMENSION	Score
1.	Workstation comfort	3,64
2.	Thermal comfort	3,23
3.	Air quality	3,11
4.	Privacy	2,77
5	Lighting Quality	3,94
6.	Acoustic comfort	2,85
7.	Spatial comfort	4,20
8.	Teamwork	3,49
9.	Natural light	3,01
10.	Safety and security	4,27
11.	Building appearance	4,25
12.	Visual comfort	4,12
13.	Building and remote noise control	4,28

3.3.3 Canada Revenue Agency Criteria on Work at Home

As mentioned in chapter 1, CRA has two requirements for workplace at home which are as follow:

- Exclusively to earn business income
- On a regular and continuous basis for meeting clients, customers or patients of the individual in respect of the business.

3.3.4 General Criteria of Housing

In his book *A Pattern Language*, Christopher Alexander described residential design practise through a series of patterns. Each pattern is a problem statement, presented by an illustration and followed by a solution. Of the 253 patterns he collected, the four that are most related to supplementary space are presented here (Alexander, 2018).

- Flexible office space
- Home workshops
- Workspace enclosure
- The shape of indoor space
- Windows overlooking life

3.3.4.1 Flexible Office Space

> "Is it possible to create a kind of space which is specifically tuned to the needs of people working, and yet capable of an infinite number of various arrangements and combinations within it?" (Alexander, 2018, p.690)

According to Alexander, every human organization goes through change. This is true of offices, where work groups expand, contract, and have evolving aims and functions, all of which are exposed to change.

Old buildings evidently offer greater flexibility than their modern counterparts—the modular offices which are divided by impermanent partitions. This begs the question of why old buildings provide flexible office space. The answer is that they are made up of a series of small rooms, some large rooms and a range of ambiguous spaces, all of which are connected to each other in a number of ways.

Although these spaces were originally designed to meet the needs of family life, it appears that they also suit the innate structure of work groups. Small spaces can be used as private or half-private offices; larger spaces are ideal for workgroups of two to six people; and the largest space can accommodate up to a dozen people; while a communal area has the kitchen and dining room at its hub. In addition, each space invariably has a range of walls and half-walls, as well as window-seats, which facilitates changing the internal organisation of the rooms.

From time to time, it is feasible to design and build an office or a workspace which mirrors a house, but this is only possible if one knows enough about the work group in advance to tailor the mixture of rooms and large spaces to their specific needs. More often than not, this information is not available when the space is being built, and this makes it impossible to opt for a house-like design. In these circumstances, the best option is to design and build the kind of space which can slowly and systematically evolve and become a house-like space, once the work group has taken possession of the building and moved in.

3.3.4.2 Home workshops

A present day society people (businessmen, artists, craftsmen, shopkeepers, professionals, etc.) work for themselves, either independently or in small groups, and maintain a closer connection to their environment and surroundings

In this type of society, the home workshop takes on a different role to the one it has today, where it is often little more than a basement or a garage where hobbies are pursued. Instead, the home workshop is an essential feature of the house, just like its bedrooms or kitchen. Its key feature is the relationship it has to the public street. Most of us have a fairly public work life, especially if we compare it with the privacy we enjoy behind closed doors in our homes. Even if this work relationship to public is limited, both the worker and the community can benefit if the link between the two is strengthened and expanded.

The public character of the work carried out in the home workshop is particularly beneficial and important, since it removes the workshop from its niche as the home of hobbies and moves it into the public arena. Anyone who is working there can look out onto the street and can, in turn, be seen by passersby.

This pattern proposes the idea of an extensive workshop, which incorporates all the features of a true workplace and is connected to a certain degree to the public street.

> "Make a place in the home, where substantial work can be done, not just a hobby, but a job. Change the zoning laws to encourage modest, quiet work operations to locate in neighbourhoods. Give the workshop perhaps a few hundred square feet; and locate it so it can be seen from the street" (Alexander, 2018, p.739)

3.3.4.3 Workspace enclosure

3.3.4.3

> "People cannot work effectively if their workspace is too enclosed or too exposed. A good workspace strikes the balance." (Alexander, 2018, p.847)

When designing an office, it is critical to find a balance between open and enclosed spaces. People working in very open offices often feel vulnerable and overexposed, while those in heavily partitioned offices may feel isolated. Neither isolation nor excessive exposure are optimal working conditions. In order to find the ideal balance, Alexander chose 10 variables which could potentially affect whether individuals feel enclosed or exposed in their work environments.

The variables are as follows:

1- Whenever there is a wall behind an individual

2- How many people an individual can see when working

3- The type and level of ambient noise

4- How large the space is

5- How much open space is in front of an individual

6- Whether there is a view of the outdoors

7- Whether there is wall next to an individual

8- How many people an individual can speak without raising their voice

9- How far away the next closet is located

10- The variety and number of possible sitting positions

In an ideal work environment, around 50% to 75% of an individual's work area should be enclosed by windows and partitions. When calculating this percentage, windows are worth 50% of a wall. This partially-enclosed workspace should be no smaller than 60' squared. There should be at least 8' of open space in front of each workstation. This space should always open into a larger one. A desk should never face a wall and should always offer a front or side view. If others are working in the vicinity, each workspace should offer some sort of connection to two or three other workers. No more than eight workspaces should be visually or audibly aware of each other.

3.3.4.4 The Shape of Indoor Space

Once he started to see how human forces impact the space, Alexander determined that the shape of walls is important. He suggests that every space which has walls should be recognisably separate and must also have walls which are straight. Each wall should have social spaces to both sides. The wall can, however, be rounded wherever it is open to the street for example, at an entrance.

When it comes to the angles between the walls, acute angles rarely work and are simply inappropriate because of social integrity. It is not easy to make an acute angle in a room which serves a function. The majority of rooms will shape in a way which discourages obtuse angles, since the latter do not shape well at corners - and this is where rooms often meet. Angles closer to 90-degree angles (for example, between 80 and 100 degrees) are more practical and logical.

This indicates that most spaces in a building should be polygons in plan, with straight walls and obtuse-angled corners. They will frequently resemble irregular, compacted rectangles. Sensitivity and awareness of the site, as well as the details and finer points of the plan will inescapably result in somewhat asymmetrical shapes. From time to time, they may have curved walls—if the wall is sufficiently thick to be concave on both sides, or if it is an exterior wall which does not have any key social spaces outside.

> "With occasional exceptions, make each indoor space or each position of a space, a rough rectangle, with roughly, straight walls, near right angles in the corners, and a roughly symmetrical vault over each room." (Alexander, 2018, p.888)

3.3.4.5 Windows overlooking life

3.3.4.5

> "Rooms without a view are prisons for the people who have to stay in them."

(Alexander, 2018, p.890)

In this pattern, by referring to survey research, Alexander concludes that individuals working in offices are happier when they can look out at views of urban life or nature than when stuck with less-engaging views. The amount of window space needed, however, will vary depending on the natural environment, geographical location and reflective nature of the surfaces surrounding the workspace. The following measurements should be taken as very general guidelines for the appropriate floor-to-window ratio. Although this ratio may vary from region to region, as mentioned previously, it is likely to remain constant within any given geographical area (Figure 3.22).

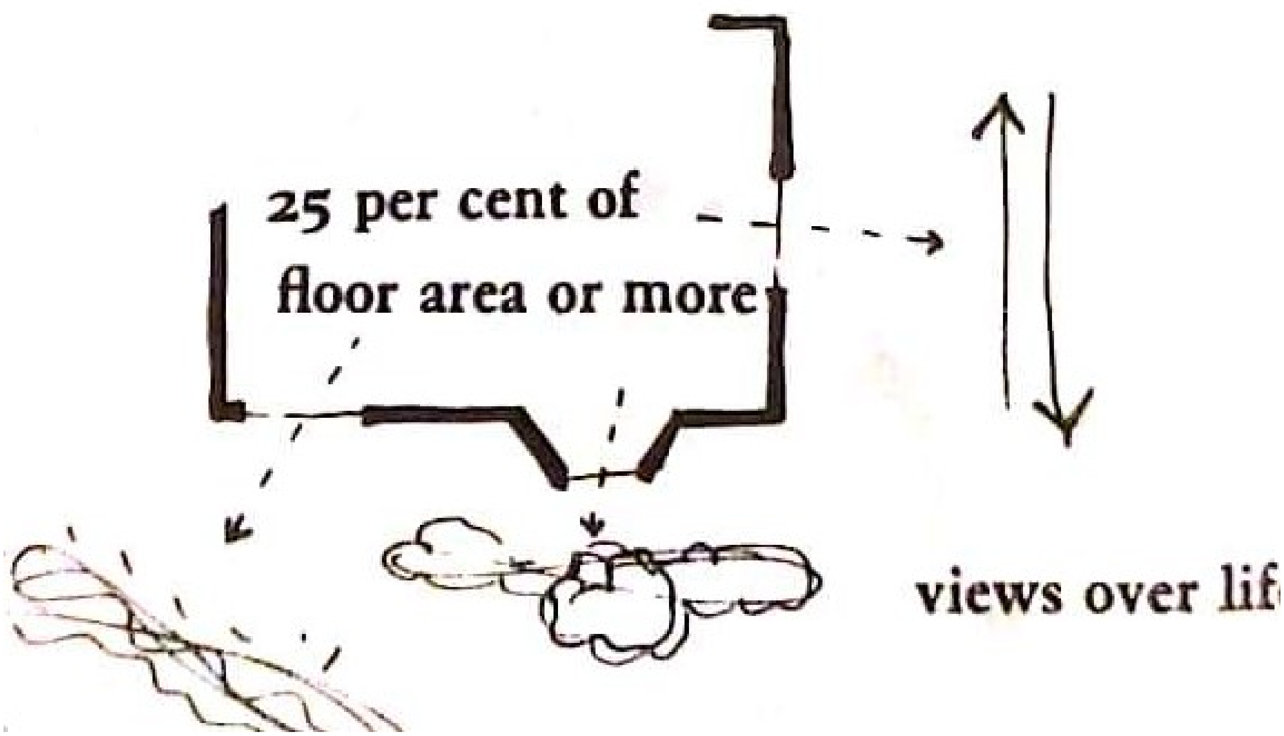

Figure 3.22. Percentage of exposure to outside (Alexander, 2018)

3.3.5 Housing Typology (Topologies de l'habitation)

The book *Pattern Language* mostly focuses on the ergonomics of space (in this case supplementary space). Housing typology mostly focuses on the entire dwelling and relationship of different spaces with one another. The criteria ranges from entrance and neutral access, visual privacy, proximity of infants to parents, to visual privacy, and the location of the central shaft and bathrooms in the dwelling. In an unpublished book, *Topologies de l'habitation,* Professor Roger B. Richard divided the general criteria of housing into 15, from dwelling to neighbourhood, to the urban fabric, as can be seen in the following list (Richard, 2016).

1- Neutral access off the entrance

2- Dwelling unit zones

3- Transversal or perpendicular facades

4- Variety of housing types

5- Soundproofing

6- Private outdoor living area

7- Visual privacy

8- Climatic impact

9- Car pedestrian symbiosis

10- Intimacy gradient

11- Individualization

12- Adaptability to the household scenario

13- Positive collective courtyard

14- Provisions of growth

15- Suppletive space

From 15 criteria, those ones which are related to supplementary space are as follows:

- Neutral access off the entrance
- Dwelling unit zones
- Visual privacy
- Transversal or perpendicular facade
- Housing types
- Provisions of growth
- Adaptability to household scenario

3.3.6 WELL Building Standards

The WELL building standard is a performance-based system for measuring, observing and certifying features of the built-environment that impact **human health** and **well-being,** through air, water, nourishment, light, comfort, mind, and fitness. WELL is based on medical research which studies the connection between the buildings where people spend more than 90% of their time and their health. The WELL certification-based assessment is granted to buildings following the WELL building standards. WELL is administered by the International WELL Building Institute (IWBI). The WELL building standard is a human-based approach to health and well-being, unlike LEED or BREEAM which have a carbon-based approach. When it comes to working from home, the following three concepts can be extracted (Figure 3.23):

Air: The WELL air concept describes a building that receives high-quality indoor air throughout its lifetime, by implementing strategies involving source elimination or reduction, active and passive building designs, and varied operation strategies.

People spend around 90% of their life in enclosed places, including houses, schools and offices. In a single day, people inhale over 15,000 litres (530 ft^3) of air, and consume four times more air than food and drink combined. Illnesses including headaches, dizziness, nasal congestion, eye problems, and sore throats are often caused by Volatile Organic Compounds (VOCs) like adhesives, paints, and air fresheners . The latter substances can also cause chronic diseases or even cancer. Altogether, 96% of VOCs present in office blocks were found to be caused by the materials used in the construction and furnishing of the building. Work productivity can be significantly reduced because of air quality issues like this, and more importantly, people can become sick. Productivity can be improved by 8-11% by reducing the number of pollutants and the levels of CO_2, and enhancing ventilation. All such activities improve indoor air quality.

Light: Exposure to light and developing light settings that promote visual, biological, and mental health are at the heart of the WELL light concept.

Research has shown a positive relationship between proximity to windows and productivity. Windows offering views of nature have an even more significant impact. Furthermore, research has indicated that exposure to light can affect a person’s mood and lessen the symptoms of depression. Those suffering from depression or recovering from a heart attack have been found to recover more quickly if placed in rooms with large, sun-facing windows, in comparison to patients with similar conditions placed in rooms with obstructed or mundane window views. Moreover, a relationship has been found between exposure to light and depression, as well as impaired cognitive function. Furthermore, work performance is enhanced when employees are exposed to nice views and bright light.

Thermal Comfort: The objective of the WELL thermal comfort concept is to enhance human productivity and achieve maximum thermal comfort for all individuals using a building. This will be accomplished by effective HVAC system design. The design will be made according to individual thermal preferences.

Thermal comfort is a mental satisfaction, generated via a homeostatic system, in which heat losses and gains are balanced to ensure that the core body temperature remains inside its optimal range of 36-38 °C [97-100 °F]. This process is controlled by the hypothalamus. Olfactory, ergonomic, and thermal issues can contribute to feelings of disruption, distraction, and irritation in the workplace, ultimately causing dissatisfaction at work. Thus, user satisfaction is significantly impacted by thermal comfort. Providing more control for the user in this aspect can greatly improve satisfaction. In warmer settings, there is a 4% decline in the productivity of employees, which increases to 6% in cooler settings.

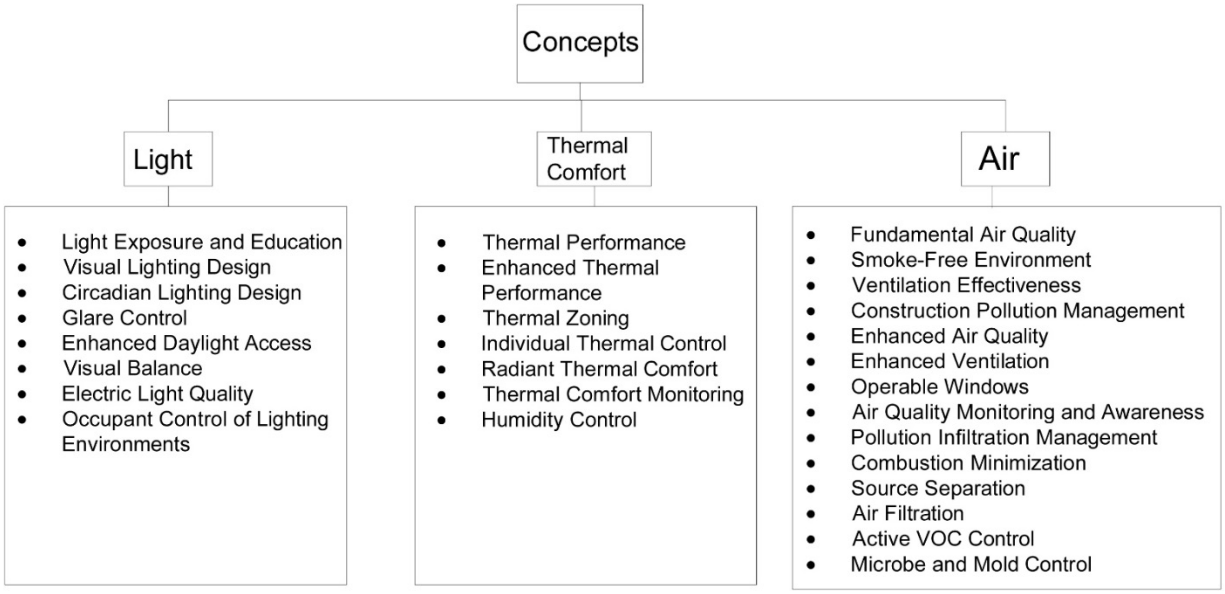

Figure 3.23. Three concepts and features of WELL building standards (International WELL Building Institute, 2019)

3.4 Extrapolating Criteria for Supplementary Space

A set of criteria, selected from the different sources mentioned above, will be formulated into the specific requirements for the supplementary space (Figure 3.24).

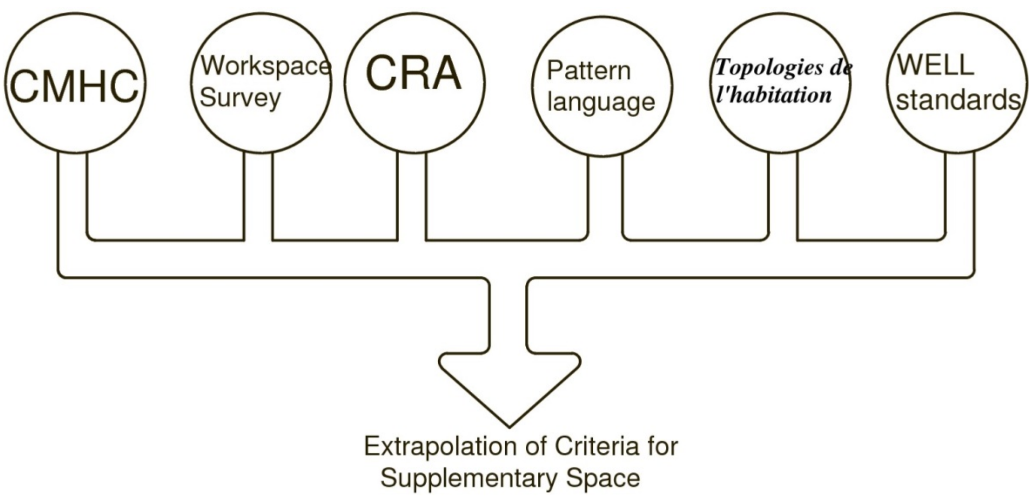

Figure 3.24. Extrapolating from six sources

Well-Being Criteria	Criteria of workplace	Basic criteria of housing	WELL building standard
CMHC Guidelines	**Vischer Survey**	**Pattern Language**	**International WELL Building Institute**
Health comfort	Workstation comfort	146: Flexible office space	Visual Lighting Design
Quality of the environment	Thermal comfort	157: Home workshops	Glare Control
Safety and security	Air quality	183: Workspace enclosure	Daylight Access
Personal activities	Privacy	191: The shape of indoor space	Electric Light Quality
Social relationships	Lighting quality	192: Windows overlooking life	Smoke-Free Environment
Building integrity	Acoustics comfort	***Topologies de l'habitation***	Ventilation Effectiveness
Spatial requirement	Spatial comfort	Entrance and neutral access	Enhanced Air Quality
Acoustics	Teamwork	Dwelling unit zones	Enhanced Ventilation
Visual comfort	Natural light	Visual privacy	Operable Windows
Thermal comfort	Safety & security	Housing types	Source Separation
Air quality	Building appearance	Provisions of growth	Thermal Performance
	Visual comfort		Thermal Monitoring
	Building and remote noise control		Humidity Control
	CRA		
	Exclusive for business		
	Meeting client/ customer/patient		

Figure 3.25. Perspective and features of all criteria together

There are 53 criteria deduced from the six sources of criteria illustrated in Figure 3.25. Some criteria, such as safety and building integrity, are delivered by the dwelling unit itself. Others, such as furniture and lighting, can be customized by the user after occupancy. This study focuses mainly on those criteria that the architect must accommodate during the early design process for the workspace. Some criteria are shared between different sources, with the same criteria named differently, such as natural light, 192: windows overlooking life, operable windows, and daylight access. The shortlist of all criteria is presented in the Figure 3.26.

Well-Being Criteria	Criteria of workplace	Basic criteria of housing	WELL building standard
CMHC Guidelines	**Vischer Survey**	**Pattern Language**	**International WELL Building Institute**
Spatial comfort	Visual Privacy	Home workshops	Daylight Access
Acoustics	Acoustics comfort	***Topologies de l'habitation***	Enhanced Air Quality
Air quality	Natural light	Entrance and neutral access	Thermal Performance
	CRA Criteria	Dwelling unit' zones	
	Exclusive for business	Housing types	
	Meeting client	Provisions of Growth	

Figure 3.26. Shortlist of criteria

Therefore, 10 functional criteria are to be implemented that are directly related to the supplementary space:

1- Housing types
2- Provisions of growth
3- Dwelling units' zones
4- Entrance and neutral access
5- Dimensional comfort
6- Sound-proofing comfort
7- Spatial and visual privacy

8- Thermal comfort

9- Air quality

10- Natural light

Criterion 1 – Housing types: Housing types influence the feasibility and location of supplementary space. The relationship of supplementary space to the entrance, the location of the staircase, and the number of stories all have an impact on the location of supplementary space. The exposure of the unit to the outdoors is a key factor for the location of the supplementary space. Based on this criteria, there are three main types of units that must be considered: transversal (lateral access or split-level access), single sided (i.e., double-loaded corridor), and corner orientation units (i.e. perpendicular facades).

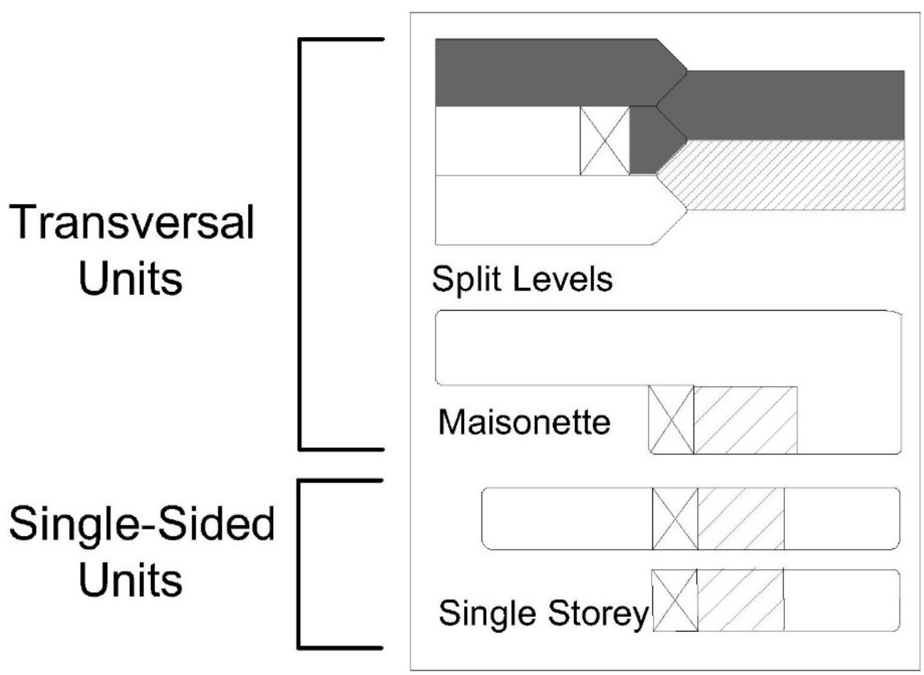

Figure 3.27. Housing types criterion

Criterion 2 – Provisions of Growth: This is the ability to expand the area of the supplementary space. It allows users to combine, add to, and change the function of the space. For instance, changing the location of supplementary space to a second living room or to a bedroom. The criterion could also rely on an eventual trade-off of a space between

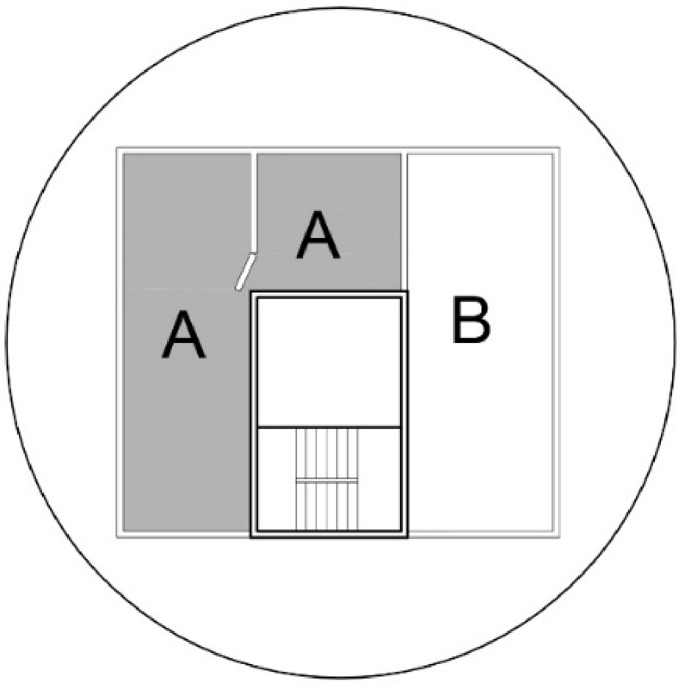

Figure 3.28. Provisions of growth criterion

adjacent dwelling units either horizontally or vertically. Such a feature will be further elaborated in chapter four.

Criterion 3 – Dwelling Unit Zones: There are three zones within a household: individual areas, services, and social/family areas. Not only does such a distinction matter for privacy, but it also helps with the performance criteria of the household. For instance, the service area can work as a buffer zone and reduces the noise from the socio-family zone to the individual areas. Although the supplementary space can be a bedroom, it should be located independently or marginally to maintain privacy from the rest of the dwelling.

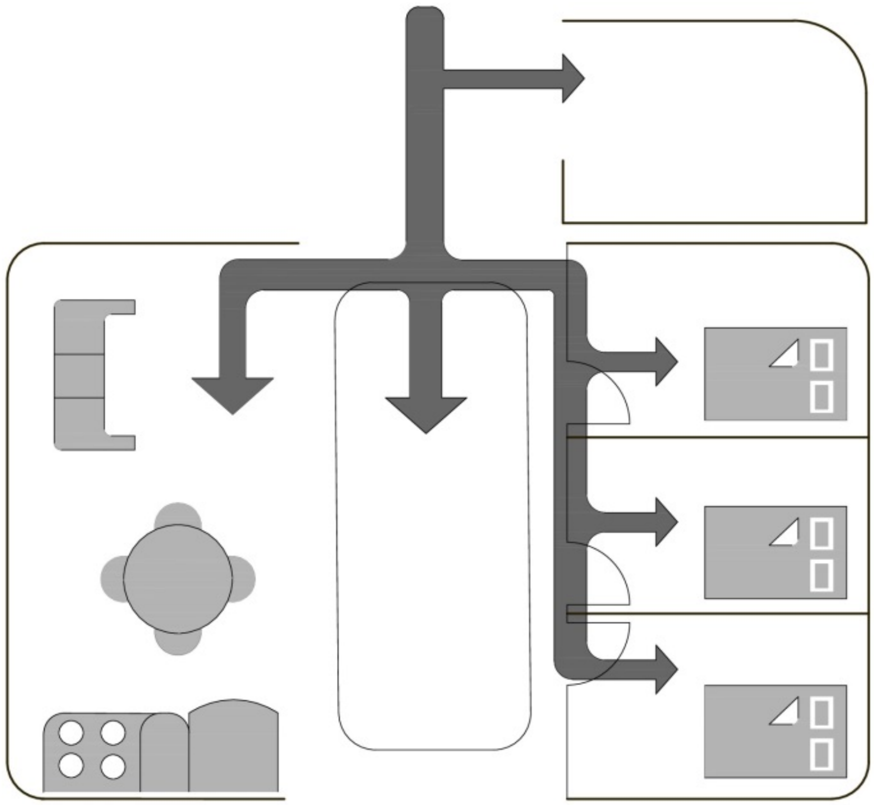

Figure 3.29. Dwelling unit zones

Criterion 4 – Entrance and Neutral Access: This factor concerns entering one zone without moving through another one. The visitor should have a separate path to the living room and the bedrooms. This is in conjunction with the dwelling unit zone criterion, as both deals with privacy. The user of the supplementary space must use its own path to commute so the privacy of the rest of occupants in the household would be preserved.

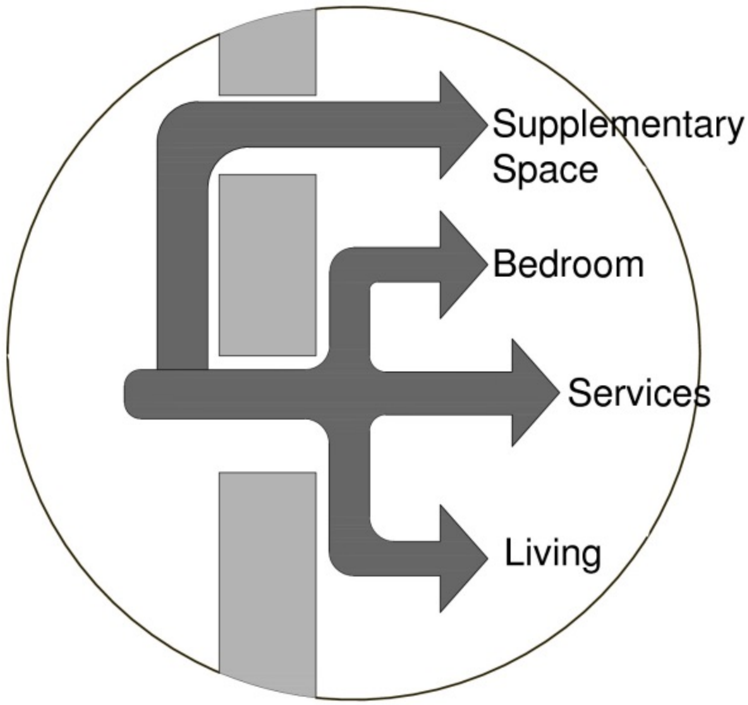

Figure 3.30. Neutral access

Criterion 5 – Dimensional Comfort: Dimensional comfort is associated with easy movement, freedom of choice, furniture arrangement, security, washroom access, etc. According to Lausen, research shows that workers in a spatially-comfortable environment have a 13.5% more positive productivity. It is important for the supplementary space to have dimensions that allow for easy movement of both the user and the visitor.

Additionally, improper computer workstations and poor furniture design are costly to society. In the U.S., lower back work-related injuries are estimated to cost billions of dollars in compensation annually (Carlopio & Gardner, 1992). A document published by Public Works and Government Services Canada (2012), *Workplace 2.0 Fit-up Standards,* examined the quality of the workplace from different angles. The information ranges from technical standards (such as telecommunications infrastructure), to planning, to detailed drawings for designing the workspace.

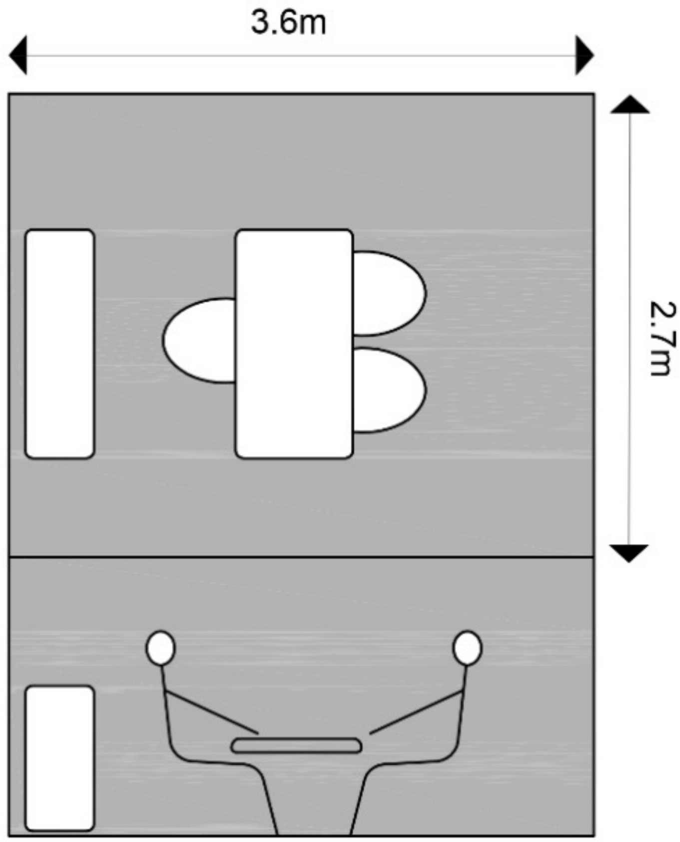

Figure 3.31. Dimensional comfort

Criterion 6 – Sound-Proofing Comfort: Sound is the most important environmental factor in the workplace. Unwanted noise is the single most common reason for workplace complaints: it has a positive correlation with environmental discontent (Nemecek & Grandjean, 1973) and job dissatisfaction (Sundstrom, Town, Rice, Osborn, & Brill, 1994). The key criterion is the ability to select the wall with a higher STC-value, leading to the soundproofing of the supplementary space. STC 60-65 is suggested by the National Building Code of Canada.

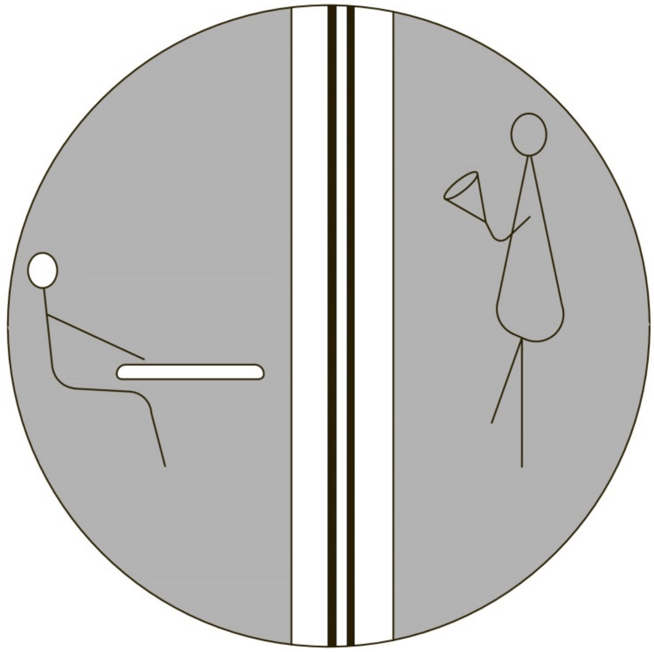

Figure 3.32. Sound-proofing comfort

Criterion 7 – Spatial and Visual Privacy: Pennock and Chapman (1971) have indicated that the concept of privacy emerged from environmental psychology and encompasses a range of needs or situations that include the visual and physical need for space through psychological separation; control over space; freedom of activity; and low population density. It is sometimes considered a coping strategy that enables the individual to control environmental stress. Privacy can be defined in several ways. According to Sundstrom (1986), it can be classified into spatial and visual forms. It includes both seclusion from noise as well as isolation from visual stimuli and unwanted observation (Danielsson, 2010).

In the supplementary space, spatial privacy involves physical seclusion from the rest of the dwelling. It is achieved by obstructing direct visibility and the sudden appearance of visitors, as well as separating visitors' view from the rest of the household. Sundstrom

(1986) describes the three central ideas of privacy in the office as the retreat from people, control over information, and regulation of interaction. The location of supplementary space should offer visual privacy in the multi-family floor layout (Marquardt, Veitch, & Charles, 2002) (Stokols, 1975).

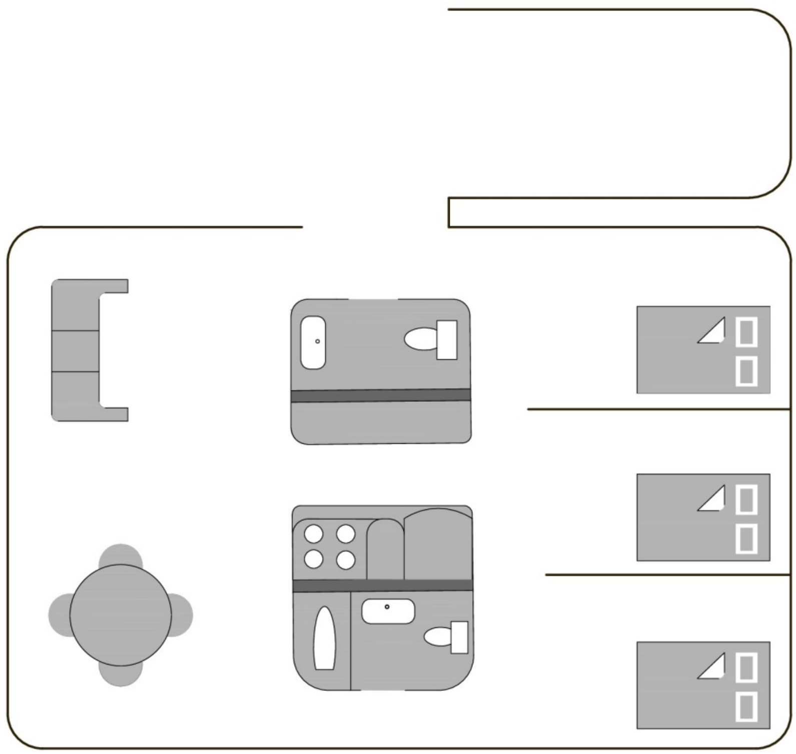

Figure 3.33. Spatial & visual privacy

Criterion 8 – **Thermal Comfort:** According to BOSTI (1981), uncomfortable temperatures are linked to unhappiness in the workplace; frequent fluctuations in temperature also cause lower job satisfaction. A significant proportion of employees in offices and factories find that the temperature is either too high or too low. Once Supplementary space is in use, the issue becomes supplementary space temperature difference from the rest of dwelling. While the optimal temperature for the supplementary space is 21ºC (70ºF), it could be 25ºC (75ºF) for the rest of the dwelling. A multi-zone heating and cooling system could be a possible solution.

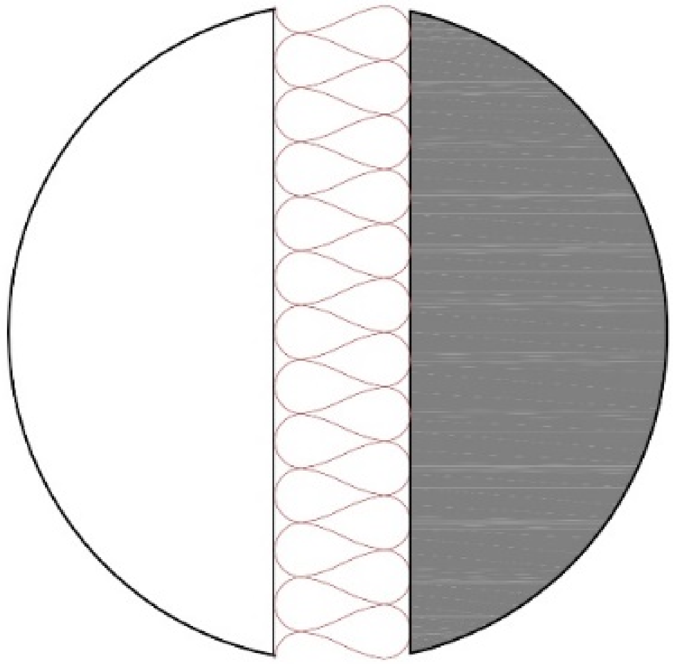

Figure 3.34. Thermal comfort

Criterion 9 – Air Quality: Sundstrom (1986) noted that air quality is related to the satisfaction of supplementary space users. BOSTI (1981) also found that a fall in air quality leads to a decline in job satisfaction.

Moderate air movement and humidity, as well as freedom from pollution are characteristics of good air quality. Infrequently changed air is usually the cause of bad air quality in the workplace and results in a perception of a stuffy environment. Exposure to the outside (with a window) is the main solution for this criterion in supplementary space (Danielsson, 2010).

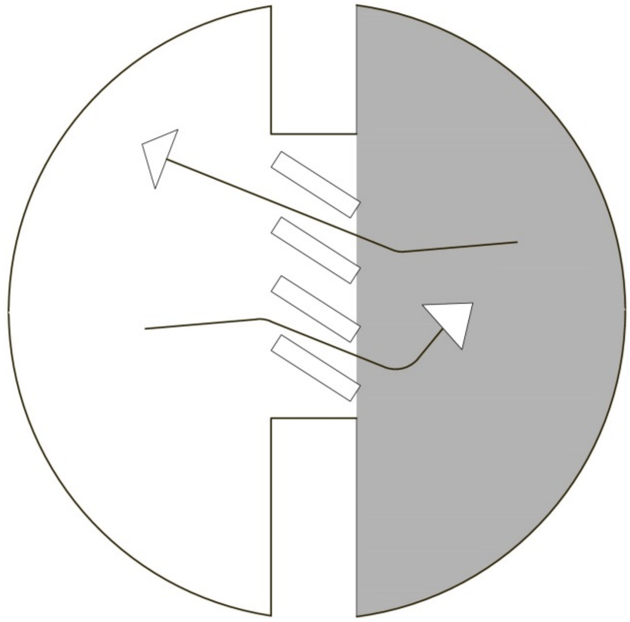

Figure 3.35. Air quality

Criterion 10 – Natural Light: Studies show that exposure to natural light has health benefits. Kaplan et al. (1988) found that office employees with exposure to daylight and a view of the outside had lower levels of job stress.

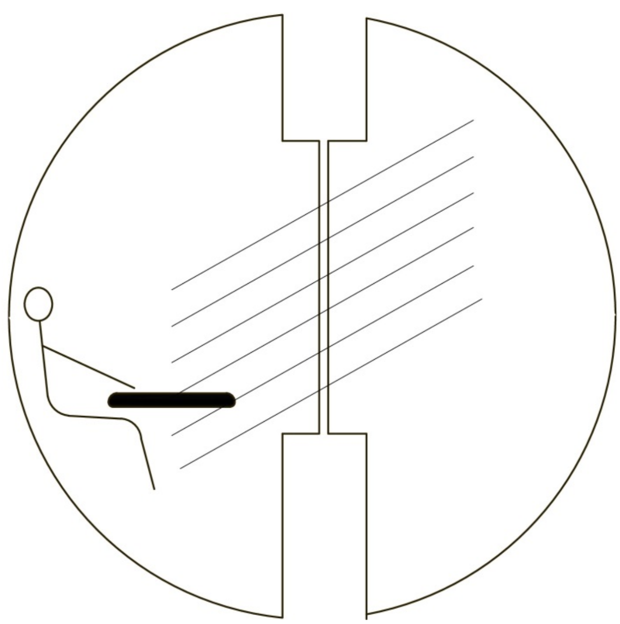

Figure 3.36. Natural light

It is widely accepted that workstations with windows are highly preferred by office workers and add to their satisfaction with the physical environment (Sundstrom et al., 1994). Access to natural light is even more relevant and feasible in a multi-family residential building: the National Building Code of Canada requires that any living space within the dwelling unit must be directly adjacent to the outside.

3.5 Chapter 3 Findings

There are 53 criteria deduced from the six sources of criteria. This study focuses mainly on those criteria that the architect must accommodate during the early design process for the workspace. Therefore, 10 functional criteria are directly related to the supplementary space: housing types, provisions of growth, dwelling units' zones, entrance and neutral access, dimensional comfort, sound-proofing comfort, spatial and visual privacy, thermal comfort, air quality, and natural light.

Although these criteria are applicable to most dwelling units, they are critical in the case of the supplementary space, mainly on the basis of respecting the privacy of the other functions. This is obviously related to the fact that working from home could also mean receiving different business visitors (partners, clients, consultants, etc.); it is actually a requirement when an income tax deduction is claimed to the Canada Revenue Agency (section 3.3.3).

Based on the above the criteria of supplementary space can be seen in next page.

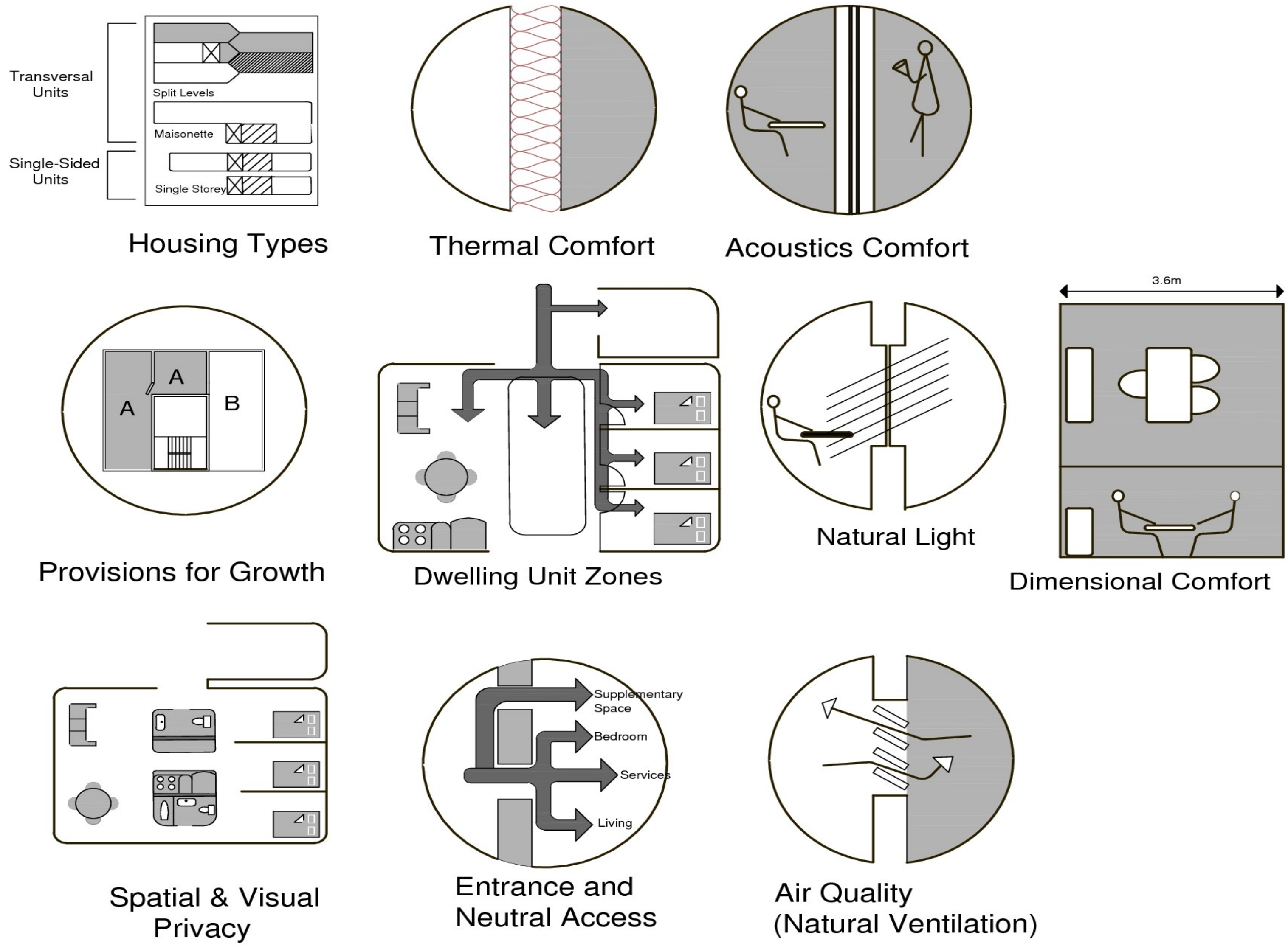

Figure 3.37. List and diagrams of Criteria

4 Integrating the Supplementary Space within an Adaptable Framework

The concept of adaptability is the key concept for accommodating change in architecture and housing, especially in the case of the supplementary space. Therefore, the model for supplementary will be governed by adaptability strategies.

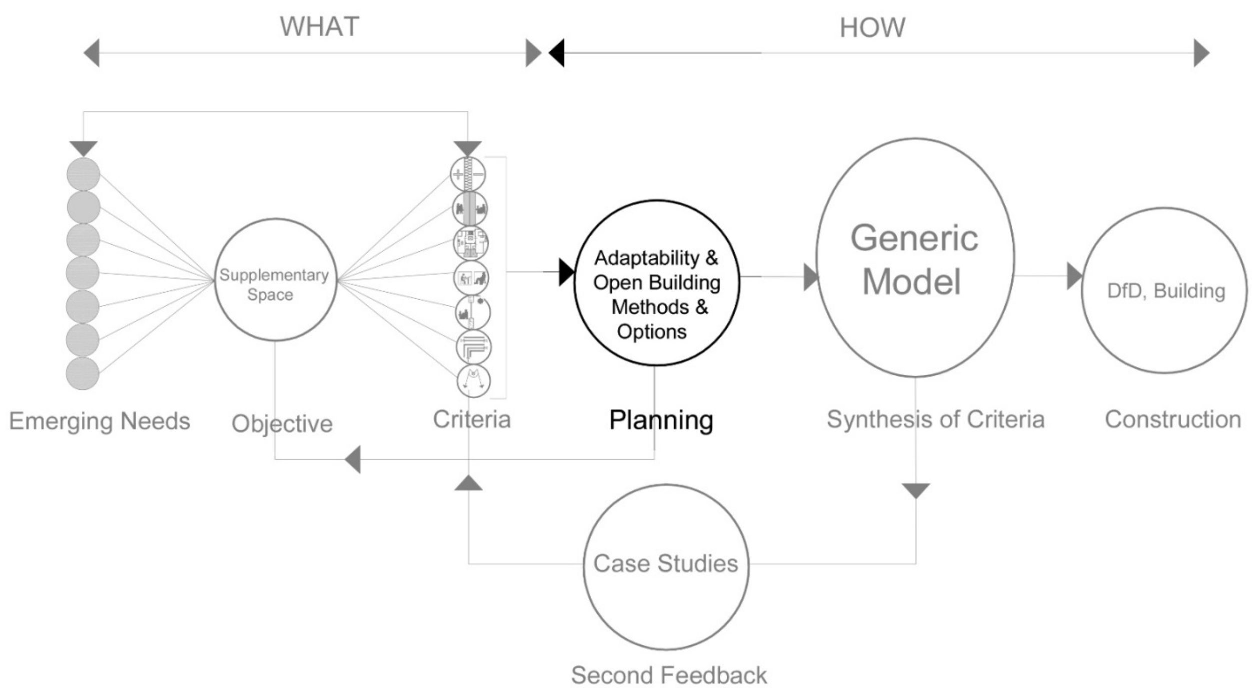

Figure 4.1. Map of research, adaptability & Open Building implementation

4.1 The Conventional Building Industry

The conventional building industry has been practiced for a long time. In this method, most of the components are fabricated at the site. In comparison with other construction methods (such as industrialized building), it relies more on manpower, consumes more natural resources, and generates more waste.

Implementing methods to conserve energy, such as limiting the use of natural resources and the production of waste, should be the primary aim of the construction industry to promote global sustainability. When it comes to a space's potential to accommodate several activities through building's lifespan, conventional housing design envisions a single, determined usage for the space. Such a limitation makes it difficult to modify a dwelling to accommodate users' emerging needs. In conventional building context heavily relies on destruction, major modification, renewal, or replacement, such building practices generating unnecessary waste at the end of a building's life.

According to the CIB document (2003), conventional building/construction delivery influences environmental, social, and economic systems. As a result, the outcomes of this conventional building delivery are a combination of three competitive elements: construction expenses, long duration, and quality. The key dilemma generally lays in the reality that developers, designers, and engineers frequently imagine buildings as motionless and everlasting (Sjostrom & Bakens, 2003). Therefore, they do not consider future conversions to be necessary. Optimization of short-term standards like building expenditure, time, and quality are their principal focus. On the contrary, the sustainable methods of building construction treat these conventional elements like sub-factors that form a portion of a sustainable global system, with economy, social, and environmental approaches (Figure 4.2)(Durmisevic, 2006).

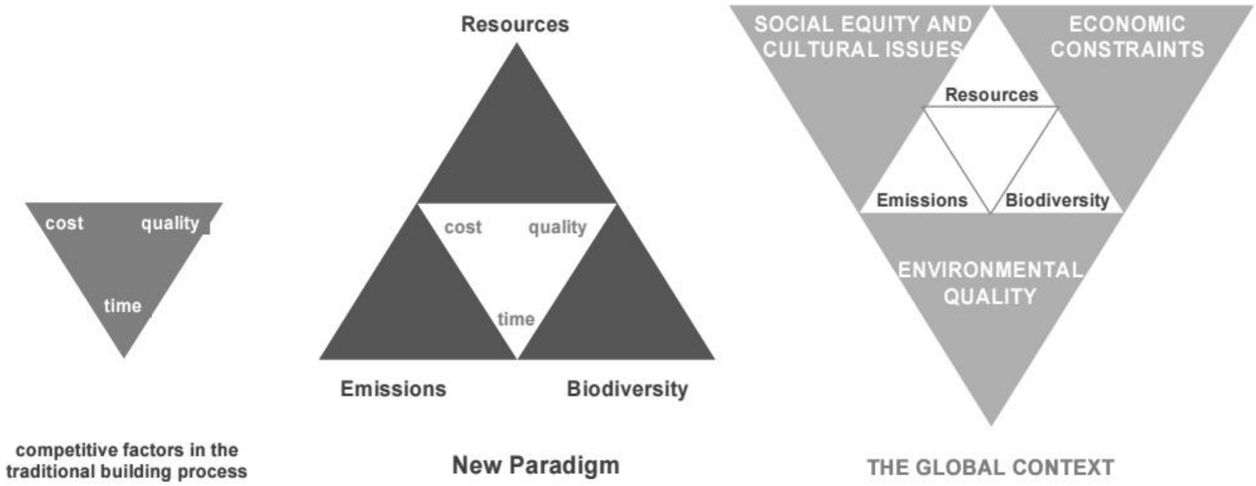

Figure 4.2. The new approach in global context CIB, 2003, (Sjostrom & Bakens, 2003)

Implementing a sustainable approach into building systems must go beyond the conventional ways of designing where merely the optimization of quality, cost, and time are considered. A sustainable approach needs to consider different operational phases of the building in the future, as well as the demolition phase. The changes in operational phases of the building and the demolition phases have a negative impact on economic, social, and environmental systems (Blengini & Di Carlo, 2010; Durmisevic, 2006).

The conventional housing delivery has a dominant linear-direction where the design was founded on the designer's previous interaction and experience of the space in question. Therefore, this phenomenon is applicable to how design stages are established, including schematic design, concept creation, design development, and construction. Such a process is generally led by the architect who defines the use of every space. These systems acknowledge a single end-of-life situation, however, if the situation changes, the user will be required to travel to another location that meets their new situation requirements. As a result of increasing demand concerning sustainable growth, , linear design processes advocate a piece-by-piece process concerning sustainable construction, wherein structures are defined by their spatial usage (Kara, Georgoulias, & Silvetti, 2012). When using traditional building methods, the amount of changes involved impacts the overall economic life of the building. Thus, other than the operational costs impacting the total life cycle costs (mostly through energy use), construction methods are also important with regards to the life cycle costing (LCC) of a building and its related environmental effects. Total life cycle costs can be affected substantially by decisions made in the initial stages of design.

4.1.1 Product Design vs. Building Design

The product design cycle has evolved over time. As a result of the vast material and energy input and output, the need to assess its sustainability is recognized. During the early stages, designers can use this consideration to make a selection from a number of different designs, or alternatively, from several production scenarios (Boothroyd, 1994; Drexhage & Murphy, 2010; Durmisevic, 2006).

The process of building design must be comparable to the life-cycle-based process used in product design. To alter the conventional linear building design process, additional environmental end-of-life scenarios must be considered. Indeed, the designer's ability to anticipate the different lifecycles increases a building's end-of-life utility (Figure 4.3). This is an indication that there should be a cyclic, rather than a linear, design model, one that allows for the transformation of spatial aspects throughout various stages of the dwelling's life (Zhi-Yuan, 2003). Such a model presents a series of end-of-life choices concerning the spatial use of a building.

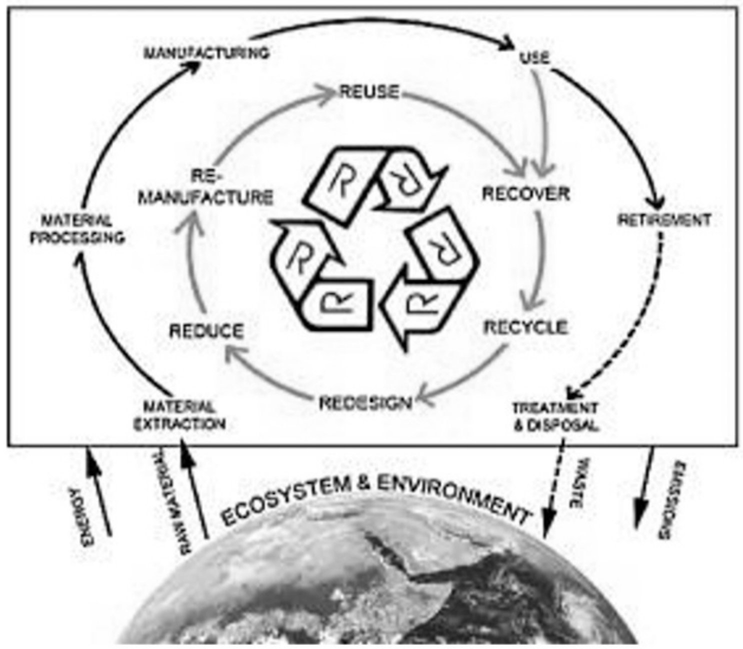

Figure 4.3. Time and ecosystem design process graph (Zhi-Yuan, 2003)

4.1.2 Life Cycle in Product Design

From engineering to the social sciences, the theory of the life cycle has become a model for analyzing phenomena related to the process of change. In regard to product design, scholars understand that both product development and manu facturing theoretically pass through different stages. It has four phases: introduction, growth, maturity, and decline (Figure 4.4). In short, the life cycle describes the behaviour of a product from its introduction to the end of its life. The evolutionary sequence of product design encompasses all the phases from the initial design to manufacturing and distribution, and could be extended to cover the phases of use (Giudice, La Rosa, & Risitano, 2006).

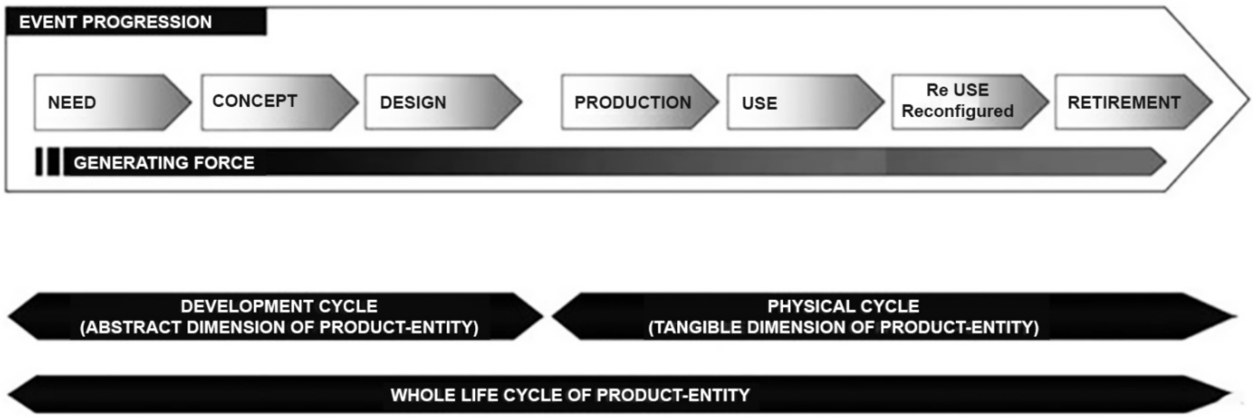

Figure 4.4. Life cycle theory in product design (Giudice et al., 2006)

The life cycle consists of two major parts:

- The development cycle: This phase includes the identification of the need(s) that the product will meet, the conceptual design, and progress engineering, which all lead to the final product prototype.
- The physical cycle: this includes all the phases that the product goes through from cradle to grave:
    - Production,
    - Reuse,
    - Reconfiguration, and
    - Retirement

Thoroughly studying and collecting information on each phase helps the designer create a set of phase-specific requirements (Giudice et al., 2006).

4.1.3 Designing for Reuse in Other Industries: Remanufacturing, Reconfiguring, Recycling, and Maintenance

Several companies in the computing and automotive industries have implemented a product retrieval program wherein items are returned, reused, and subsequently disassembled. Such institutions acknowledge that there are several end-of-life situations concerning their products, including remanufacturing, recycling, and reuse (Kumar, Rosenberg, Bouzida, Swendsen, & Kollman, 1992).

Remanufacturing: This strategy involves the reconfiguration of a given system to re-establish its condition as "refurbished" or "good as new." This may include reusing functioning parts while replacing others and utilizing a tight quality-control process to guarantee that the re-manufactured product has the abilities, functions, and tolerance of a new product (Kuei & Madu, 2001).

Design for Recycling: once they are no longer useful, vehicles retain value by providing spare parts, and this a dismantling industry. This industry is based on prolonging a vehicle's usefulness through the disassembly of its parts at the end of its functional life cycle, before utilising these recovered parts in other vehicles. This is the optimal choice for the environment as it minimises the energy used to bring an automobile's life cycle to an end (Durmisevic, 2006).

Both import firms and manufacturing firms founded the Automotive Recyclers of Canada (ARC) in 1997 (Recyclers, 2002). The ARC resulted in greater recycling processes of automobile parts and has had a positive impact on automobile dismantling (Figure 4.5). The firms that take part in the scheme are already utilising up to 90% of their end-of-life vehicles, with around 86% being employed for a different purpose through recycling

(Recyclers, 2002). In addition, the ARC created a sophisticated parts locater network which connects the inventory of hundreds of auto recyclers across the country. With a simple search, a specific recycled part can easily be found.

Figure 4.5. .Automotive Recyclers of Canada (ARC). Recycled inventory locator across the country (Miller, Soulliere, Sawyer-Beaulieu, Tseng, & Tam, 2014)

Reuse: The Z1, a BMW car has a plastic skin that can be removed from the main metallic chassis in 20 minutes. As a result of its design, it is easy to repair, and broken parts can be quickly taken out and replaced. Siemens Nixdorf's prioritization of environmentally-friendly design ensures that, in 90% of cases, the firm's eco-computers can be re-appropriated and reused (Figure 4.6).

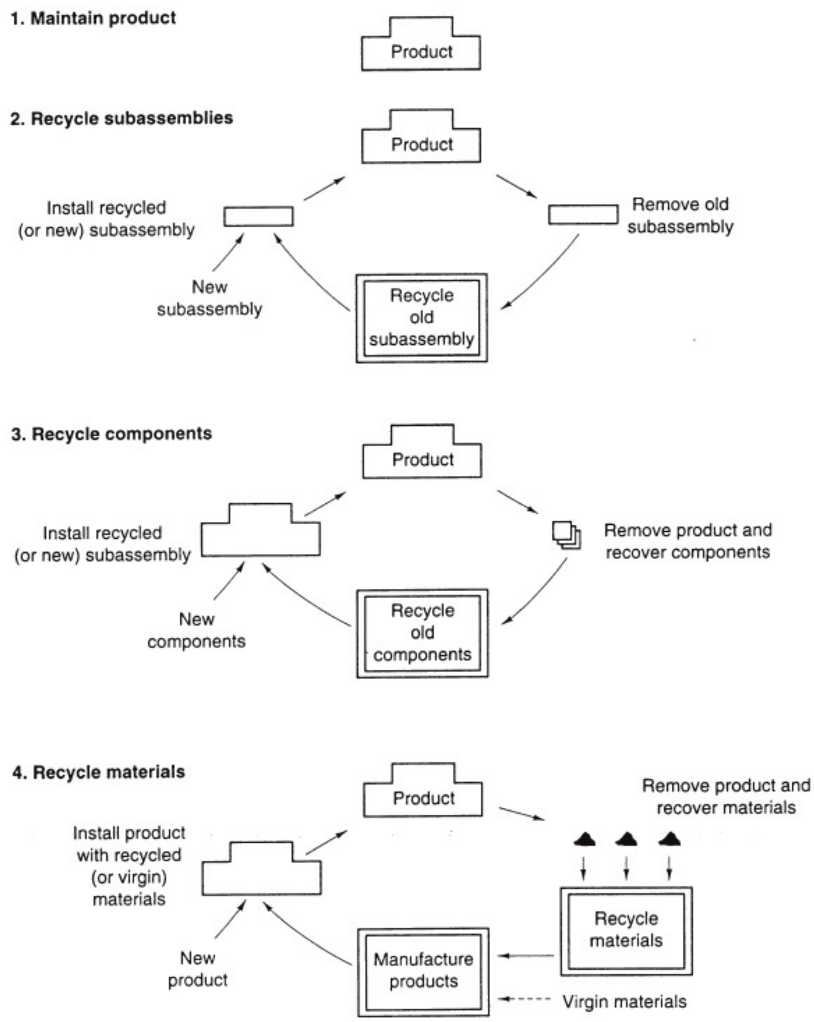

Figure 4.6. Hierarchy of the end of life options in the automobile industry(Miller et al., 2014)

4.2 Adaptability in Housing

The difference between flexibility and adaptability is elaborated by Schneider and Till as follows:

"While adaptability is achieved through designing rooms or units so that

> they [can] be used in a variety of ways, primarily through the ways that rooms are organized, the circulation patterns and the designation of rooms, for example a room can be used both as office and bedroom … flexibility is achieved by altering the physical components of the building: the tool to join together rooms or units, through sliding or folding walls and furniture, for instance the partition walls are flexible." (T. Schneider & Till, 2016a, p.15)

Based on these measures, adaptability mainly refers to the capacity of the internal organization (space) of the unit to accommodate change. Flexibility, by contrast, involves all the building components that can be moved (Albostan, 2009). These terms, however, are not strictly defined in the literature.

Flexibility: Flexibility allows homeowners to adjust their surroundings to social and behavioural changes physically. The *Oxford English Dictionary* (OED) defines *flexibility* as being "capable of bending easily without breaking; able to be easily modified to respond to altered circumstances or conditions." For example, a door is flexible, but not the space in front of it. Lelieveld, Voorbij, and Poelman (2007) explain it as:

> "The term flexible architecture describes an architecture from which specific components can be changed in response to external stimuli, for example the users or environment. This change could be executed by the building system itself, transformed manually or could be any other activity to transform by an external force." (Cuperus, 2001, p. 1; Lelieveld, Voorbij, & Poelman, 2007)

Adaptability: According to the OED, the word *adaptability* means "able to adjust to new conditions, able to be modified for new use." Adaptability applies not only to physical modifications, but also to the repurposing of space.

Schneider and Till (2005b) describe adaptable housing as "housing that is designed for choice at the design stage to accommodate change over its lifetime" (T. Schneider & Till, 2005, p. 157). The Canadian Mortgage and Housing Corporation (CMHC) defines it as architecture that allows homeowners to reconfigure their living space as their lifestyle changes. In addition, adaptable housing is equipped to accommodate different conditions, such as children, disabled users, older parents, and those who work from home (ACT, 2011).

Adaptable housing is relevant for users with diverse lifestyles, as it meets their requirements from the beginning to the end of their occupation. Hence, architects can employ this concept extensively (Duygu, 2009). According to Schnider and Till, "long-term consideration[s]" make adaptable housing a prime design objective:

Adaptability is an important consideration in the design of housing if it is to be socially, economically, and environmentally viable. The degree of adaptability is determined on whether "capable of different physical arrangements" (T. Schneider & Till, 2016a, p.157).

The need for change is universal, and adaptability is the way to accommodate it over a long period of time without demolitions. Furthermore, incorporating adaptability into the design can fulfill various functional demands within a limited space. In addition to its economic benefits, adaptable housing has ecological ones as well, especially with regard to conserving energy and resources (Narahara, 2010). Adaptable designs require fewer materials, less energy and labour, the outcome of such a design is deferring in demolition, producing less waste and lower costs (Kendall & Teicher, 2010; T. Schneider & Till, 2016a).

Medical advances have extended people's lives, resulting in the need for more care and accessibility; therefore, living spaces should be able to change as the occupants age. As time goes by, homeowners may make spatial alterations, but these rarely keep pace with their lifestyle. Because home modifications are costly, time-consuming, and sometimes impossible, people are forced either to move or to change their habits or lifestyle to suit their existing dwelling (Kendall & Teicher, 2010).

The introduction of adaptability helps the occupants improve their living space at a minimal cost, avoid expensive and destructive alterations, change their habits, and avert the pressure to move from their homes (Lans & Hofland, 2005).

4.2.1 Designing Adaptable Housing

Buildings should meet the demands of a rapidly evolving world (Benros & Duarte, 2009). However, "as household members grow older, their habits, lifestyles, and use of space change" (Leupen et al., 2005, p.15), and yet the common approach to housing tends to ignore these considerations. For instance, couples may have to increase the size their home to accommodate children, or a professional may need to build an office space to work from home. At the same time, technology and network protocols now present affordable opportunities to assess the quality of housing and thereby show how poorly the traditional approaches meet homeowners' requirements.

In the past, architects and designers built permanent structures whose rigidity has ultimately made them incompatible with the changing lives of modern dwellers. Future use and repurposing were not part of the initial design, so major expensive alternatives are required to meet the new needs.

Adaptable housing considers all the timeframes that are part of human life. These include short timeframes such as the daily trajectory from morning to night, as well as longer timeframes that encompass the life stages—birth, childhood, teens, adulthood, parenthood, and the limitations of getting old (Figure 4.7).

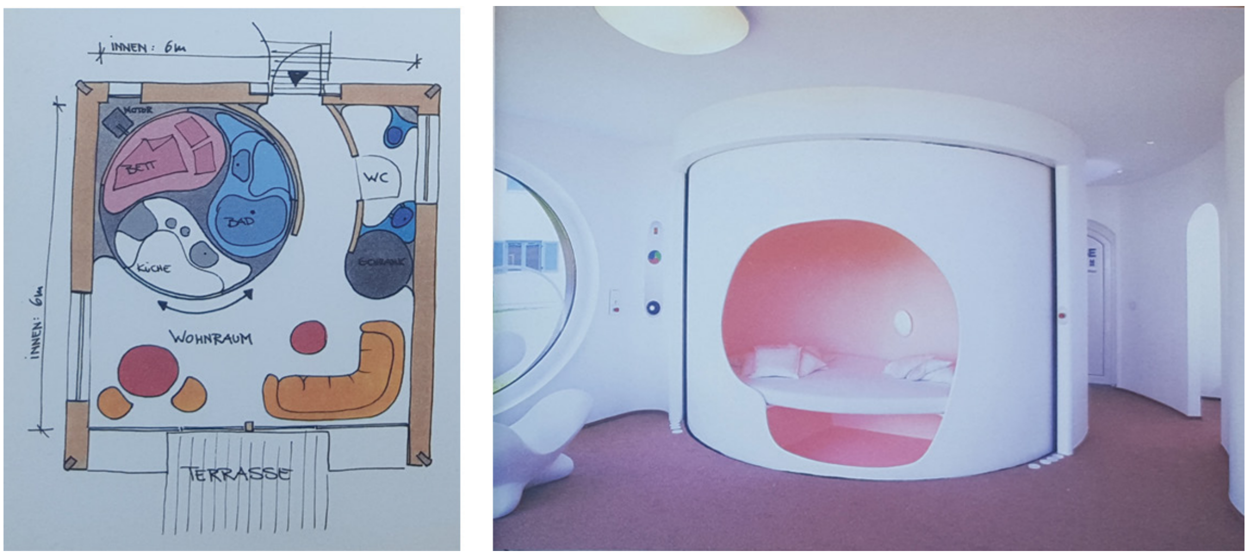

Figure 4.7. Rotor House (Leupen et al., 2005)

Current technology has encouraged the incorporation of more adaptable features, such as movable partitions and adjustable facades. However, for various reasons, most interior floor plans have remained tied to the requirements of the past, and are not keeping up with modern or future lifestyle expectations.

4.2.2 History and Theory of Adaptable Housing

The evolution of adaptable housing is significant; therefore, this section reviews the history of adaptable housing and its relationship to needs, technology, and user demands.

In their book, *Spatial Agency: Other Ways of Doing Architecture,* Schneider and Till portray three episodes for adaptable housing (2013):

The first upsurge in adaptable housing occurred due to the economic and social effects of World War I. After 1919, smaller living spaces were needed to house entire families. The debate about the best solutions for the new reduced-space standards was first encapsulated by Marcel Breuer in 1929; he proposed new ways of arranging apartments to suit different situations (Trencher, 2000). Mies Van der Rohe also mentioned “flexibility as one of the most important concepts in architecture” (Acharya, 2013). For these authors, adaptable housing became a moral, social, and economic response of architects to society in the framework of modernism and minimalism (T. Schneider & Till, 2016a).

The second episode occurred during the technological improvements in the 1930s. . In particular the adoption of industrialized solutions such as prefabrication enabled the construction of better adaptable housing units (. Schneider and Till (2013) further discussing prefabricated housing in detail and offers many case studies. After World War II, the idea of mass housing was developed in the United States. In *The American Family Home* (1986), Clifford Clark traces the rise of the kit of parts, a form of adaptable mass housing that was popular in the suburbs of major cities (T. Schneider & Till, 2016a).

In the third episode, emerged in 1960s, the emphasis shifted towards user participation, as architects envisioned designs that could accommodate future changes and improve quality of the space. In *Individual Housing,* Trencher notes the backlash against industrialization in the work of architects like Alvar Aalto, along with the desire to meet diverse individual needs and avoid the repetition of a single unit. Noting the automobile industry’s increasing ability to customize cars to suit individual preferences, Womack states that this serial production should also be possible in the housing industry. In addition, the idea of "mass customisation" in housing is mentioned in *Future Perfect* by Stanley Davis. In his book *Modernity and Housing,* Rowe maintains that even when houses are mass produced, each prospective homeowner should be able to customize and manipulate his or her dwelling before it is assembled by machines. Moreover, in *Housing without Houses: Participation, Flexibility, and Enablement,* Hamdi discusses the social and political aspects of adaptability modes in which the occupants can choose their "unit" (T. Schneider & Till, 2016a).

4.3 Open Building Theories and Principles

The architecture of adaptability is considered to be one of the most important achievements of the Modernist Movement (Henket & Heynen, 2002). Most adaptability theories and practices are based on the **hierarchical principle** in architecture (Kendall & Teicher, 2010).

Bosma and Van Hoogstraten (2000), in their book *Decision Making for Flexibility in Housing*, remark:

> "Noted theoretician and architect Christopher Alexander (1964) suggested a principle that attributes the quality of adaptability in open systems to the physical independence of their sub-systems. According to Alexander, the principal properties of hierarchical open systems in architecture can be summarized as follow: They are composed of interrelated sub-systems organized in levels' are capable of exchange with their environment; can be

organized into relatively independent subassemblies; and their organization contributes to their adaptability." (Bosma, Van Hoogstraten, & Vos, 2000), p.29)

4.3.1 SAR Group and Niklas J. Habraken

In 1965, the SAR Stichting Architecten Research (Foundation for Architect Research) was created by a group of architects in the Netherlands. Supported by engineers, contractors, construction industry professionals, and others, the goal of SAR was to "stimulate industrialization in housing." It sought to explore the issues surrounding architecture and housing, and to propose new guidelines for housing design to avoid placing people in a standard "chicken cages" spatial arrangement

Niklas J. Habraken, a Dutch architect and theoretician, became the director of SAR and initiated the basic principles in this field (Habraken & Teicher, 1999). Drawing on the hierarchical principle of sub-systems, Habraken theorized that, in housing, the roles of the community and the individual are distinct. Habraken believed in re-establishing the dweller as an active participant in housing design, and developed a methodology for linking the processes of housing design and decision-making to their technical implementation (Dluhosch, 1974; Habraken, Boekholt, Dinjens, & Thijssen, 1976).

A hierarchical principle is also an important tool in contemporary housing design. For example, Niklas J. Habraken (1976) employed the hierarchical principle as one of the main concepts for designing the base building (Support). In his book, *Variation: the Systematic Design of Supports,* he notes:

"The theory behind the method of designing the housing can best be described using the concept, already used in a general sense in many disciplines, of a 'system'. Every building can be regarded as a system component, ordered according to certain rules. These components could be material ones, walls, floors, and roof, etc. Alternatively, a building can be considered a system of space, a system in which the spaces are the components, and relationship between those spaces confirm to certain rules." (p.205)

4.3.2 Open Building Implementation

The Open Building (OB) movement elaborates on the implementation of Habraken's approach into practical design and construction guidelines. Notably, CIB W104 Commission is promoting this approach.

Kendall and Teicher (2010) assert that commercial base buildings are not completed until their users have defined the functions and purposes of each unit. The unit is not finalized by the builder or owner, who is unaware of the occupant's interests; rather, the tenant participates in the completion of his/her own interior and completes the final finishes. Kendall and Teicher endorse Open Building in the residential sector as well, where the generic house could be finished and modified by its users rather than by the developer or the builder. OB distributes the responsibility of building between the builder and the occupants. Instead of spending money and time customizing the unit, the builder can minimize costs and make the building more affordable for the user. In the future, the user can improve the dwelling gradually, based on his or her desires and needs, when money and time permit. Therefore, this approach effectuates the roles of both the builder and the occupant through construction process (Kendall & Teicher, 2010).

4.3.3 Support and Infill

The division between INFILL and SUPPORT is the basic principle of the open building approach developed by Habraken. The SUPPORT involves the structure along with the collective distribution of services and is the permanent part of a dwelling provided by the builder, architect, and society (collective). The INFILL includes the interior parts of a unit such as partition walls, the kitchen, and bathrooms, which are defined by the occupant (Figure 4.8). Depending on the building system and the context, the Envelope will be connected to the INFILL or the SUPPORT. The components associated with the INFILL tend to change in cycles of 10 to 20 years (Habraken et al., 1976). These transformations may be occasioned by the occupants' shifting requirements and preferences or by the need for technical upgrades (SUPPORT).

Based on this theory, SAR produced extensive research on the issue of supports. For instance, *SAR 65* outlined the general method of creating residential supports regardless of the size or layout of dwellings, while *SAR 73* proposed a methodology for designing urban tissue. This was the 10/20 cm "tartan" band grid that eventually became a standard module in Europe.

Likewise, to provide for increasingly differentiated ways of living, the Japan-based Urban Housing Technology Research Institute has introduced basic frame and infill accommodation models via the Kodan Skeleton & Infill (KSI) R&D Program (Figure 4.9).

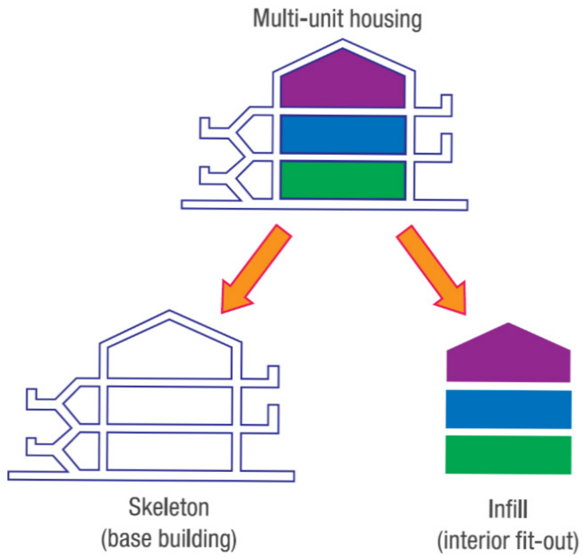

Figure 4.8. Support & Infill, John Habraken, (Kendall & Teicher, 2010)

There is an under-floor circulation of utilities to every section from a main shared service channel, while the framework is concrete. Consequently, movable dividing walls can be incorporated, while the position of the bathroom and kitchen can be altered, offering complete adaptability.

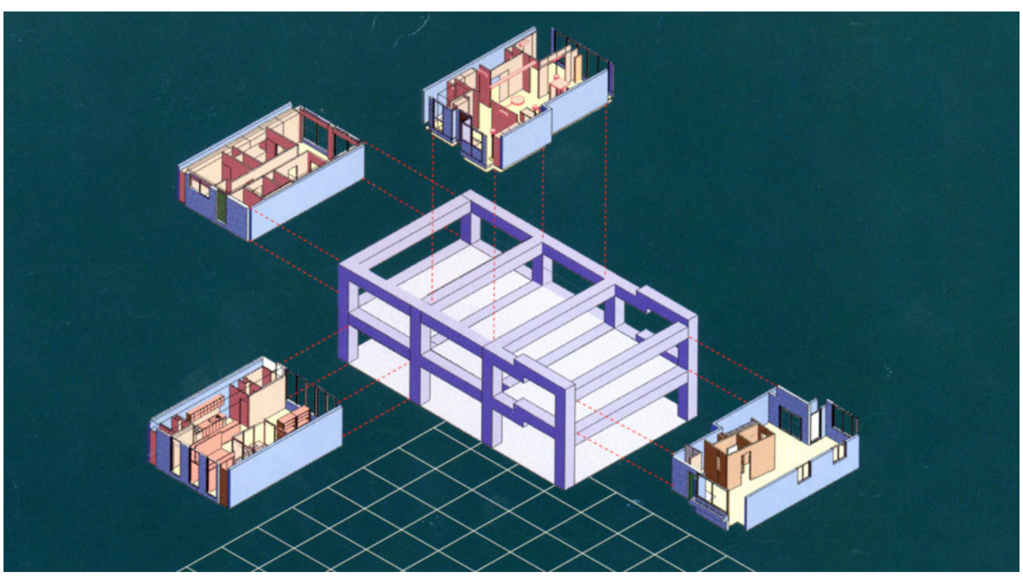

Figure 4.9. Multi-purpose framework KSI (Kodan Skeleton & Infill) (Urban Renaissance Agency 2003)

4.3.4 Theory of Levels and Layers

The hierarchical principle explored by Habraken serves as a foundation for the *theory of levels,* which divides the design process into the following five categories (Figure 4.10):

- The land-use level, where the decisions are made by governmental authorities.
- The fabric level, where decisions are also made by urban planners, councils, and municipalities.
- The urban tissue level, where decisions are made by urban designers and architects.
- The base building or Support level; where a collective process, led by architects and engineers, provide alternatives to the user.
- The fit-out level, or infill, where individual decisions are made to meet the needs of the occupants with the assistance of architects, engineers, interior designers and users (Cuperus, 2001; Kendall, 2001).

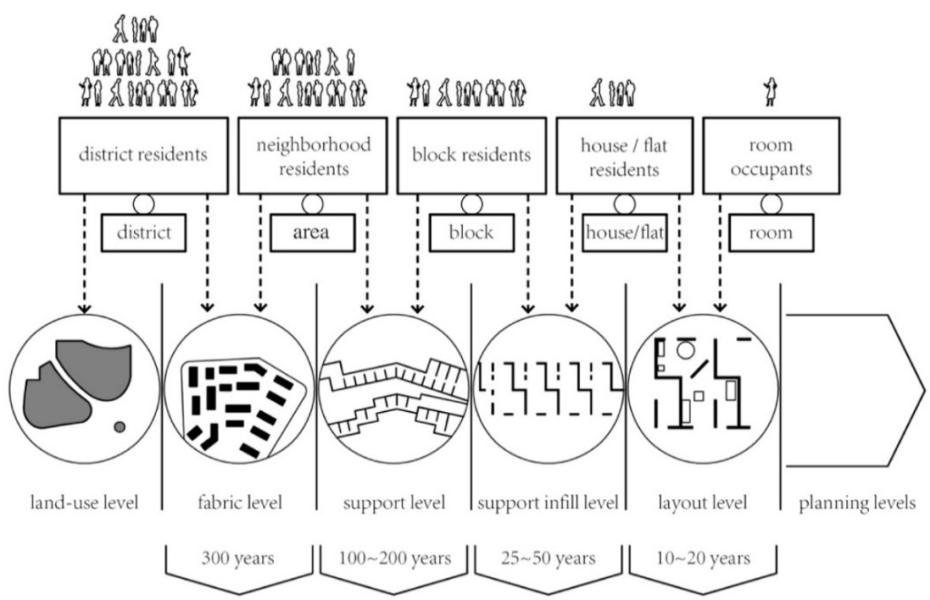

Figure 4.10. Decision-making levels, Habraken, (Kendall & Teicher, 2010)

Stuart Brand takes an alternative approach based on the frequency of change. In *How Buildings Learn* (1995), Brand categorizes structures into six layers, or "six S's," based on the lifespan of each component, from the shortest (stuff) to the longest (site) (Figure 4.11) (Brand, 1995; Mallory-Hill, 2004):

- Stuff (furniture and appliances)
- Space-plan (floor plan)
- Services (wiring, HVAC, acoustics)
- Skin (envelope)
- Structure (building frame)
- Site (urban location).

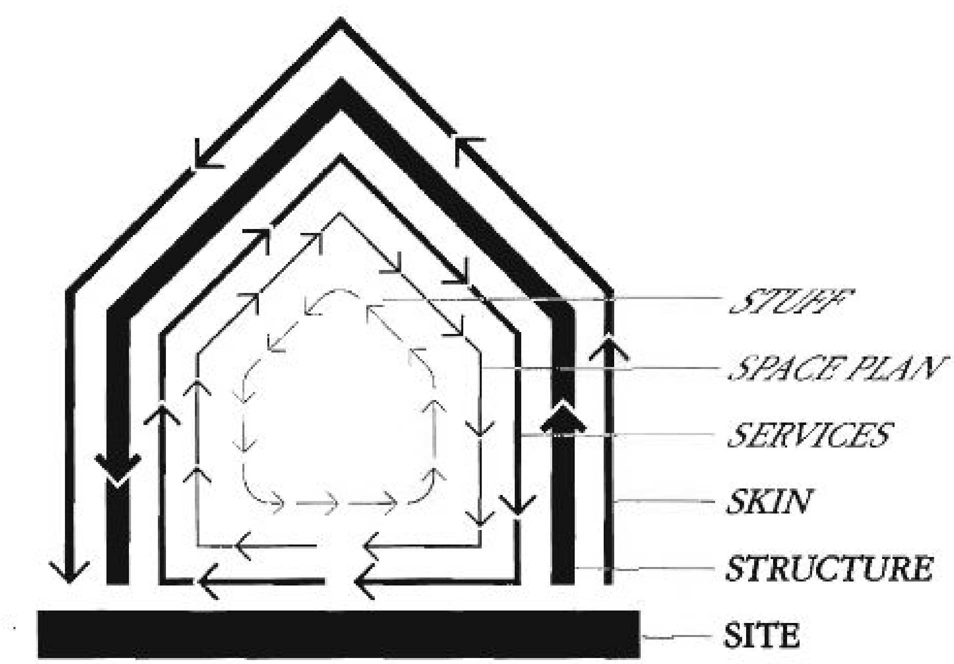

Figure 4.11. Shearing layers of change (Brand, 1995)

Brand's aim is to disconnect the different components to maximize the degree of decision-making within each one. Although these components often interconnect, in this paper we focus mainly on the last two levels—SUPPORT and INFILL in Habraken's approach and layer planning in Brand's approach (Figure 4.12).\

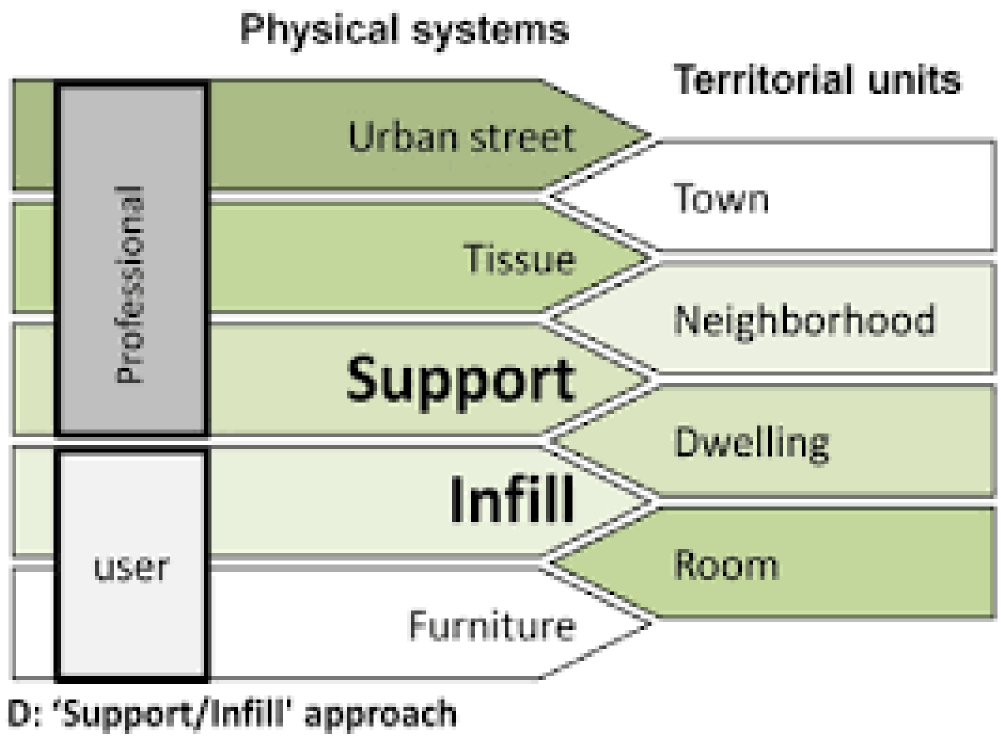

Figure 4.12. User engagement in SUPPORT AND INFILL (after Habraken, 2006)

4.4 Floor Plan Representation

Habraken's approach provides a suitable systematic floor planning method for organising the supplementary space in a floor layout (Leupen, 2006a). In his book, *Variation: the Systematic Design of Supports* (1976), Habraken explicitly formulated an effective systematic design for support. Therefore, Habraken's approach is a schematic assimilation of criteria and provides a framework for introducing supplementary space for spatial implications.

4.4.1 Introduction to Zones and Margins Method

"In order to meet the criteria of design, the floor planning methodology of the dwelling unit must be explicitly formulated, so that during the design process the results can be evaluated" (Habraken et al., 1976, p.15). In this method of drawing floor plans, modular lines will create a system of zones and margins to help the designer in organizing the design (Habraken et al., 1976; Kendall & Teicher, 2010; Leupen, 2006b). According to Habraken, not all floor planning satisfies the criteria. The priority of more important criteria must be defined based on the situation. He further emphasizes that the evaluation of floor planning solutions employed in design must be based on satisfying the criteria by checking the alternative layouts (Habraken et al., 1976).

4.4.2 Zone Distribution

The constraints upon the transversal size and position of spaces are contained by a combination of longitudinal zones called a *zoning* or *zone distribution* (Van Leusen, 1990). In *Variations: The Systematic Design of Supports,* there are four zones altogether (Figure 4.13):

α- zone*:* Alpha zone is a private space inside the dwelling and adjacent to an exterior wall.

β-zone: Beta zone is a private space inside the dwelling but not adjacent to exterior wall.

δ –zone: Delta zone is a private space outside the dwelling, such as a balcony for porch.

γ- zone: Gamma zone is a public space outside the dwelling, such as a corridor.

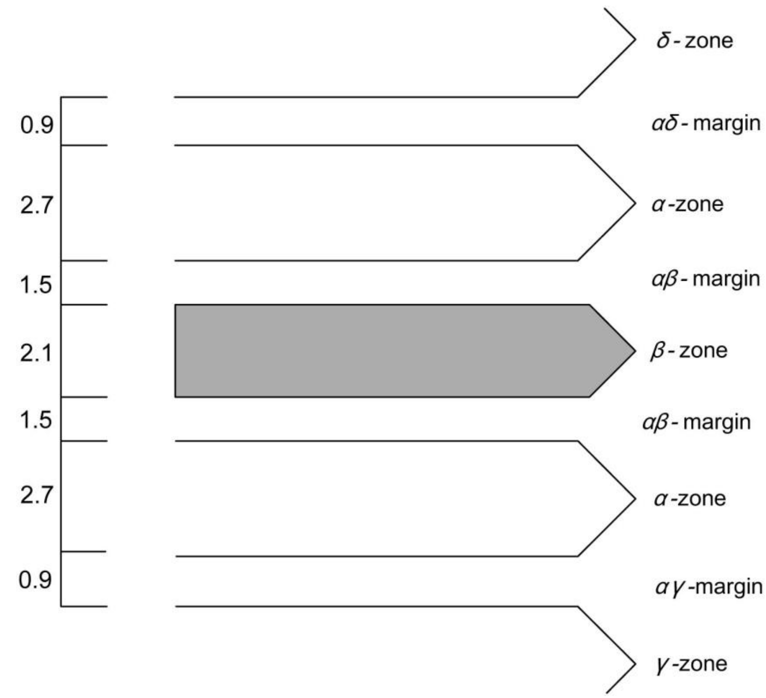

Figure 4.13. A zone distribution in which β-zone is positioned between two α-zones (Habraken et al., 1976)

Zones are always at a certain distance from one another; this distance is referred to as a margin. A margin is named after the two zones that it separates: the space in between an α-zone and β-zone is the α β margin (Van Leusen, 1990). There is one general rule with respect to the position of spaces in relation to the zoning: in the transversal direction, every space begins and ends in a margin (Habraken et al, 1976). In other words, spaces must fully intersect with zones. Furthermore, the margin itself is providing the opportunity to increase or reduce the space.

The first step is to make a distinction between **family and individual spaces.** Living areas and bedrooms (*habitable spaces*) are allocated in the *α*-zone, and *service spaces* (bathrooms, toilets) in the *β*-zone (Habraken et al., 1976). The constraints imposed by the zone distribution upon the size and position of habitable spaces and of services spaces (such as the bathroom or kitchen) are presented in Figure 4.14 (Van Leusen, 1990).

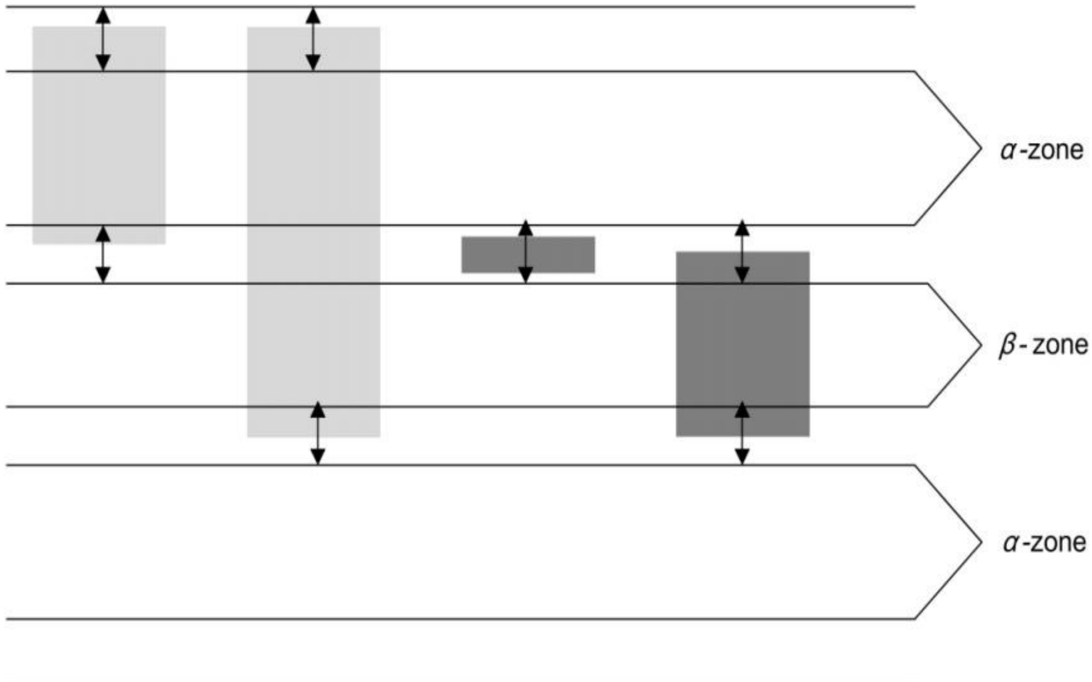

Figure 4.14. Different positions, habitable spaces are light grey and service spaces are dark (Habraken et al., 1976)

Since habitable spaces need a view and natural light, an *α*-zone is positioned close to the facade. A β-zone may be positioned at any depth from the facade.

4.4.3 Sectors and Sector Group

A *sector* is a certain length of a zone, in which there is no obstruction within it. In the majority of examples, a sector corresponds to the free length between transversal partition or a partition and the structural walls. However, the scope of the SAR representations is not limited to cases where structural walls are transversal (Habraken et al., 1976). The constraints restricting the support structure in the dwelling's layout are described as a *sector group*. In order to facilitate its application, the whole method is modular, as presented in Figure 4.15.

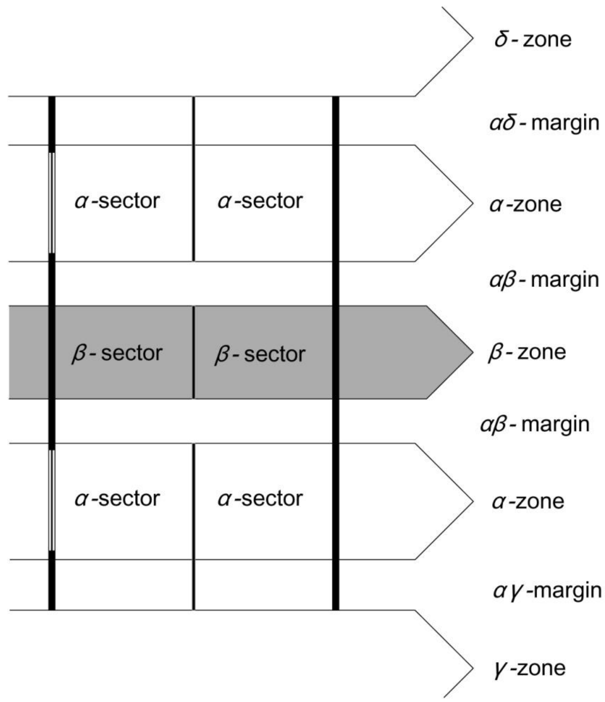

Figure 4.15. Sector and sector group (Van Leusen, 1990) (Habraken et al., 1976)

An example of a multi-family unit floor plan, designed based on the distribution of zones, is presented in Figure 4.16.

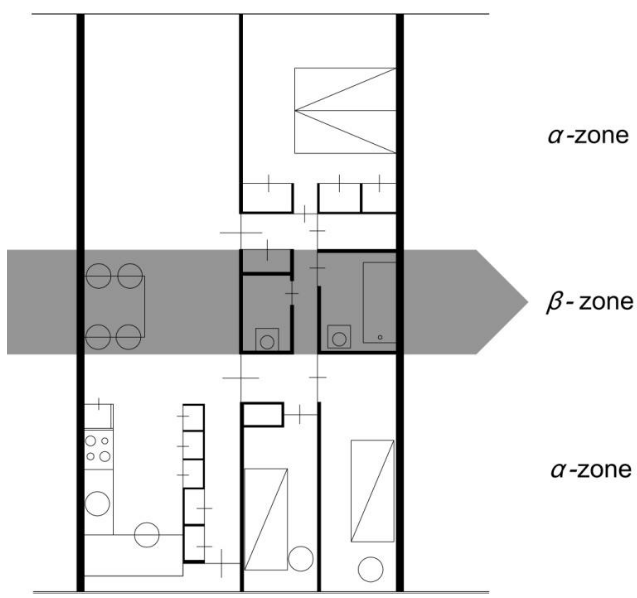

Figure 4.16. The distribution of zones on floor plan (Habraken et al., 1976)

Figure 4.17 shows a similar floor plan representation, which was used to develop various spatial configurations in the floor plan of a dwelling.

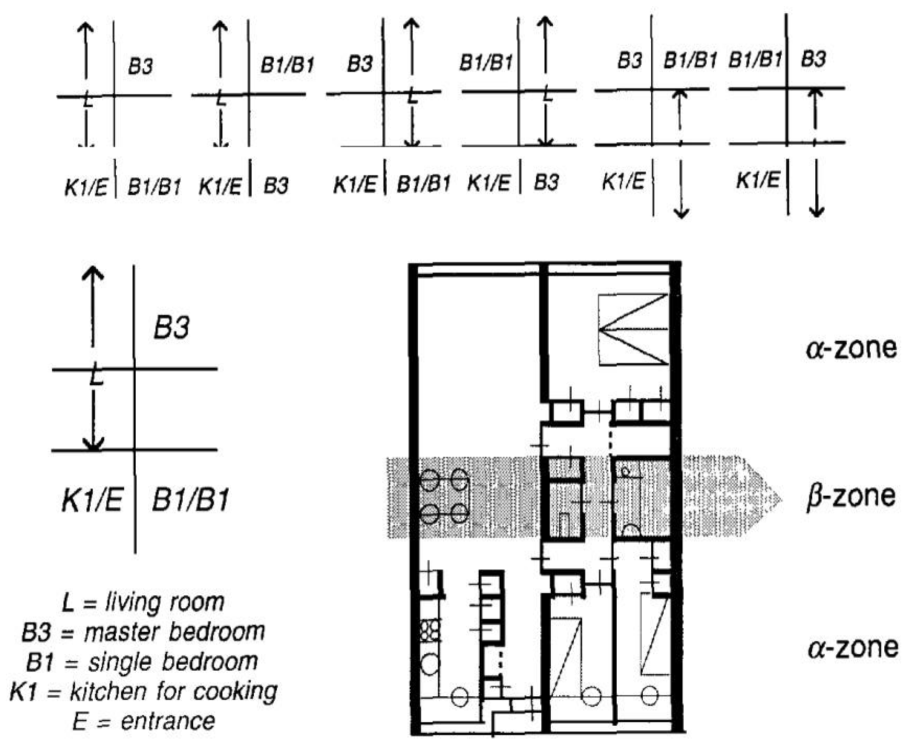

Figure 4.17. Above: six basic variations. Below: basic variation (left) and sub-variation (right) (Habraken et al., 1976)

4.5 Zoning Distribution in Supplementary Space

As mentioned earlier, the location of the supplementary space must be within at least a portion of an α-zone. Therefore, an α-zone must be located in a dwelling just after the corridor. The maximum size of the supplementary space could start from the end of the γ-zone and ending at the beginning of the *β*-zone. Maximum and minimum size can be a portion of the α-zone (Figure 4.18).

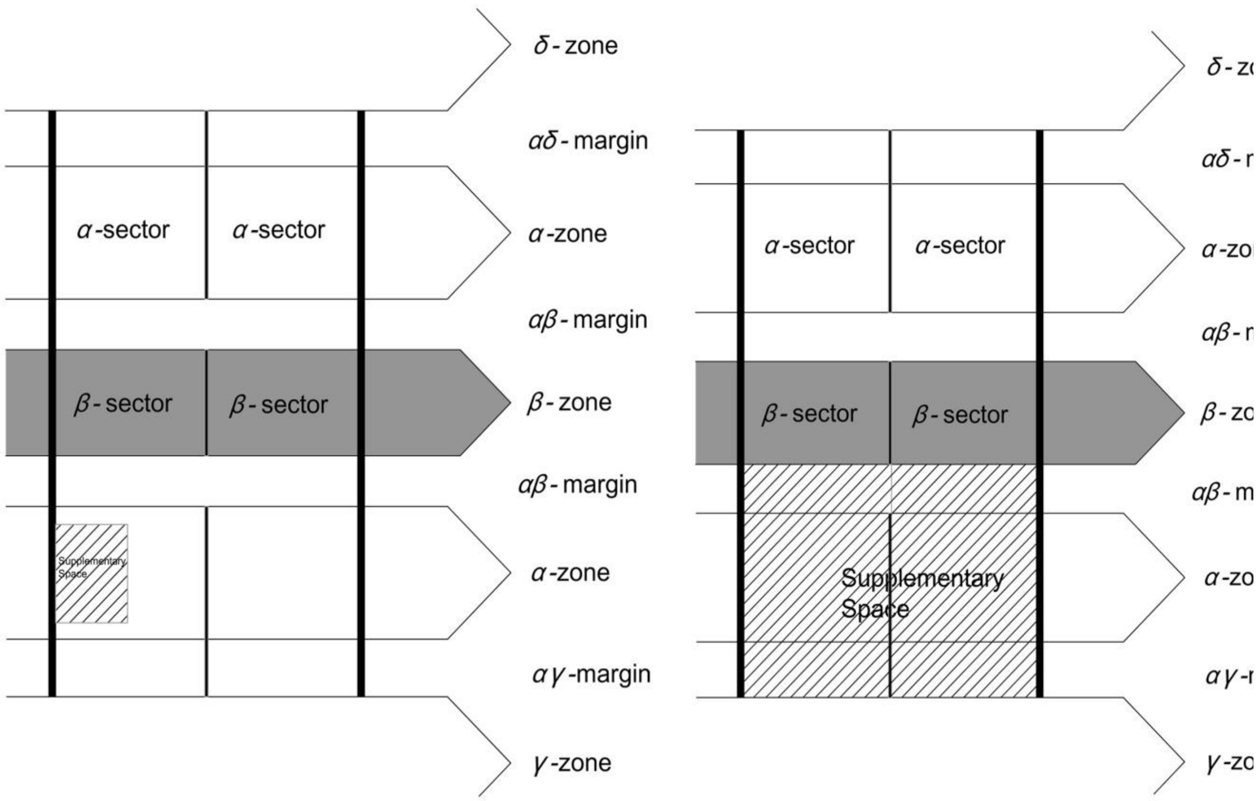

Figure 4.18. The zoning presentation method, John Habraken, minimum and maximum area of supplementary space.

4.5.1 Spatial Order of Supplementary Space

To examine the SAR method, the order of zones in the above unit with supplementary space can be organized as follows:

1- *γ*–zone:

- The location of the corridor.
- The location of unit's main door.
- When the supplementary space has its own entrance, it will be leading up to this zone.

2- $\alpha\,\gamma$ margin:

An exterior hallway for the dwelling.

- The supplementary space could start from the beginning of this margin.
- The supplementary space's door could be in this margin.
- If the building's corridor and the interior hallway of the unit are parallel to each other, the width of this margin is more than zero.
- If the building corridor and the unit hallway are perpendicular, the width of this margin is more than zero.

3- First α-zone:

- Supplementary space occupies a portion of or the entire zone.
- The α-zone must be adjacent to one of the exterior walls.
- The opening to outside must be on the exterior of this zone as well.

4- $\alpha\,\beta$ margin:

- The supplementary space can continue to the end of the α β margin.
- The location of the laundry room, storage, foyer, etc. could be in this margin.

5- β-zone:

- Services are located in this zone.
- The supplementary space ends before this zone.
- The β-zone could work as the buffer space between the first α-zone and the second

α-zone.

- It is recommended that spaces such as the laundry, storage, and closets are located in this zone, where they work as a buffer space between the first α-zone and the second α-zone.

6- Second *α*-zone:

- The second α-zone is where the private spaces are, such as private bedrooms and the living room.
- It is recommended that the largest distance would be between this zone and the first α-zone, where the supplementary space is.

7- *α δ*-zone:

- Since the space is limited in multi-family homes, the width of this space is usually zero.

4.5.2 Zoning Representation in Case Studies

More than 80 condominium projects were investigated in the City of Montréal, which consisted of more than 600 floor plan layouts. **As mentioned before, the "supplementary space" concept is being used unintentionally in some of these units.** It was only present in four projects and eighteen floor plan layouts (3% of the total). This is far less than the expected demand for supplementary space. In an interview with the developer of the Ekres condominium project, he emphasized that the implementation of additional bedrooms by the entrance was purposefully done to attract buyers who work from home. From the aforementioned eighteen floor layouts, the three most successful ones will be presented hereafter, accompanied with the floor plan zoning representation proposed by Habraken.

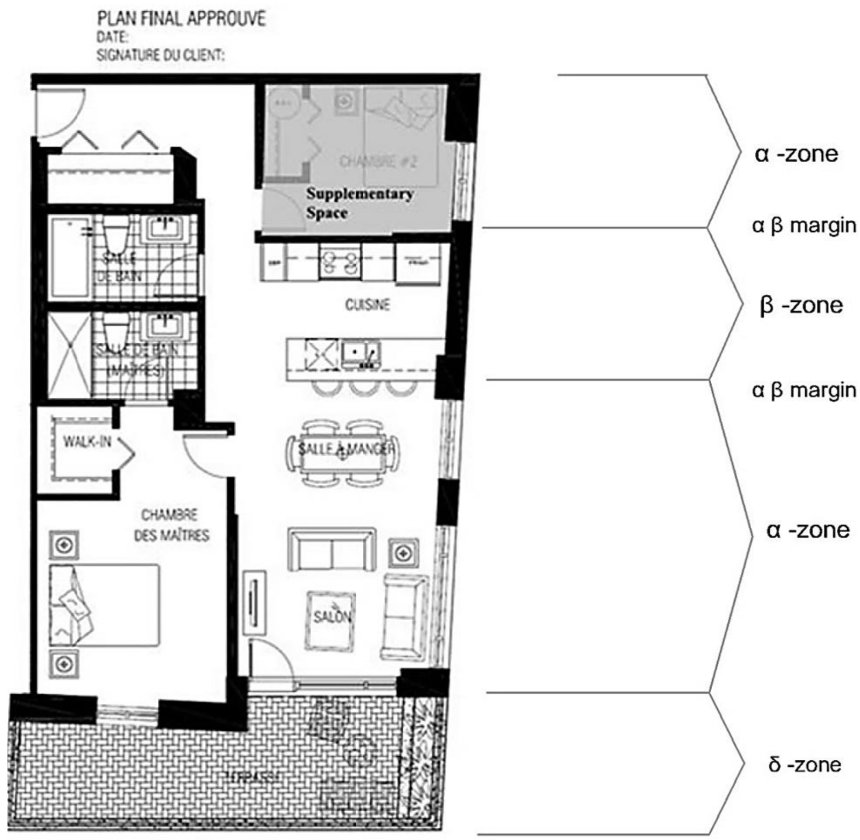

Figure 4.19. Ekres condominium, Montreal

Design Analysis

- The designer separated two α-zones from each other to include visual and spatial privacy, and less obstruction for visitors to access the rest of the dwelling.
- The β-zone includes the kitchen and the bathroom. This zone acts as a buffer space

between the first and second α-zones (where the private spaces are).

- The supplementary space can have natural light and ventilation.
- The soundproofing could be adjusted according to the user's needs.
- It is difficult to have a separate entrance to the supplementary space from the circulation core.
- The spatial and visual privacy in this housing type is low, since visitors have a view of the dwelling. Additionally, since the β-zone area is small, there is not much distance between the two α-zones.
- Provisions for growth are possible as there is no wet component (bathroom or

Figure 4.20. Rue Peel condominium, 1292sqf, Montreal

kitchen) in the first α- zone.

Design Analysis

- The designer suitably separated two α- zones from each other to include visual, and spatial privacy and less obstruction for visitor to access the rest of the dwelling.
- The bathroom located within the first α- zone can be used for the supplementary space.
- The β-zone includes the kitchen and the bathroom, which acts as a buffer zone between the first and second α- zones (where the private spaces are).
- The supplementary space can have natural light and ventilation.
- The soundproofing could be adjusted according to the user's needs.
- It is difficult to have a separate entrance to the supplementary space from the circulation core.
- The spatial and visual privacy in this housing type is low, since visitors have a view inside the dwelling. Also, since the β-zone is small in area, there is not that much distance between the two α- zones.

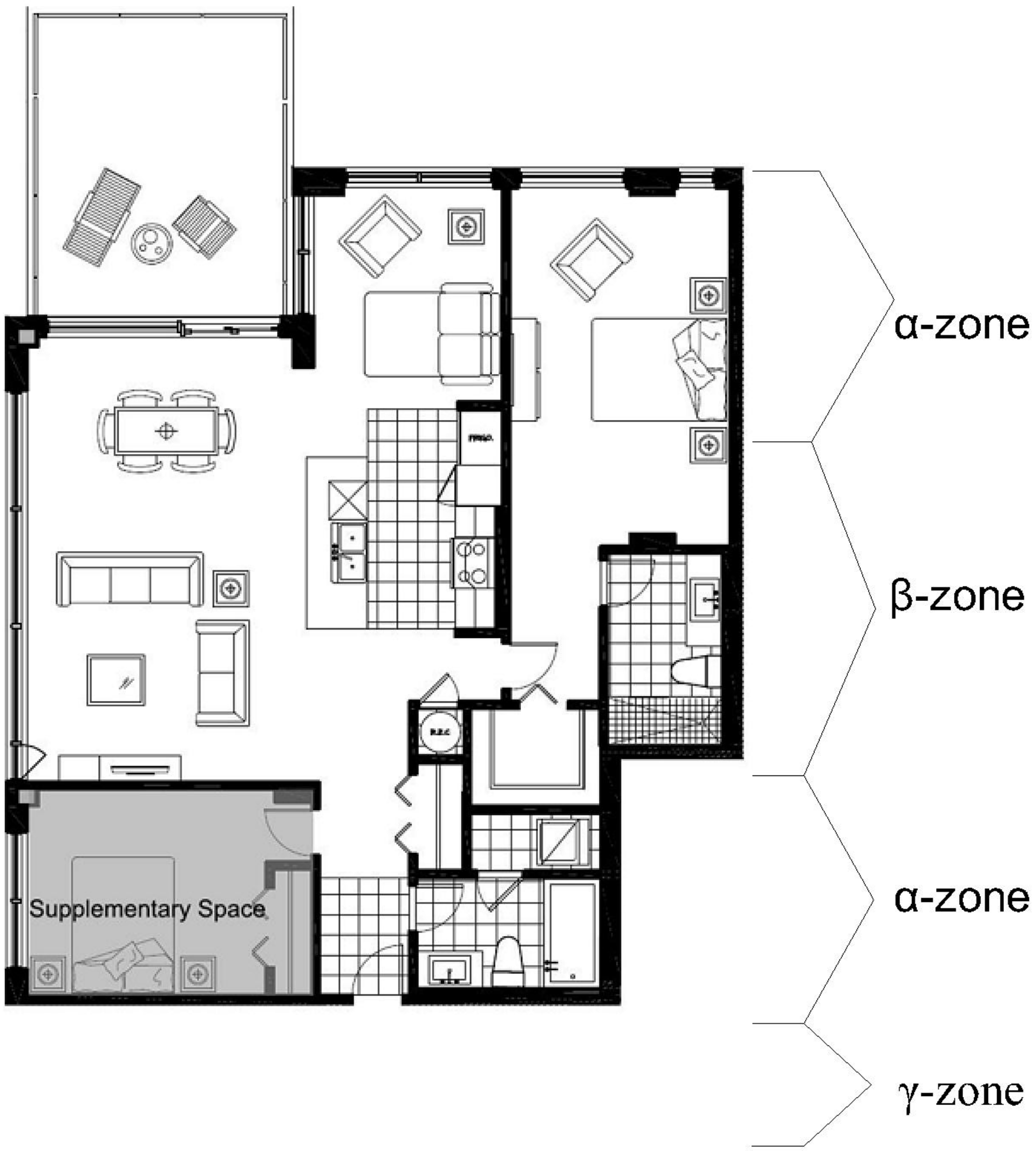

Figure 4.21. Bluemaree condominium, 1320 sqf, Montreal

Design Analysis

- The designer suitably separated two *α*- zones from each other to include visual, and spatial privacy and less obstruction for visitors to access the rest of the dwelling.

- The bathroom located within the first *α*- zone can be used for the supplementary space.
- The β-zone includes the kitchen and the bathroom. This zone acts as a buffer zone between the first and second α- zones (where the private spaces are).
- The spatial and visual privacy in this housing type is low, since visitors have a view of inside the dwelling. Also, since the β-zone is small in area, there is not that much distance between the two α- zones.
- The provisions for growth are limited, blocked by the bathroom in the first *α*-zone next to the supplementary space.

4.6 Planning for an Adaptable Supplementary Space

The ability to accommodate future modifications is the main purpose in Open Building floor planning design. The supplementary space, together with the rest of the dwelling unit, should be integrated in the OB floor plan. Schneider and Till discuss the degree of achieving floor plan adaptability from the participant's perspective (user's perspective) as follows:

> The degree of adaptability is determined in two ways. First the in-built opportunity for adaptability, defined as 'capable of different social uses', and second the opportunity for adaptability, defined as "capable of different physical arrangements (T. Schneider & Till, 2016b) p. 2.

With adaptability being a facilitator of supplementary space, the focus is on providing a variety of built-in choices before the user's occupancy (designing the support).

4.6.1 Growth by Exchange

The ability to grow by exchange is an important technique in adaptable housing. Growth by exchange involves designing a building's skeleton to facilitate the procurement of extra space, wherever there is an agreement between two neighbours. The extra space could eventually become a supplementary space. The Asemwald housing project in Germany is a fine example of growth by exchange (Figure 4.22).

Figure 4.22. Growth by exchange: Asemwald housing, Germany, 1972 (T. Schneider & Till, 2016a)

In 'Growth Homes', a project designed by Herman Hertzberger, the buildings have the potential for future horizontal extensions. Each unit is comprised of two parts, finished and unfinished, and the unfinished part can be customised at the occupants' discretion (Figure 4.23).

Figure 4.23. Groeiwoningen, Almere, Netherlands. Herman Hertzberger, 2002 (Leupen, 2006a)

4.6.2 Interchangeable Room

Another solution is a non-specific room that is shared between two units, as agreed upon by the occupants depending on their needs. This space can become an additional bedroom, a supplementary workspace, or a guest room. However, this arrangement has complicated implications that must be coordinated among the two owners and the management of the building (Figure 4.24).

A more elaborate design of this type could include plumbing services and a plug-in kitchen, which may be used as a studio or self-contained office area, a young adult's room, etc. In this design, a separate entrance is a great advantage (T. Schneider & Till, 2016a).

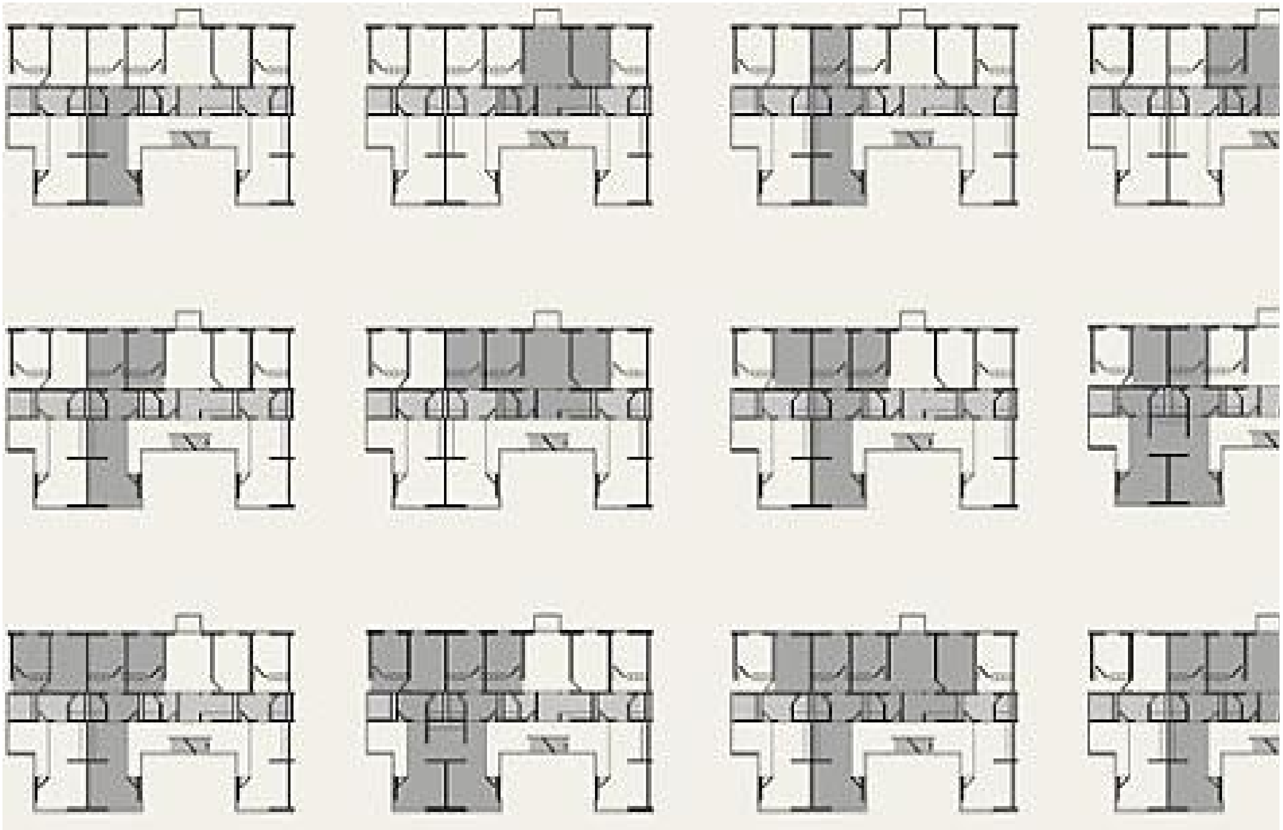

Figure 4.24. Hellmutstrasse, Zurich. ADP-architekten (T. Schneider & Till, 2016a).

4.6.3 Clear Spans and Base Structures

"Clear spans" with a provision of open space are a way of designing with a limited number of permanent elements. "[F]aced to the vitality and diversity of potential occupancy, the reaction is to provide a frame and within it empty generic space that can be filled in and adapted over time" (T. Schneider & Till, 2016a), p.39. The architects may intentionally leave a generic space as incomplete for the users to fill in according to their needs and demands.

The "polyvalent organizations" for "base structure" is generally divided into permanent "modules" with standardized dimensions appropriate for diverse functions (Figure 4.25).

In this approach, the sizes of the modules are standard and they have fixed in form, but it is possible to join two or more modules together or to divide a module into smaller parts.

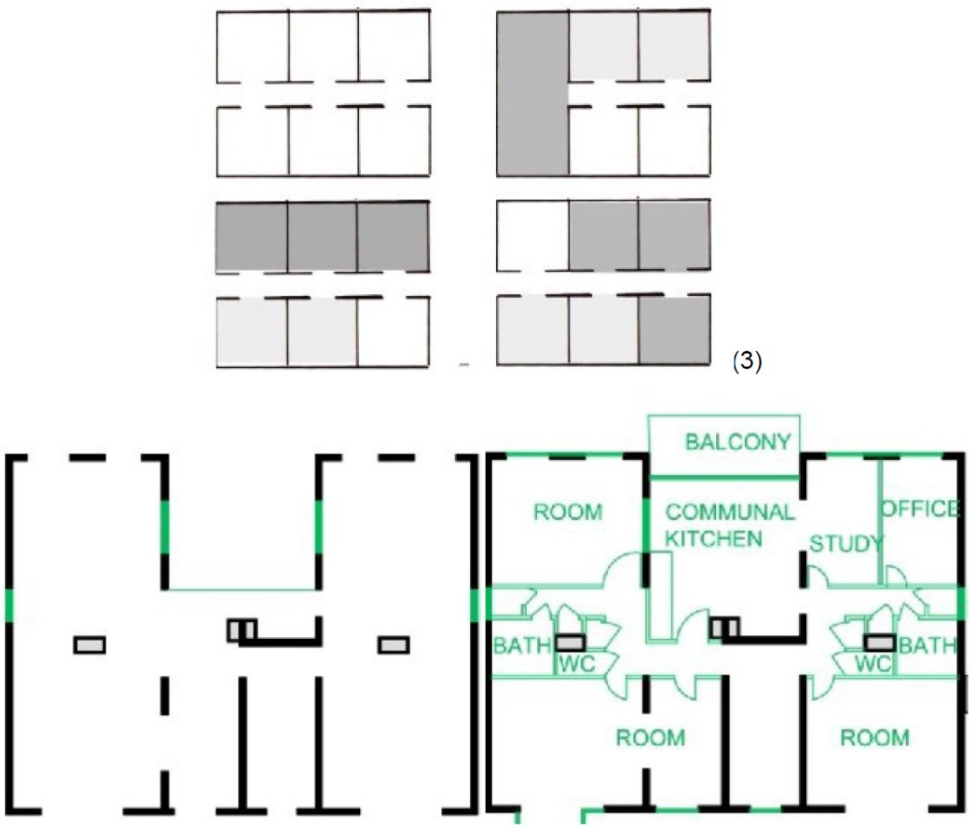

Figure 4.25. Flexible Woningbouw Apartments, Rotterdam, 1984 (Duygu, 2009)

4.6.4 NEXT21

The most successful example of adaptable housing is an experimental housing project built in 1994 by Osaka Gas Ltd. NEXT21 is an experimental multi-unit family housing project that applies the OB approach to satisfy individual and societal needs (Figure 4.26). Its aim is to provide an opportunity to the occupants to verify new concepts for sustainable multi-family housing.

Figure 4.26. NEXT21, Yositika Utida et al, Osaka (Osaka Gas, 2013b)

After the completion of the building in 1994, three complementary phases with different goals and agenda were introduced for the project:

1- (1995-1999): Seeking to simultaneously realize “amenity“ and “energy-saving” environmentally-friendly living

2- (2000-2006): Special consideration of the global environment and comfortable daily living.

3- (2008-2013): Housing and energy systems to support sustainable urban living.

Each phase has been assessed through three themes (Figure 4.27):

1- The demonstration of environmentally-symbiotic housing

2- A demonstrative model of sustainable housing (social assets) characterized by a long-lasting skeleton (base building) and infill (interior fir-out).

3- Provide the opportunity for testing, monitoring and evaluating home appliances and housing facilities/systems.

A combination of phases and themes with respect to each other is demonstrated in Figure 4.28.

Theme	Phase 1 (FY1994 to 1998) Seeking to simultaneously realize "amenity" and "energy-saving, environmentally-friendly living"	Phase 2 (FY2000 to 2004) Special consideration of global environment and comfortable daily living	Phase 3 (FY2007 to 2011) Housing and energy systems to support sustainable urban living
The demonstration model of the environmentally symbiotic housing	• 22 species of wild birds and 21 species of wild plants were identified on site. • Energy consumption in the entire building was reduced by 27% through the gas-powered equipment (together with the use of phosphoric acid fuel cells, solar panels and batteries) and high-performance insulation. • Water consumption was reduced by 19% through recycling of waste-water.	• A survey was conducted regarding residents' involvement in green zone management. • Energy consumption in the entire building was reduced by 30% through the introduction of CHP (Combined Heat and Power) systems. • An assessment was conducted on the performance of the kitchen sink disposer (kitchen refuse processing) system for the disposed paper and plastic materials.	• Energy consumption was reduced by 12% through electricity interchanges among dwelling units with the use of hydrogen fuel cell-powered CHP units. • Energy consumption was reduced by 15% through heat interchanges among dwelling units with the use of CHP systems. • Energy consumption was reduced by 73% through the introduction of energy-saving lifestyles including the use of renewable energy.
The demonstration model of sustainable housing (= social assets) characterized by a long lasting "skeleton" (base building and utility systems) and flexible "infill" (interior fit-out – "everything behind your front door")	• A series of renovation projects with direct user participation demonstrated the capacity of the skeleton-infill (open building) principle to accommodate varied household requirements and provide high-level user satisfaction. • The ability of proposed floor plans and infill solutions to satisfy needs of dwellers was verified.	• Two types of renovation were conducted; a major renovation to divide one dwelling into two and a simple remodeling with infill rearrangement. • An experimental housing project for a SOHO (small office home office) worker/resident was conducted.	• House convenient for taking over (adaptable housing for different families and different generations) was created, as a solution to problems of the aging society with a declining birth rate. • An experiment to promote exchanges among local communities was conducted through the use of showcase exhibitions focused on local cultural/historical resources (U-CoRo or Uemachidaichi Communication Room).
To provide the opportunity for testing, monitoring and evaluating home appliances and housing facilities/systems	• 36 items of home appliances and residential systems were commercialized.	• A project to demonstrate PEFC (polymer electrolyte fuel cell for home use) was conducted. • Energy consumption was reduced by 10% through the introduction of systems that enable visualization of energy use.	• A project to demonstrate SOFC (solid oxide fuel cell for home use) was conducted using three types of SOFC designed for multi-unit housing projects, to confirm the feasibility of the three types in terms of installation and maintenance operations.

Figure 4.27. The theme and major results of respective phases (Osaka Gas, 2013a)

The project conducts "dwellings-in-use" evaluations to find solutions for the aging society and any lifestyle changes (Figure 4.29). Six major social-change subjects were selected, which were then addressed in the housing design. Each subject has been the basis for the design of an infill solution.

Category of household	Single(s)				Couple only			Couple and child(ren)				Single parent and his/her child(ren)		Other
Family models / Six social needs	A young or middle-aged single	Shared by multiple young or middle-aged singles	An elderly single	Shared by multiple elderly singles	DINK (double income no kids)	Husband and housewife	Empty nest	Couple and young child(ren)	Working couple and young child(ren)	Middle-aged or elderly couple and their child(ren)	Working middle-aged couple and their child(ren)	Single parent and his/her child(ren)	An elderly person and his/her child(ren)	Three-generation family
Child-raising								○	○			○		△
Elderly-only households			○	○			○						△	
Increasing emphasis on privacy of individual members of family		○		○	○		△		○	○	○		○	△
Family support (for childraising, nursing care, etc.)			○	○			○	△	○			○	○	○
Diversification of work styles	○	○	○	○	○		△		○	○	○	○	○	△
Networking of individuals	○	○	○	○	○	△	○		○	○	○	○	○	△

○ Applicable △ Sometimes applicable

Figure 4.28. Relationship between family types and six social needs (Osaka Gas, 2013a)

The project incorporates the idea of support and infill (Figure 4.29). It separates each layer of the building, not only its skeleton but also all its mechanical, electrical, and service components (Maiellaro, 2001).

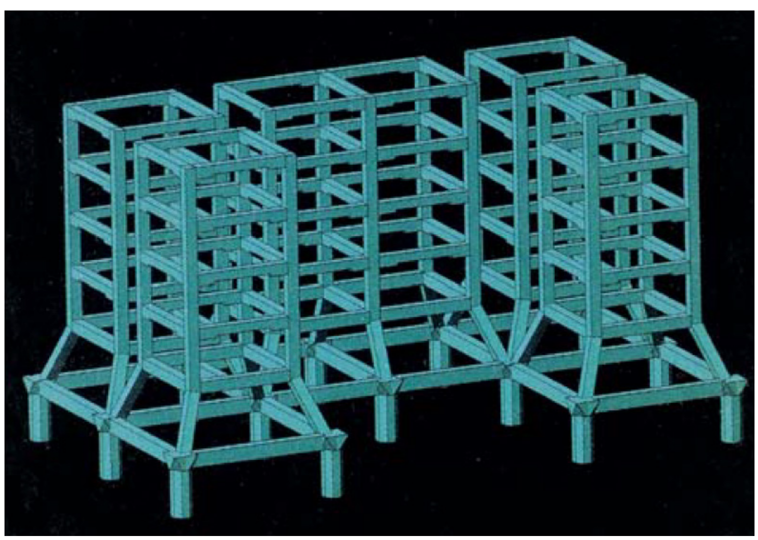

Figure 4.29. Skeleton of NEXT21, Yositika Utida et al (Osaka Gas, 2013b)

The residential zone on the 3rd floor consists of six "towers" that are 7.2 by 7.2 meters squared, standing 3.6 meters apart from each other (Figure 4.30).

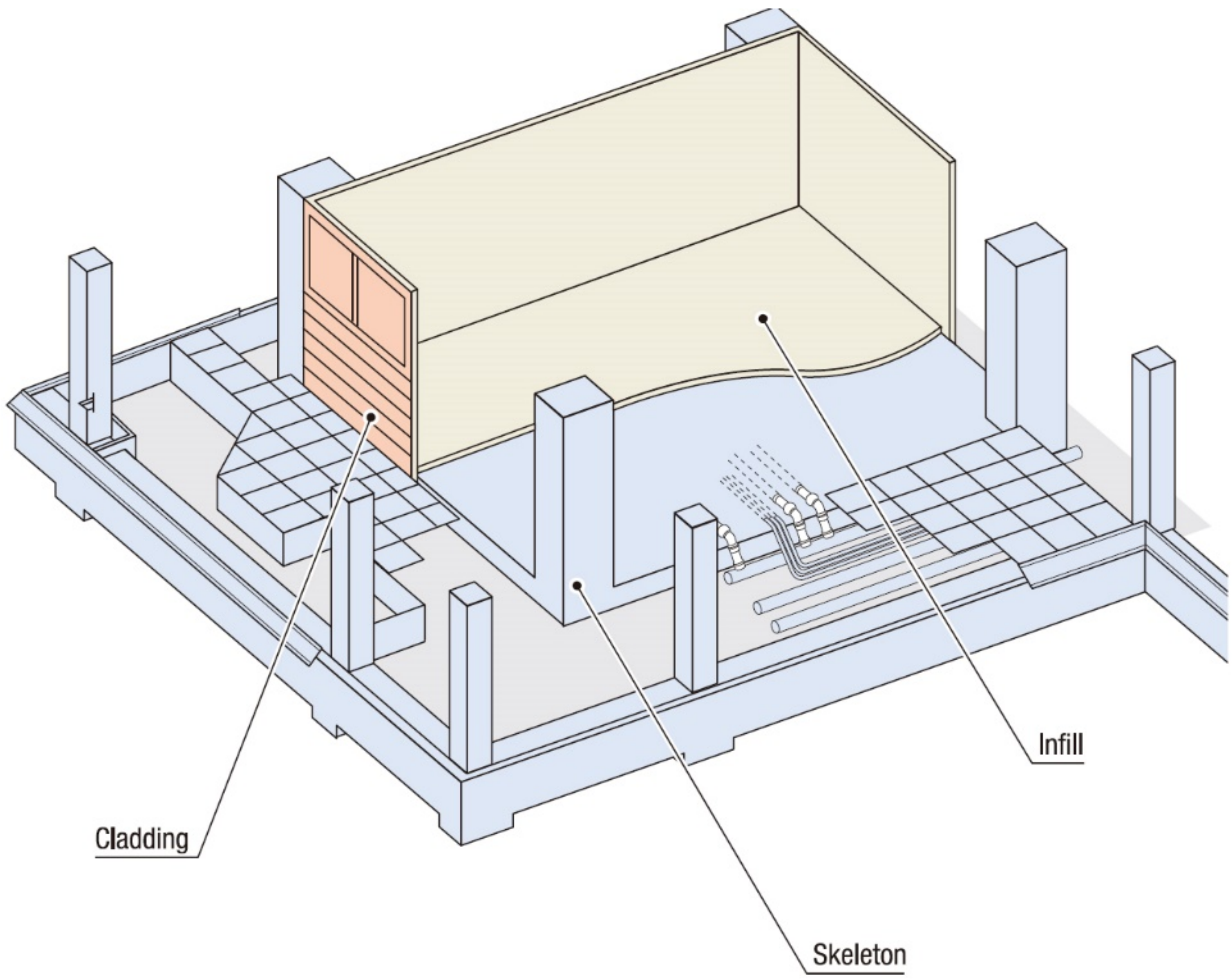

Figure 4.30. NEXT21 Infill, Skeleton and Cladding. Yositika Utida et al (Osaka Gas, 2013b)

NEXT21 uses components such as modular outer walls (cladding system), which can be replaced or rearranged easily from the inside. According to the visual level of interaction with the outside corresponding to the philosophy of occupant, accommodating the most introverted to the most extroverted ones (Figure 4.31). All the components are designed to be modular. The basic concept was generated by Professor Yositika Utida, who managed to get the skeleton designed by one team, the cladding system by another team, while different designers were responsible for the design of each dwelling, following the "rules" for positioning infill and cladding elements developed by their respective teams (Figure 4.33).

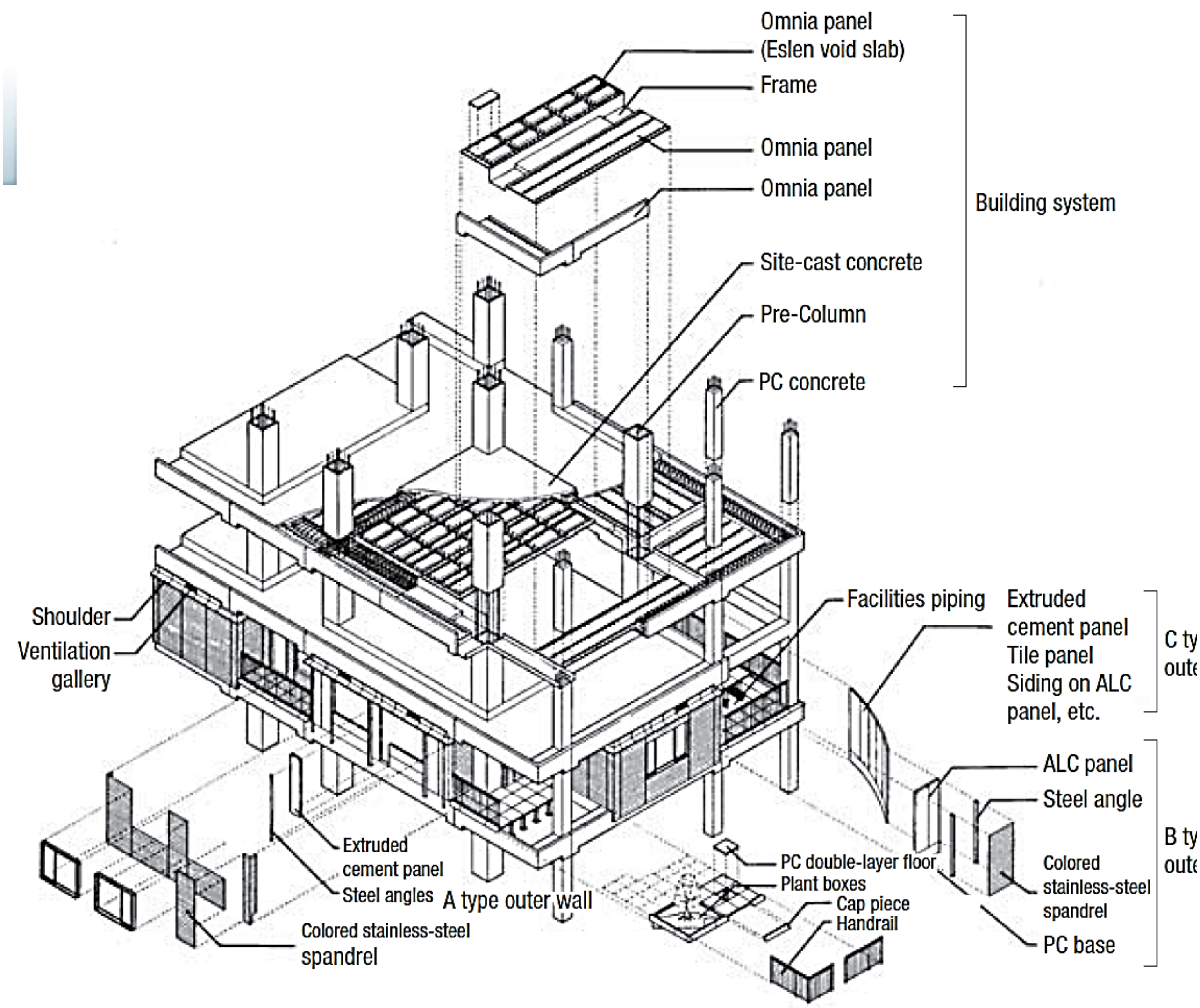

Figure 4.31. NEXT21 layers. Yositika Utida et al (Osaka Gas, 2013b)

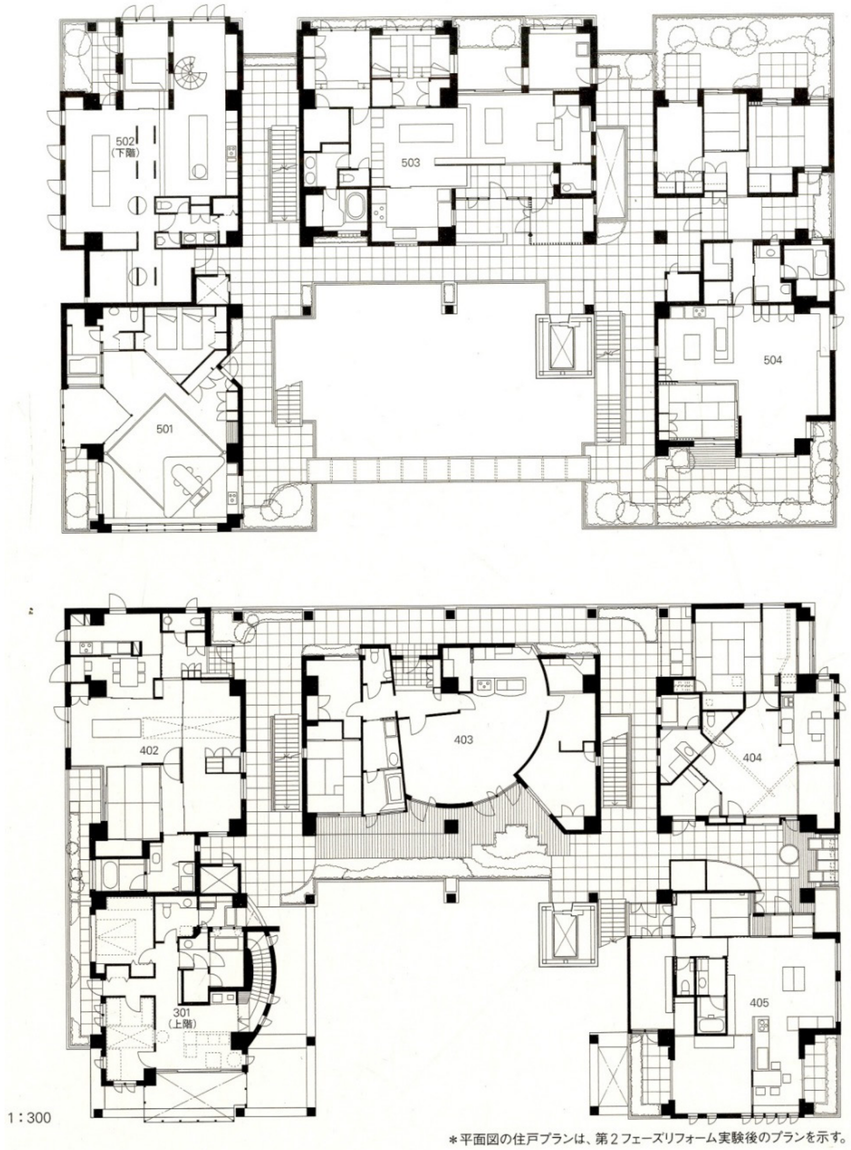

Figure 4.32. NEXT21 floor plan, Yositika Utida et al (Osaka Gas, 2013b)

Intermediate spaces: In phase three, experiments with intermediate spaces were conducted. Its aim was to verify challenge the new role of housing to promote exchanges between dwellers (indoor) and other residents (outside world), or multi-unit housing and the wider community.

In this project, two types of experimental "intermediate" spaces were created. The first one is a private "activity" space inside a dwelling unit that can help create exchange opportunities. Such a space encourages people to turn off the air conditioner in the room and come outside to enjoy fresh air in the outdoor environment.

The targeted type of family for this kind of unit is a middle-aged couple whose child has grown up and already left home (Figure 4.33). The multiple access routes to indoor spaces of this unit play the role of facilitating people's exchanges and gatherings. Such accessibility, as well as the employment of movable walls, allows this dwelling space to adapt to changing residents' lifestyles over the course of time and to accommodate successive uses by different families.

Figure 4.33. Resilient home. Space converted to accommodate a cooking class. Yositika Utida et al (Osaka Gas, 2013a)

Blank Spaces: Another example of floor plan adaptability in NEXT21 is the "handmade workshop unit," a portion of the dwelling distinguished as a workspace (Osaka Gas, 2013b). The workspace is designed as a completely separate layer with its own entrance and bathroom (Figure 4.34). In addition to having a high level of options in its infill, NEXT21 features many units that are exposed to the outside from more than two directions, allowing the potential for expansion in the floor plans.

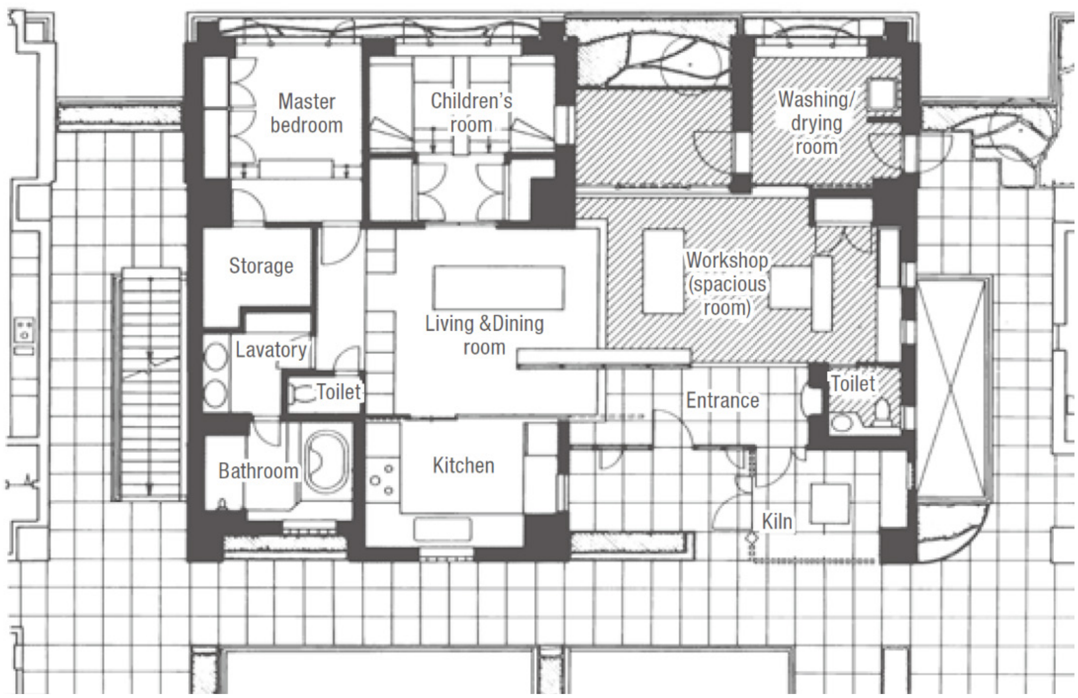

Figure 4.34. Handmade workshop unit, Yositika Utida et al (Osaka Gas, 2013a)

Osaka Gas (1993) also explains how occupants can modify the façade, which is composed of small, horizontal stainless steel cladding units and modular glazing panels, both of which are easily modified (Figure 4.35).

Figure 4.35. Façade modifications, NEXT21, Yositika Utida et al, Osaka, 1994

4.6.5 Comparing Physical Levels of Typical Housing to NEXT21

Typical multi-family housing in Canada is built with brick façades, concrete slabs, and block or brick partitioning walls. Even though these elements all have varied uses and technical life cycles, the way in which they are assembled created a fixed physical scenario. The diagram on the left in Figure 4.36 shows how a typical Canadian housing project freezes most of the functional levels in one fixed physical level. The diagram on the right shows an alternative solution where five physical levels have been separated. Five independent levels provide easy reconfiguration of building partitioning and electric components (Durmisevic, 2006).

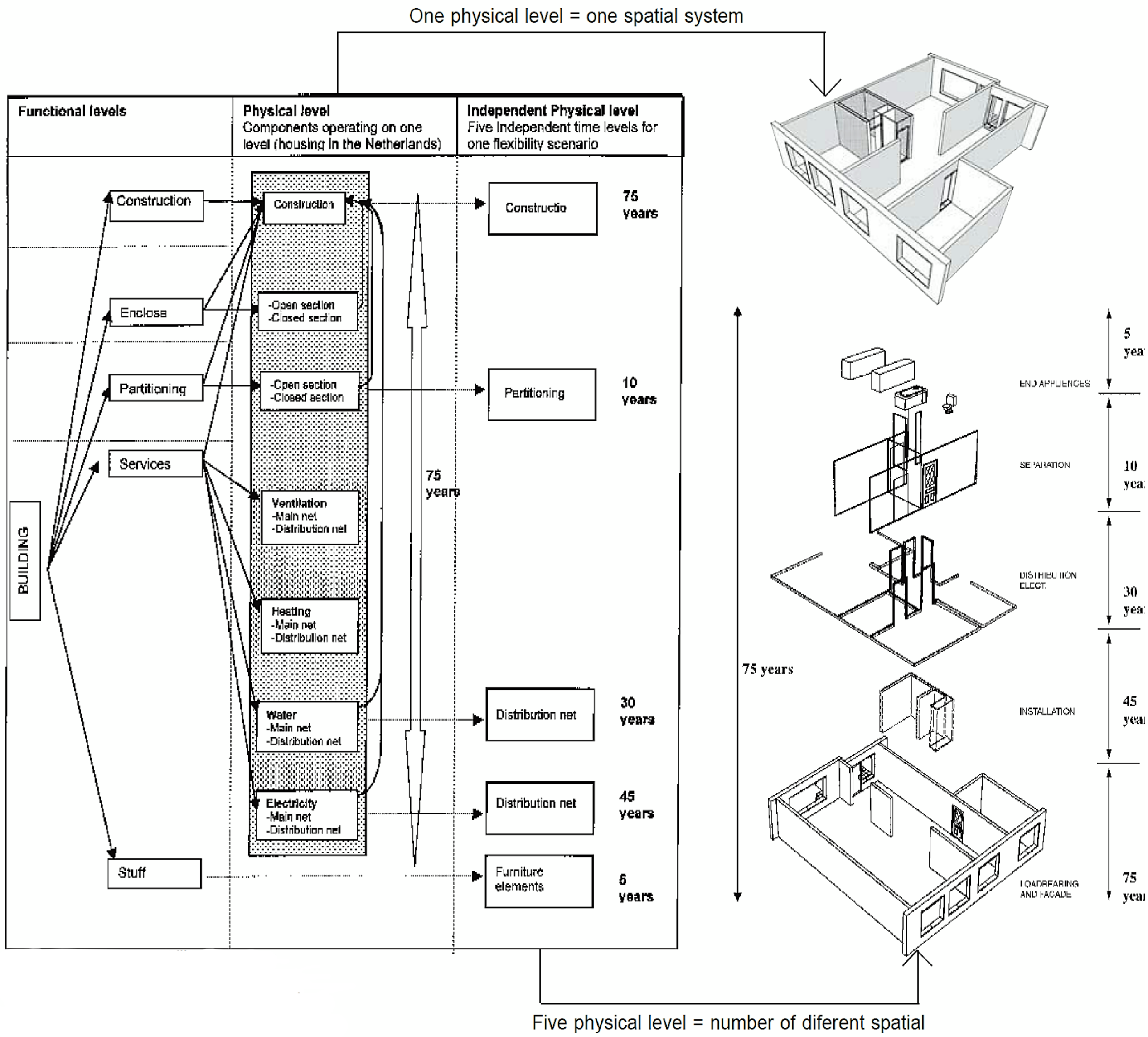

Figure 4.36. Left: typical housing project in Canada. Right: alternative solution, where five levels are separated (Durmisevic, 2006)

NEXT21 offers a variety of independent physical levels to allow for greater adaptability. As shown in Figure 4.39 (on next page), 11 independent physical levels define the functional levels. This was made possible by the desired use requirements, including the dwellings having complete functional and spatial flexibility, the possibility of repositioning windows, extending apartments, as well as having access to every building component to upgrade and maintain them.

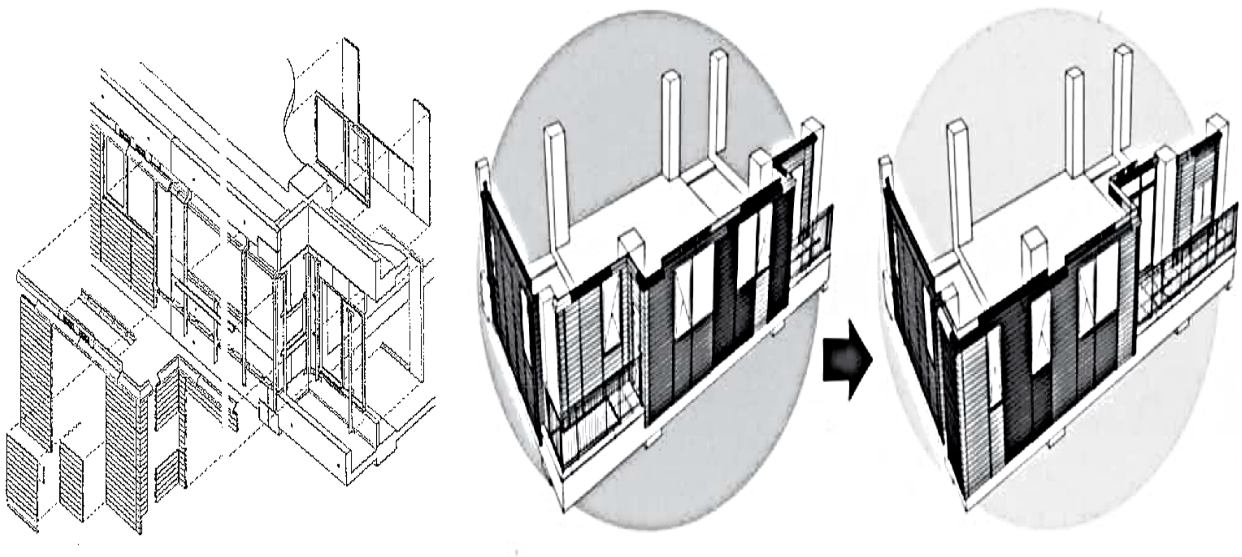

Figure 4.37. Transformation of the external façade, Yositika Utida et al (Osaka Gas, 2013a)

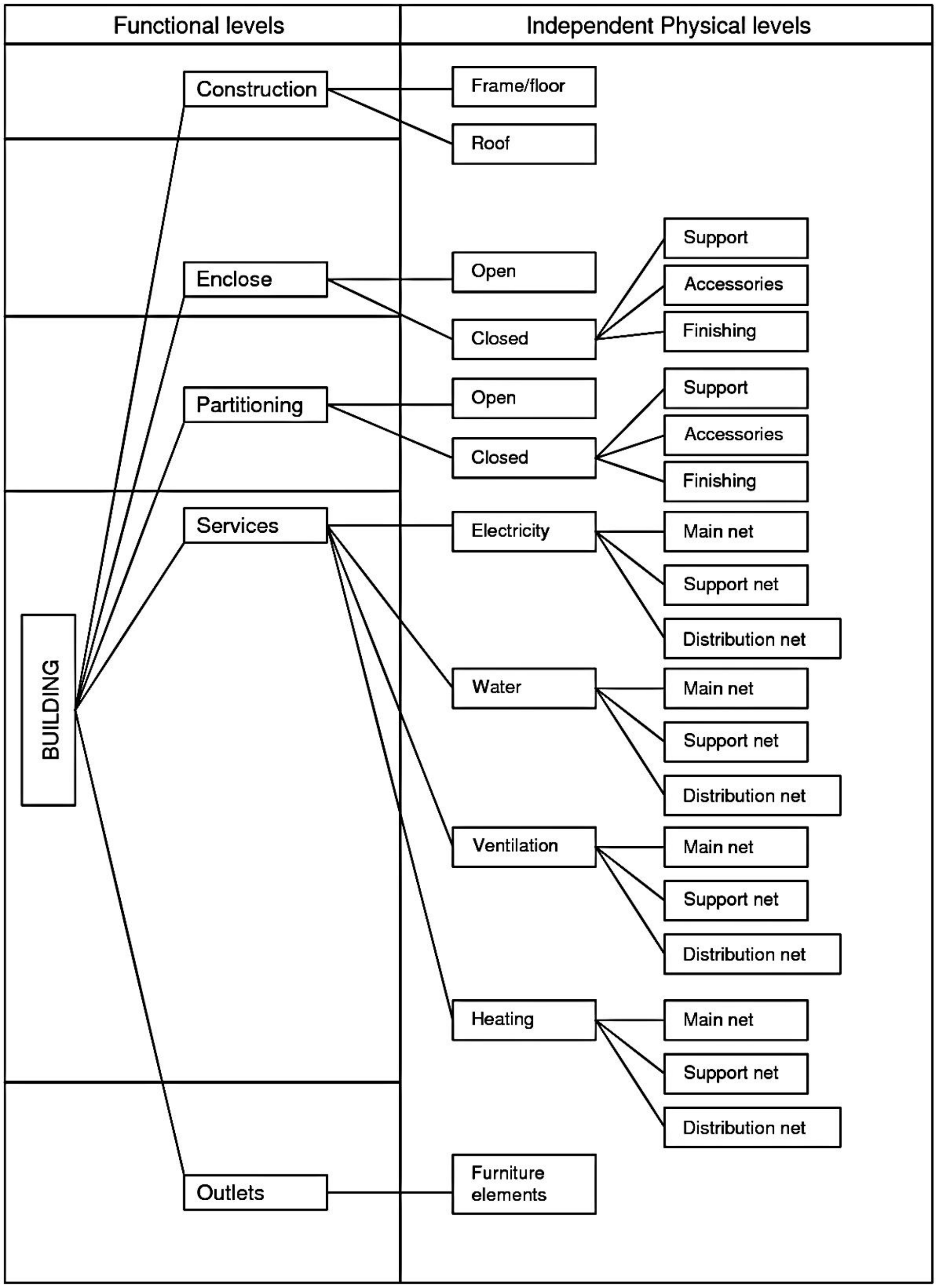

Figure 4.38. Eleven independent physical levels, NEXT21, Yositika Utida et al (Osaka Gas, 2013a)

4.7 Chapter 4 Findings

Current technology has encouraged the incorporation of more adaptable features, such as movable partitions and adjustable facades. The Open Building approach is offering a methodology to implementat adaptability into practical design and construction guidelines. A typical floor plan is represented through zones and margins. Different Open Building applications, such as the NEXT21 project and the KSI (Kikou Support and Infill) protocol in Japan, are exemplary cases which can facilitate the establishment of guidelines for designing a supplementary space.

In some cases, the supplementary space is introduced used unintentionally in some buildings in Montreal such as “rue Peel”, Bluemaree, and Ekres condominiums.

5 Generic Model and Synthesis of Criteria

The criteria are vectorized in order to reach the generic model, creating a systematic **criterion–options path** that links the functional criteria to the building and architectural levels (options). The list of criteria is divided into two parts: **utility (technical) criteria,** such as lighting, noise level, acoustics, etc., and **spatial criteria,** such as privacy, psychology of the space, etc.

The supplementary space model allows to go further than its thematic "office at home" role. Several of the "other needs" imply various levels of close relationship with the overall dwelling unit: it is the case with the grand-parents suite, the adult child suite, the children playroom, etc.

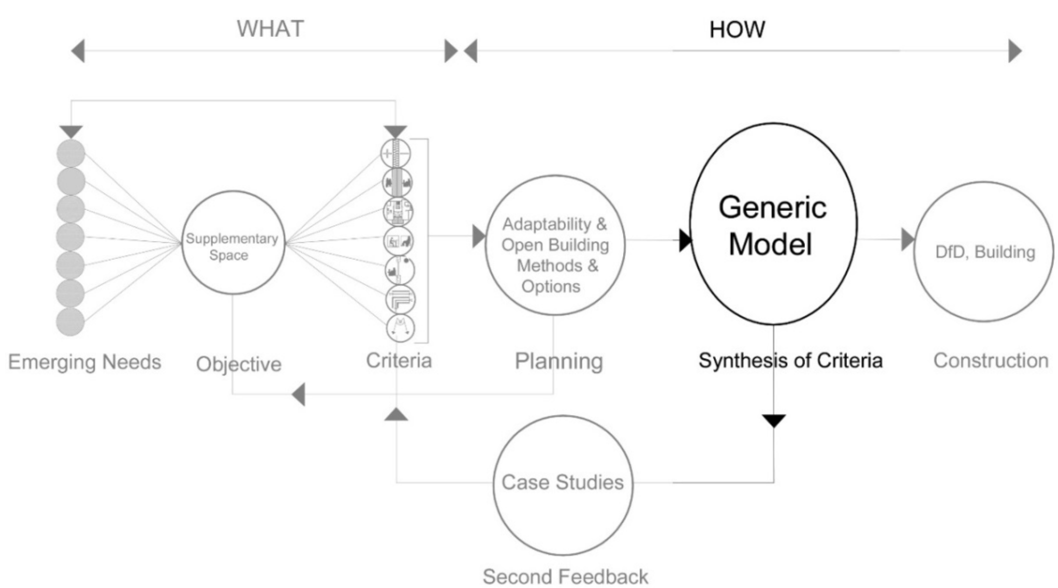

Figure 5.1 Map of research, generic model

5.1 Functional and Performance Criteria

The criteria extrapolated for the supplementary space in chapter 3 are divided into two categories: functional and performance. Performance criteria are those that quantitatively measure the success of an option, whereas functional criteria must be qualitatively assessed based on the literature and expert judgements (Bjelland & Borg, 2012; Glinz, 2008; Steskens & Loomans, 2010). For example, visual privacy is a functional criterion, as it can be accommodated by floor plan design. By contrast, soundproofing is a performance criterion measuring the noise level between two dwelling units.

The Eindhoven University of Technology (Figure 5.2) developed a method for measuring the criteria in the living environment called performance indicators of health and safety, which is represented in the following figure. The sets of functional and performance criteria are presented based on this approach, and the optimal choice is selected from the highest scores of the options (quantitative or qualitative).

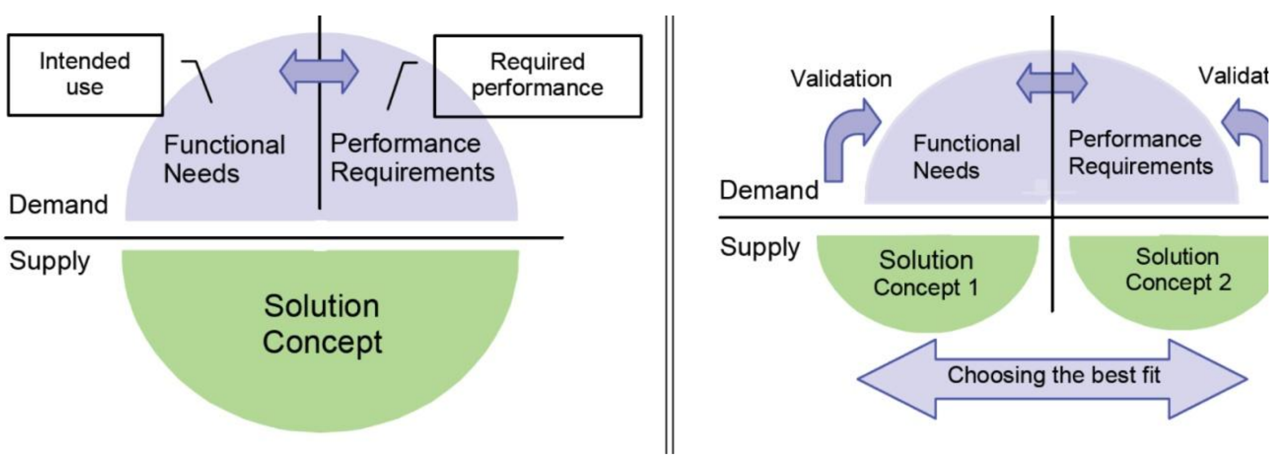

Figure 5.2. Functional and performance criteria and solutions (Steskens & Loomans, 2010)

5.1.1 Knowledge Model for Supplementary Space

A knowledge model **itemizes** the **options** and **criteria** in a way that allows each to be studied individually. As mentioned in chapter 2, the type of knowledge model chosen for supplementary space is the 3D Domain model. In their book, *Enhancing Building Performance*, Malory-Hill, Preiser, and Watson (2012) propose a 3D domain model to visualize the complexity of performance measures in **designing a workspace**. The model (Figure 5.3) contains three axes:

1) Human systems (six Levels)

2) Building systems (six Levels),

3) Architectural scale (five Levels)

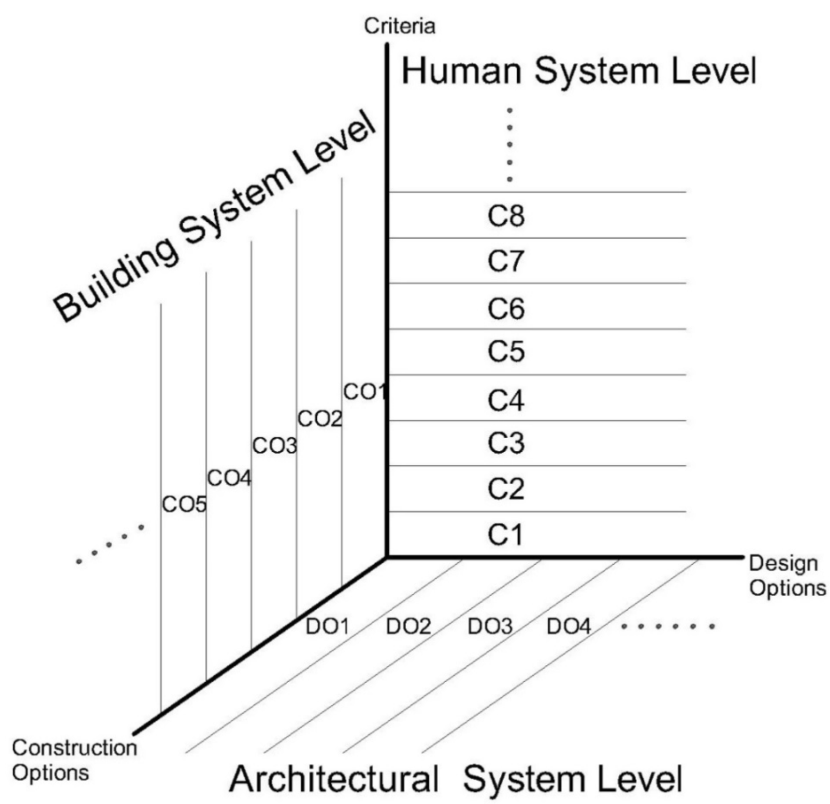

Figure 5.3. 3D Domain model. criteria (C), construction options (CO), architectural options (DO) (after Mallory-Hill, 2004)

The model employs the systems approach to show increasing scalar dimensions and combinations of human–environment interactions at various performance levels. The aim is to **break problems** and **solutions** into a manageable number of items. The placement of the criteria and options for the supplementary space into the knowledge model is illustrated in Figure 5.4.

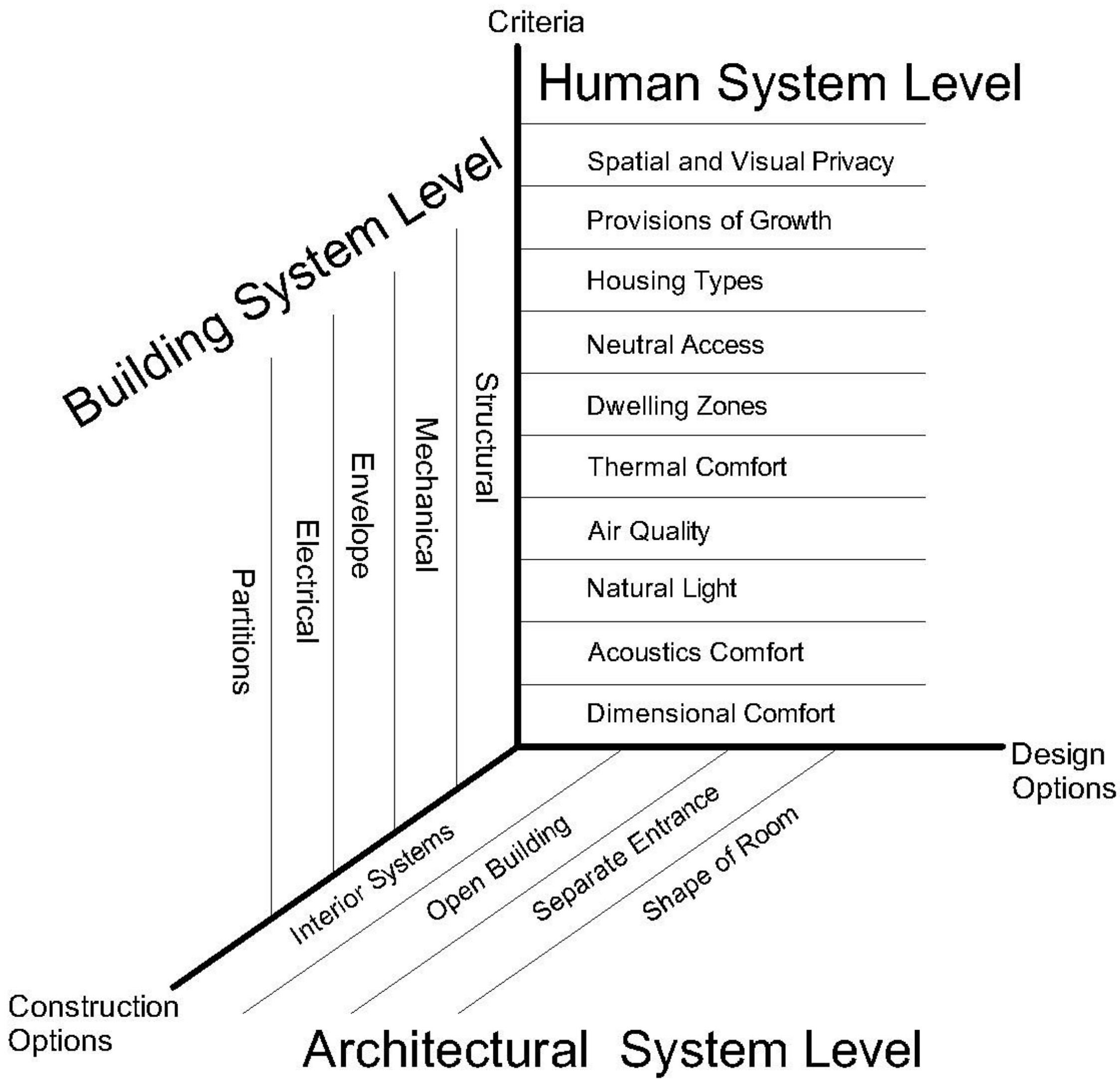

Figure 5.4. Supplementary space 3D domain model

5.1.2 Applying Criteria and Options to the Knowledge Model

Mallory-Hill, Preiser, and Watson (2012) use a hierarchical, relational diagram to show the connection between the functional criteria and performance requirements, which they call the operational path between the demand and supply. This research adopts a same approach to create a systematic **criterion–options path** that links the functional criteria to the building and architectural levels (options) by measuring or designing each proposed element. The functional criteria path for the supplementary space as a home office is depicted in the following Figure:

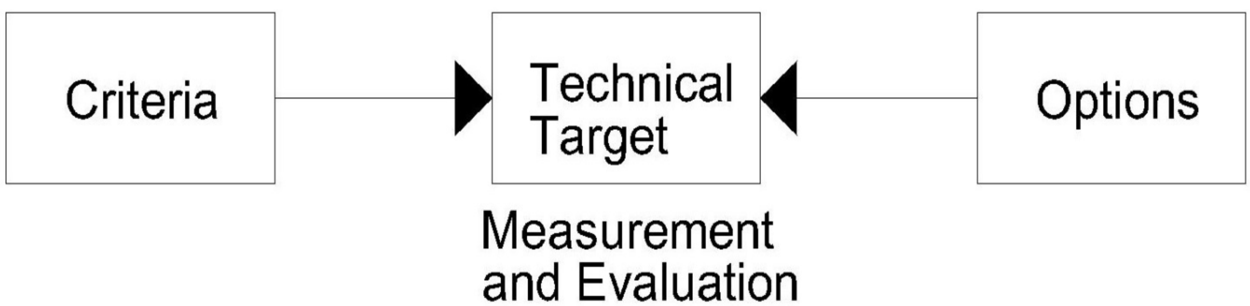

Figure 5.5. Basic knowledge model

The knowledge model assumes a direct one-to-one mapping between the problem and solution spaces (Watson, 1997). This poses a challenge for representing and retrieving architectural design cases because more than one solution can exist for any given problem.

The model is divided into two parts: **utility (technical) criteria,** such as lighting, noise level, acoustics, etc., and **spatial criteria,** such as privacy, psychology of the space, etc. The performance path for the first category is a numerical measurement (mainly quantitative), while the second category is based on sources such as literature and expert opinions (qualitative). The first category includes the measurement of temperature (indoor climate), lux (lighting), and the R value of drywall (noise level), whereas the second contains an extrapolation of concepts from the literature such as zoning and Habraken's theory of levels.

The utility and spatial criteria model will be developed for two stakeholder groups: the user of the home-office space and the remaining occupants of the multi-family dwelling.

To create a system, a current issue (the architect's working brief) must be connected to solutions for similar issues in the past. For example, when dealing with workplace **noise levels** in multi-family buildings, precedents show that walls with a higher R value have been used for soundproofing (Figure 5.6). To ensure privacy, Habraken suggests creating different zones in the floor plan (Figure 5.7).

As illustrated below, the criteria-option path is divided into two sections: construction and design options. The construction options are mainly dictated by the building systems and measurements, such as the STC rating, lux value, temperature, etc. The design options, which are the focus of this study, are created based on the designer's judgement and expertise.

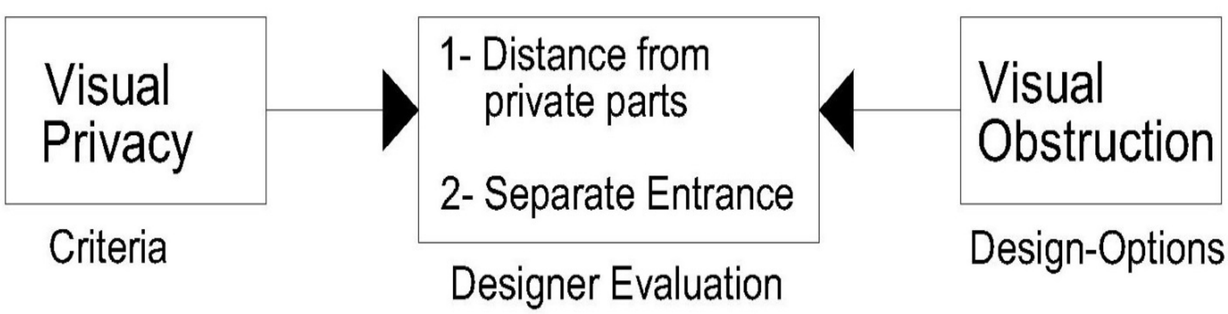

Figure 5.6. Human system level- architectural system level path (planning design options)

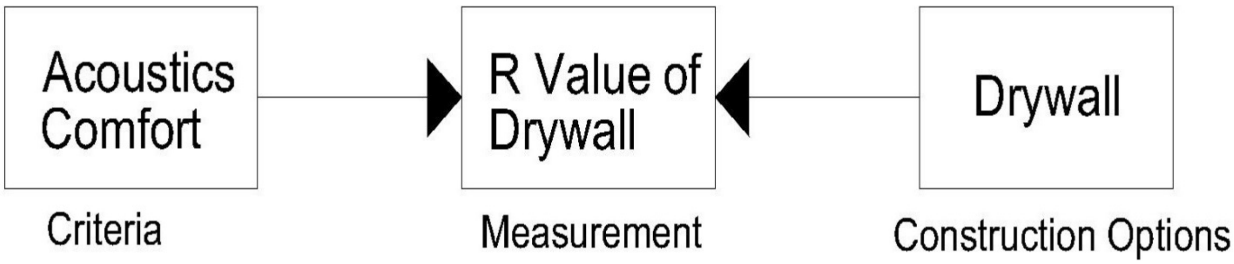

Figure 5.7. Human system level- building system level path (construction options)

Based on the criteria-requirements path, the following table compiles the list of criteria and options for the supplementary space (Figure 5.8).

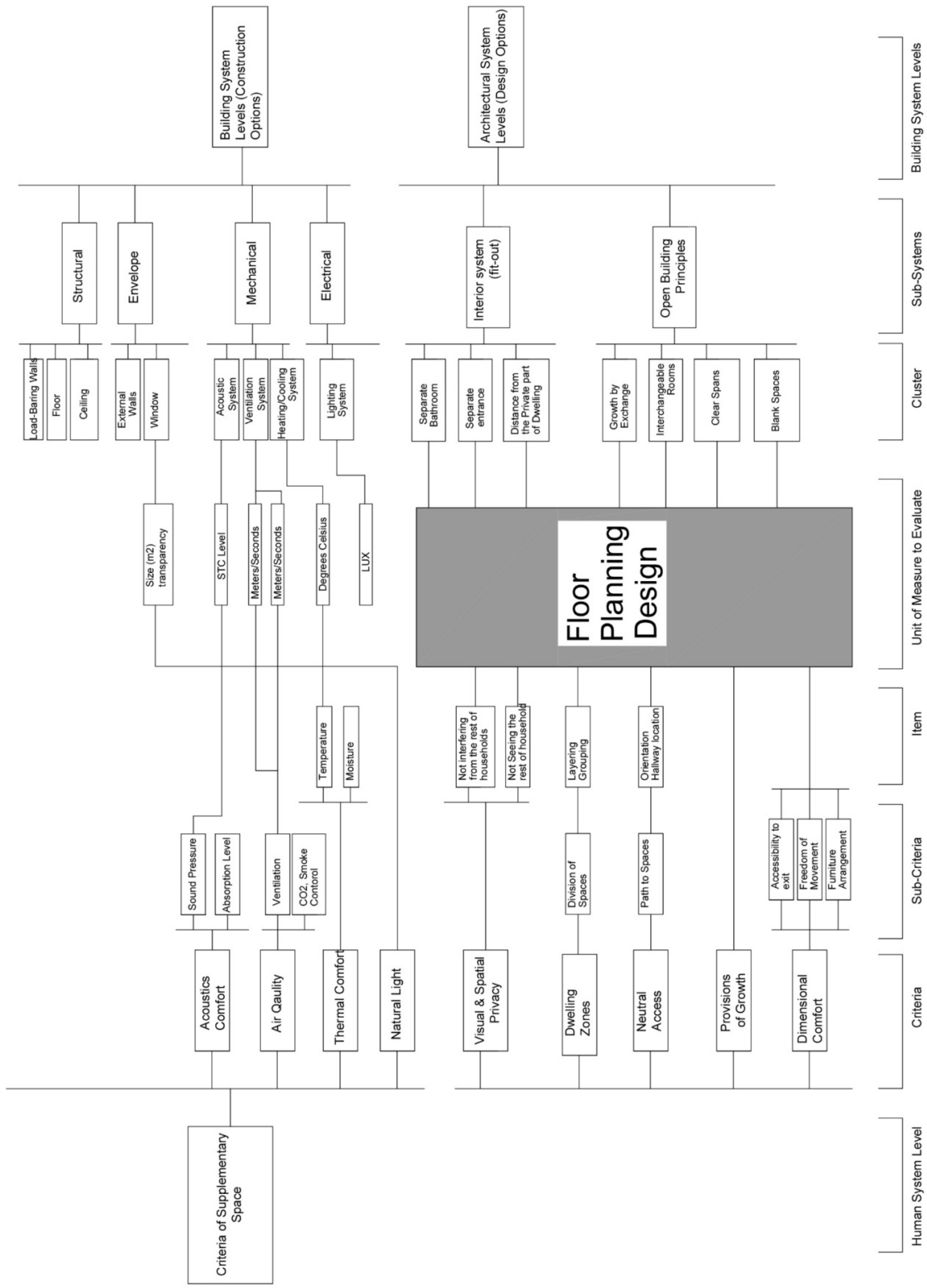

Figure 5.8. Supplementary space criteria- requirement path

5.2 From Knowledge Model to Generic Model

The criteria and options present in the supplementary space path model will be translated into the **generic model** through design. In the generic model, the architect embodies the design options developed earlier (architectural levels) at the level of floor planning (Figure 5.9).

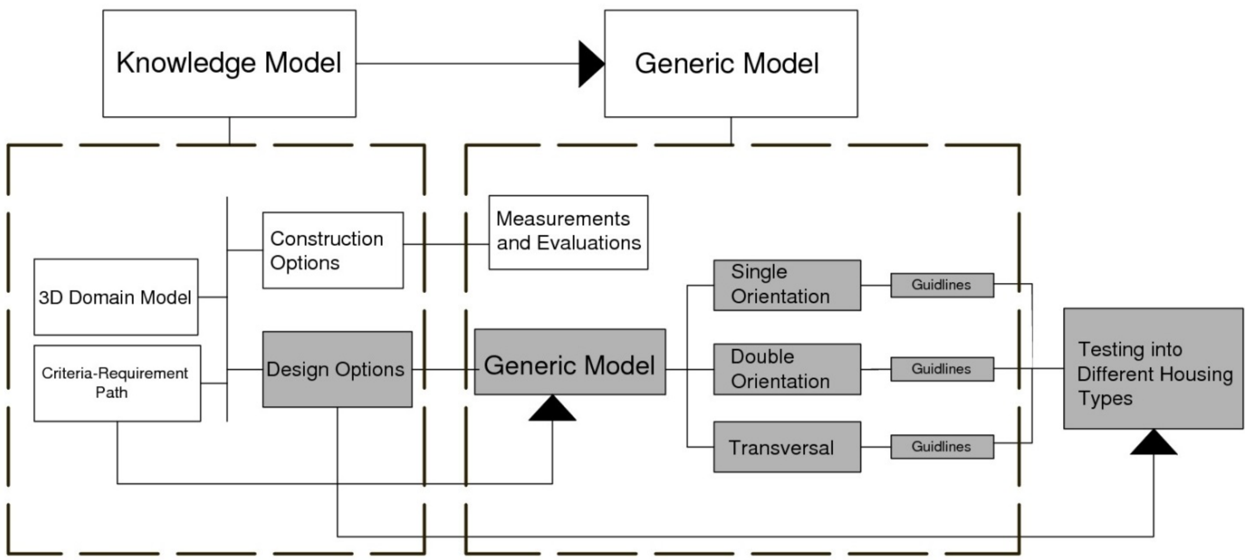

Figure 5.9. Sequence of developing knowledge model to generic model

The criteria-requirement path illustrated in Figure 5.8 contains both architectural and building systems as options. The building system (construction options) mostly involves **measurement** of **building components** such as STC level, or R-value in walls. The architectural system (design options) is the **floor plan arrangement** which must be designed by architect. These design options can be achieved through typical floor planning design, leading to the generic model. The criteria-construction options and design options are presented in Figures 5.10 and 5.11.

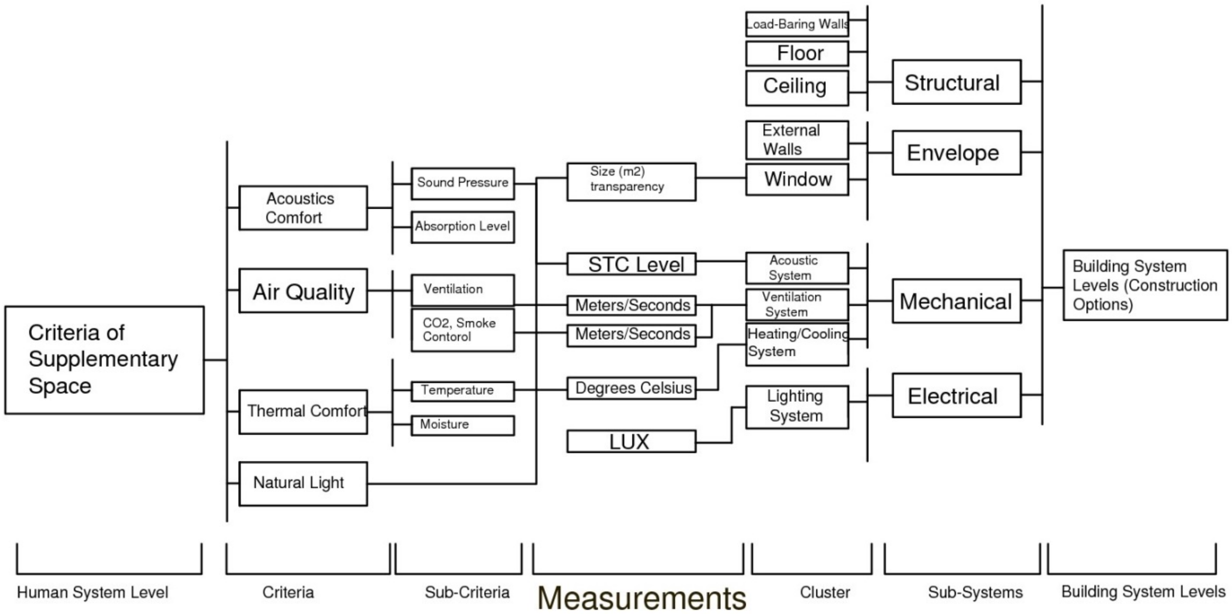

Figure 5.10. Criteria-construction options, achieved by measurements

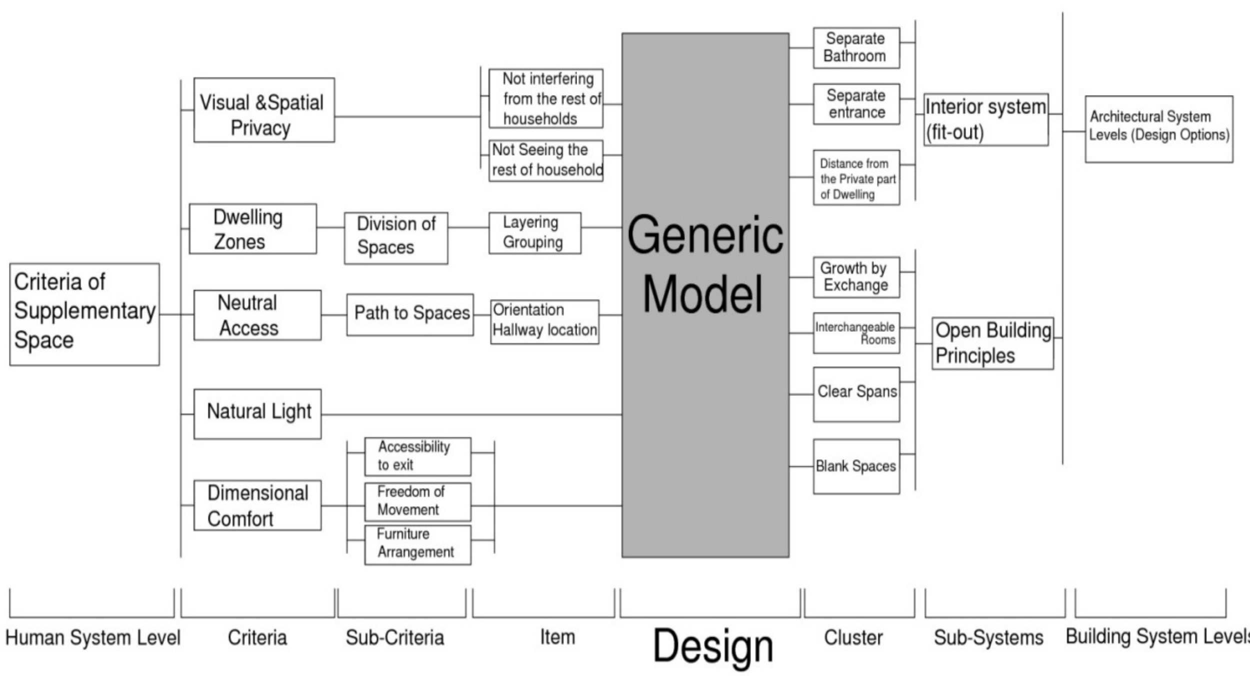

Figure 5.11. Criteria-design options, achieved through design

5.2.1 Criteria Incubation

The Generic Model proposed in the present thesis is the resulting synthesis of both the criteria governing the supplementary space and the ones governing a fully efficient dwelling unit; as described in chapter 3.

That compatibility is even more necessary as the supplementary space goes further than its thematic "office at home" role, where the privacy of the rest of the dwelling unit is fundamental. Several of the "other needs" to be also served by the supplementary space imply various levels of close relationship with the overall dwelling unit: it is the case with the grand-parents suite, the adult child suite, the children playroom, etc. Therefore, those other needs imply that the occupant of the supplementary space could often eat in the dining room, take a shower in the bedroom, enjoy the living room, etc.

Due to the different types of residential morphologies, mainly as far as the orientation of the units in relation to the outside is concerned, three basic Generic Models will be considered in sub-chapter 5.3 hereafter. Each one will take into account at the same time the specific supplementary space criteria as well as the full dwelling unit criteria.

Therefore, the purpose of the three basic generic models is twofold:

- First, to offer a schematic demonstration that both the supplementary space and the full dwelling unit functions are compatible.
- Second, to serve as guidelines for the planning of dwelling units integrating the supplementary space in a multi-family residential building.

Each criterion will be sorted out and influence a building element (Figure 5.12). Among the 10 key criteria, the following ones will have a greater influence:

Entrance and Neutral Access

Due to the multiplicity of activities expected within the supplementary space (home office, artist studio, granny suite, young adult suite, etc.), the Entrance becomes a filtering and selective process, while also taking into account the relationship between the person arriving and his/her relationship with the occupants of the dwelling unit.

A business client or colleague visiting the home office should be directed to the supplementary space without confusion and discrimination; whereas someone familiar with the occupants could benefit from the option of greeting them before proceeding to the supplementary space.

For the occupants of the dwelling unit, the Neutral Access criteria means having the option of moving straight to the living areas to join the others, to the kitchen to prepare a meal, or to his/her bedroom without having to go through the living areas. This criterion is rarely fully implemented in many recent multi-tenant buildings and that can be irritating for some occupants. An example of such is when a teenager arriving home in the evening must talk to the visiting friends of the parents in order to get to his/her bedroom.

Spatial & Visual Privacy

A visitor to the supplementary space should not be an interference in the lives of the occupants. Therefore, the location of that space independent from the main areas of the dwelling unit and separated visually. That means the supplementary space cannot be provided by the simple allocation to a regular bedroom; except when the above mentioned Entrance and Neutral Access criterion is fully met.

Dwelling Unit Zones (including the access to a powder room for a visitor)

Normally, there are three main functional zones in a dwelling unit: the household Living Area, the Bedroom Area(s) and the Service Area (kitchen, laundry room and bathroom). Mainly due to the Spatial & Visual Privacy double criterion, the supplementary space normally justifies one zone by itself: this principle will be governing the Generic Models that are to be developed afterwards. In order to be fully autonomous even for business visitors, the criterion should also imply access to a powder-room.

Natural Light & Ventilation

Since the supplementary space is a full-fledged room (not a closet), it has to meet the National Building Code and provide a window directly open to the outside. Therefore, the room needs to offer natural light and ventilation.

Acoustics Comfort

The visual and spatial privacy requirements need to be supported by specifying appropriate soundproofing partitions and measures.

Housing Types

By itself, the Housing Types criterion is generating the three basic dwelling unit geometries that are responding differently to the other criteria and, as such, will generate the three Generic Models described hereafter.

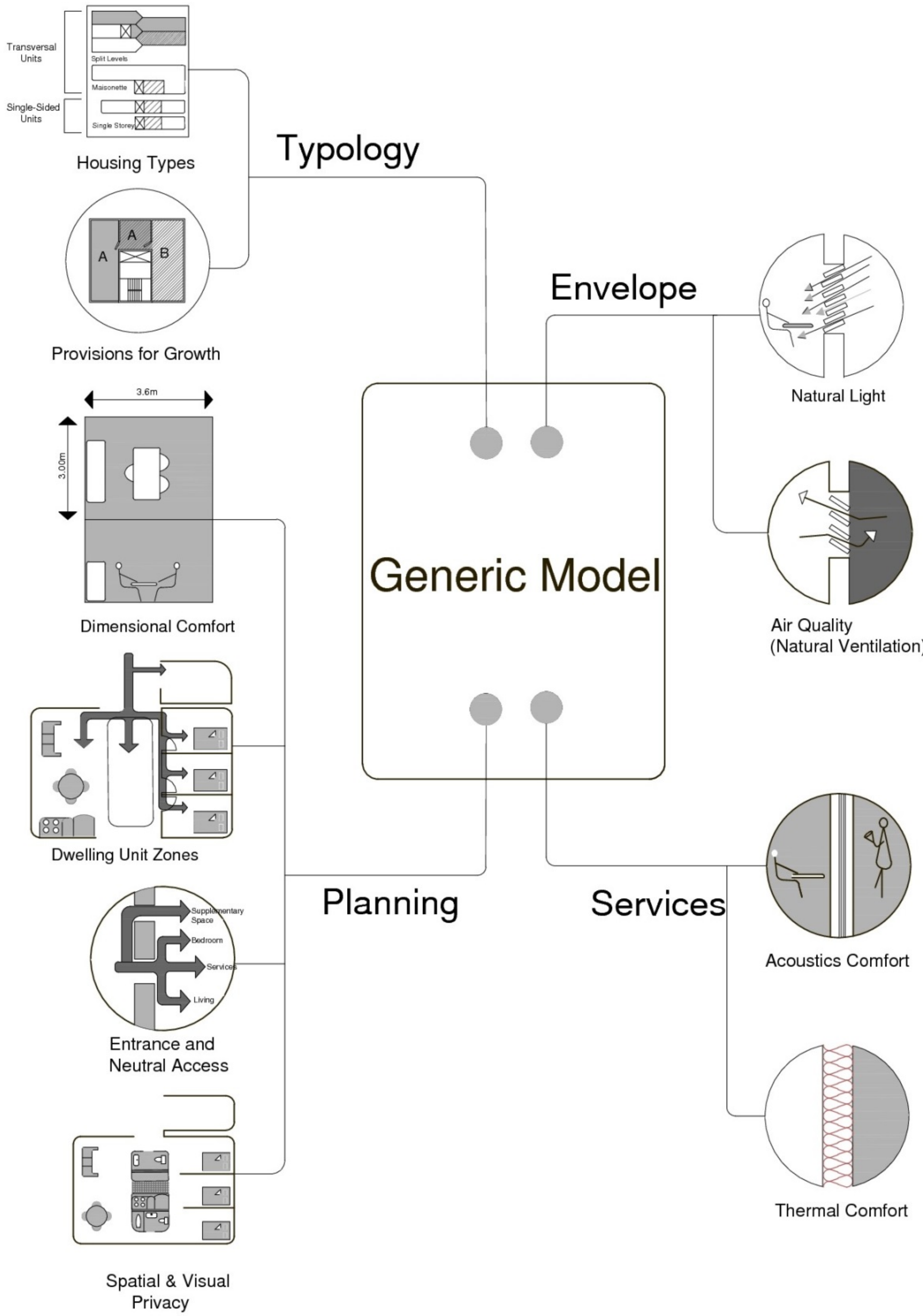

Figure 5.12. Criteria incubation

In fact, the "entrance and neutral access" as well as the "spatial & visual privacy" criteria are met in the unintentional supplementary space illustrated in the case studies of sub-chapter 4.6.1 and in some of the examples of sub-chapter 5.5. Up to the point where they are quite compatible with the generic models presented hereafter.

5.3 Generic Model Proposals

In his book, *Modern Housing Prototype*, Robert Sherwood talks about a system of **unit types** at the level of individual dwellings. He organized this classification based on the **orientation of units**; orientation referring to how the unit faces the outside (Figure 5.13). There are three general classifications concerning the orientation of units:

1- Single orientation: usually along a double-loaded corridor

2- Prependicular orientation: usually a corner location with a 90° glazed area

3- Transversal orientation: open-ended

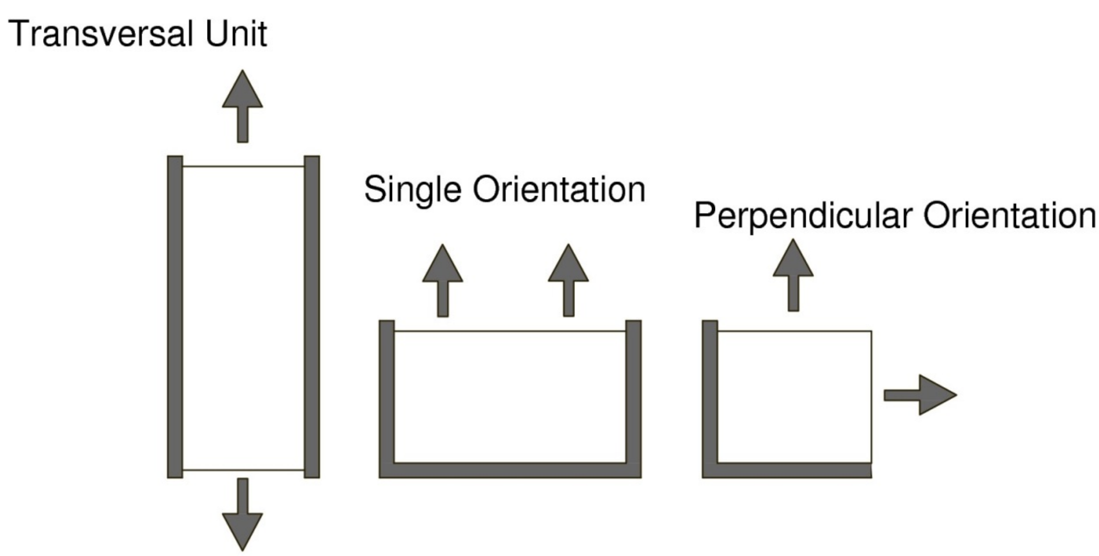

Figure 5.13. Unit types, distinguished based on the orientation (after Sherwood, 1981)

Based on the criteria and design options deduced in previous sub-chapters, three generic models were developed and are proposed in Figures 5.14-5.16. These generic models will be tested with different housing types and are also the basis for supplementary space materialization in chapter 6.

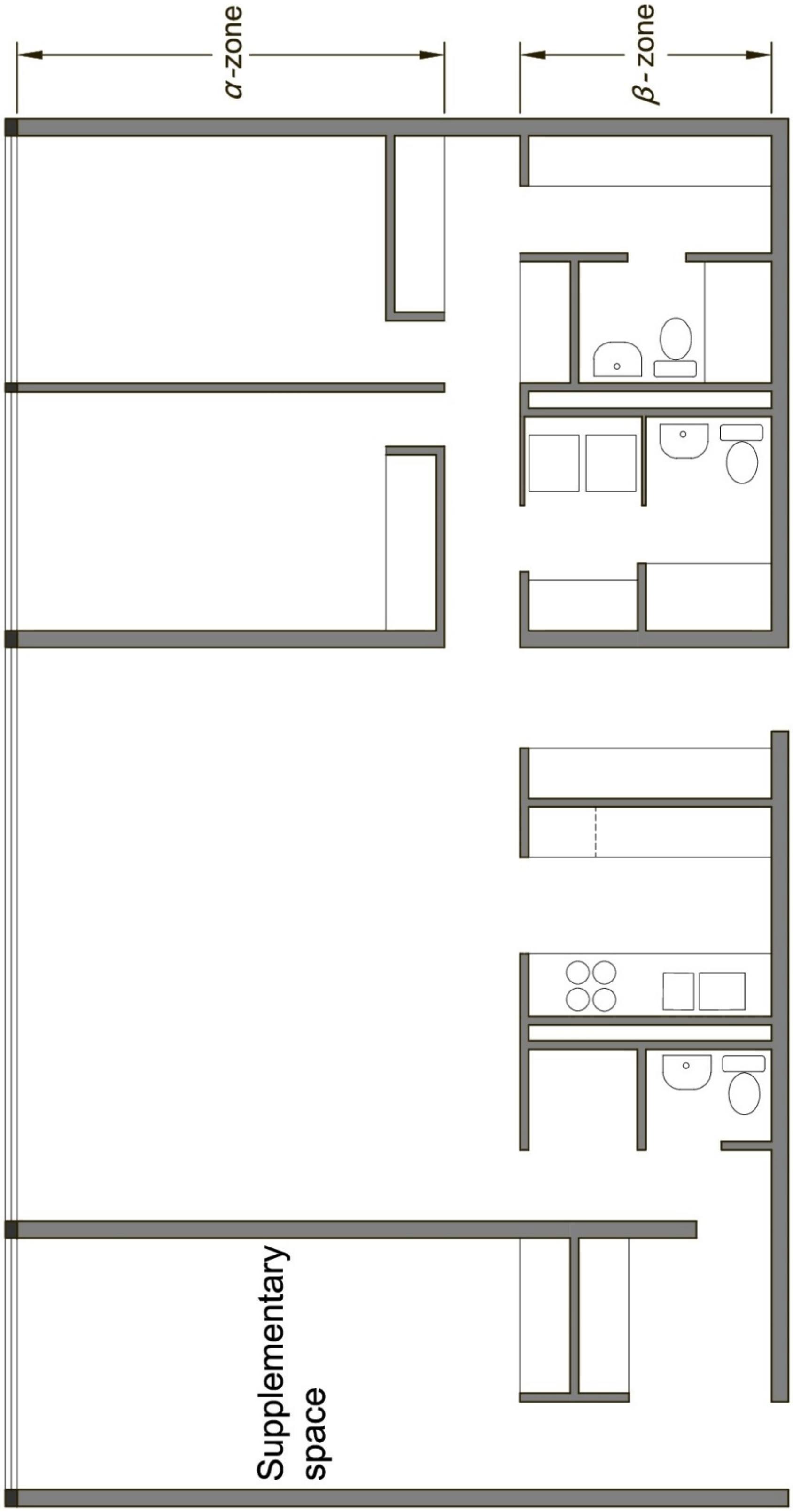

Figure 5.14. Generic model for single-orientation unit

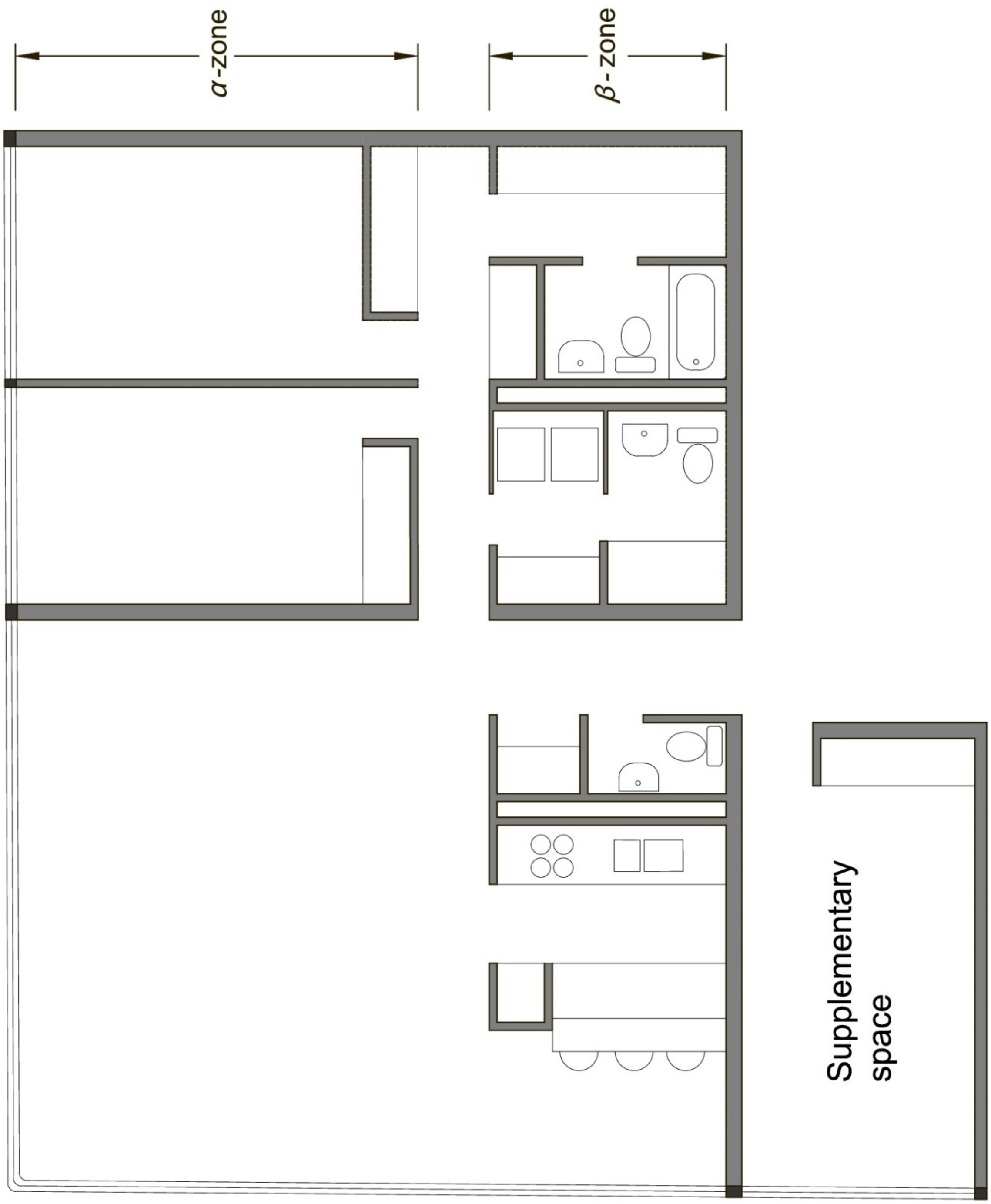

Figure 5.15. Generic model for perpendicular orientation

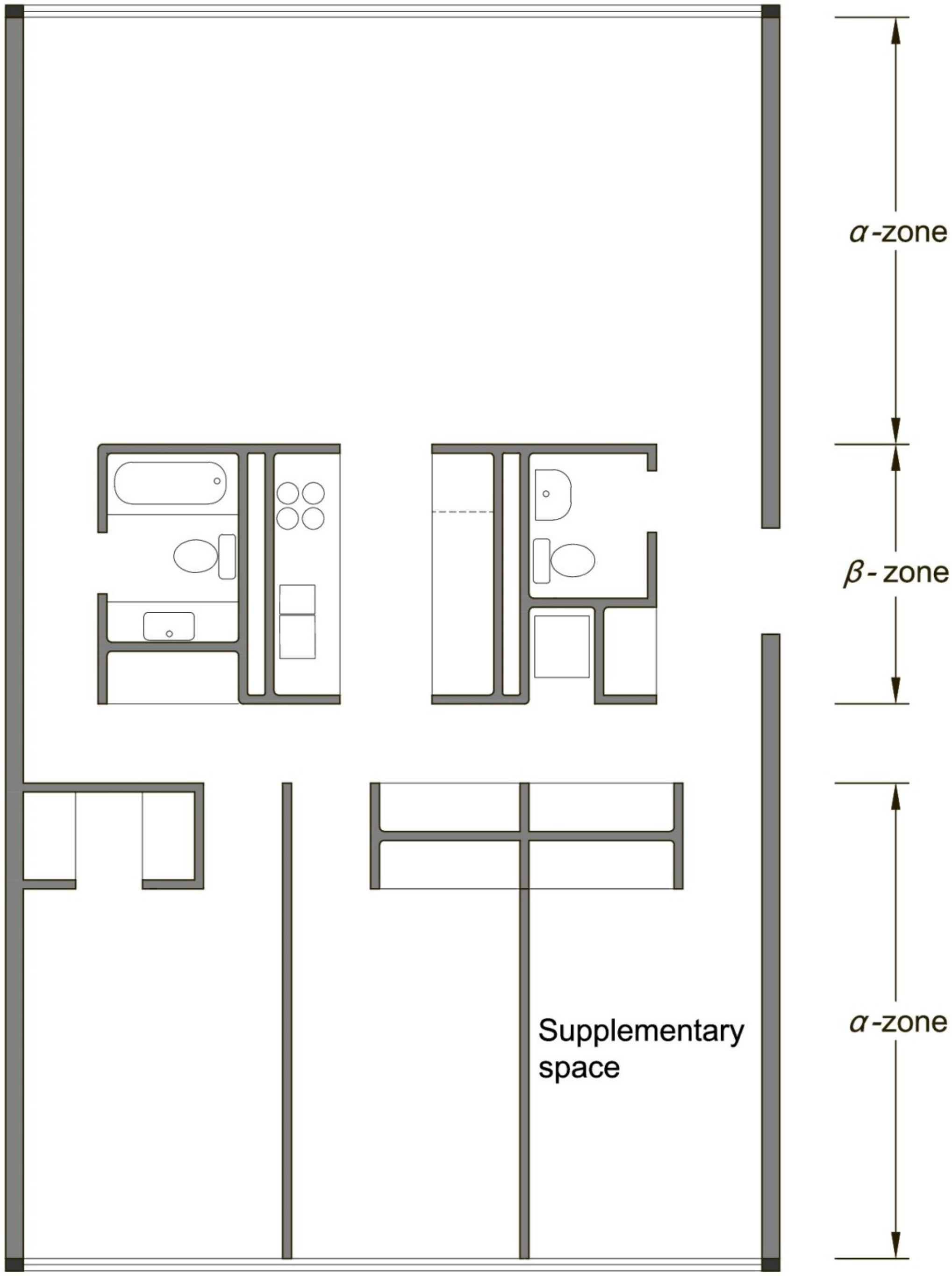

Figure 5.16. Generic model for transversal unit

5.4 Applying the Generic Model to Different Housing Types

Different types of multi-family housing will demonstrate hereafter. The feasibility of implementing the "supplementary space" in the real world along the three basic generic models. The key criteria governing those generic models are accommodated even if their designers were not formally applying them.

The typological handbooks of Sting and Sherwood present a number of precedent-based typologies classified based on "the typology of access." This classification focuses on the interior layout of a building and its units. Such an approach is appropriate as the "supplementary space" should be located inside the unit, and its location and configuration must be analyzed from within the building. The Sting approach suits the purpose of this research (F. Schneider & Heckmann, 2004a; Sherwood, 1981).

In the Hellemuth Sting book *Grundriss Wohnungsbau* (Floor Plan Atlas, 2004), the housing floor plans are divided into two parts: the floor plan in multi-family housing and the floor plan in a single family dwelling as an element of integrated dwelling complexes. Since the second classification is outside the domain of this study, the focus is only on the floor plan in multi-family buildings (Schneider & Heckmann, 2004).

Sting presents a system of typologies at one level of spatial organization in residential buildings. He recognizes that multi-family residential buildings can be efficiently described regarding repetition of **access units**, rather than the repetition of dwellings (Heckmann & Schneider, 2011; Pallado, 2011).These access units are organized in relation to corridors and vertical circulation axes. In his Ph.D. thesis*, A System of Types in the Domain of Residential Building,* Leusen (1990) states:

> "For a closer determination of the elementary forms of housing the type of access on one hand influences the floor plan layout of the individual dwelling and on the other hand determines the mutual connections between dwellings. If one follows the access principle, it can be seen that close neighborhood relations between dwellings exist solely based on the routing. These arrangement of access types in building form the actual basic systems of multi-story housing" (p.47)

The heart of Sting's classification is formed by a large sample of existing access units and is divided according to a distinction between two general categories, as follows:

A. In the first category, the access units are organized around vertical access (staircase and elevators)

B. In the second category, the units are organized along a horizontal access, mainly a corridor, within and along the building (Heckmann & Schneider, 2011; Pallado, 2011; Sherwood, 1981).

The housing types, based on the types of access mentioned above, and their different sub-types will be explained hereafter. Additionally, the floor plan simulation of the supplementary space will be investigated for each of them. Based on the outcome of the simulation, guidelines for the building as well as for the unit will be suggested for designers.

5.5 Vertical Access Types

In the vertical access buildings, the units are stacked in a group around a common vertical access (F. Schneider & Heckmann, 2004a). There are various advantages of stacking apartment groups. The identical floor plan on each level minimizes the noise level and disturbances since the rooms are on top of each other, including living rooms, bedrooms, and kitchens (F. Schneider & Heckmann, 2004a). Furthermore, it optimizes the installation of a building's technical components, such as plumbing, electrical, and HVAC installations. In this building type, often the layouts of adjacent units are mirrored to position spaces with the same function next to each other. For example, the bedroom of one unit is next to the bedroom of an adjacent unit, or the bathroom and kitchen are "coupled" between two units.

The vertical access isbased on the orientation of the units and the access; three variations can be classified as follows.

5.5.1 Transversal Units

Transversal units open to or face two opposite sides (Heckmann & Schneider, 2011; Pallado, 2011; Sherwood, 1981). These units have an open-ended orientation, which enables natural light to enter and facilitates cross ventilation through most parts of the unit.

Designed by Dan Hanganu, the *Val De L'Anse* condominium project in Nuns' Island, Montréal is a multi-family building suitable for simulating supplementary space (Figure 5.17). Each unit is about 140 m2 (Craig, 2001).

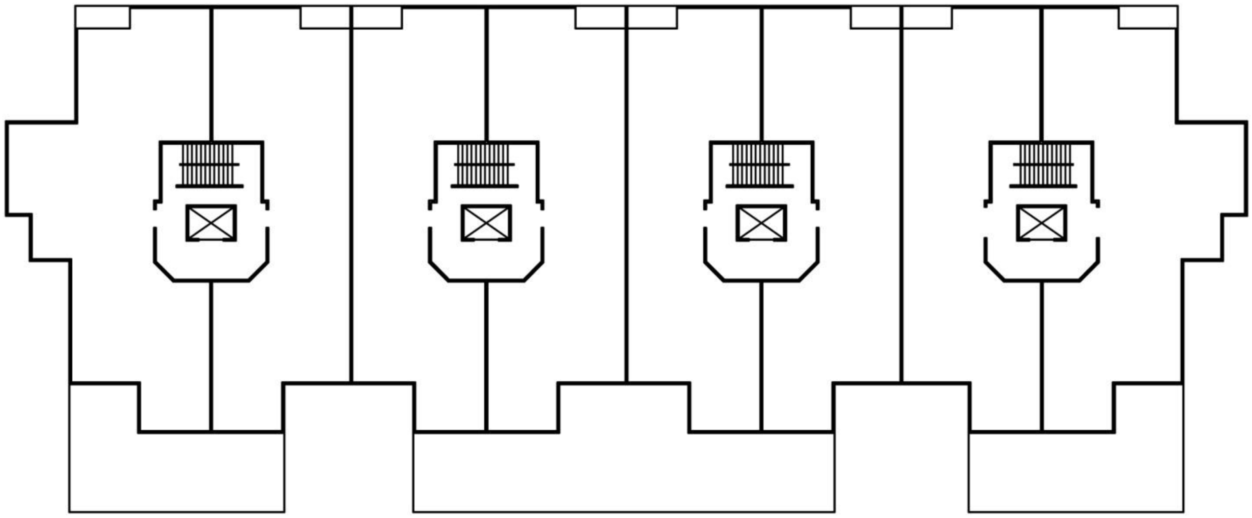

Figure 5.17. Typical floor plan, Val de l'Anse condominium, Montréal, Dan Hanganu, 1988.

Since there is separate outside access for each two units, supplementary space can easily be implemented along the corridor. Due to exposure to the outdoors and its size, the supplementary space can be an autonomous unit with its own separate access (Figure 5.18).

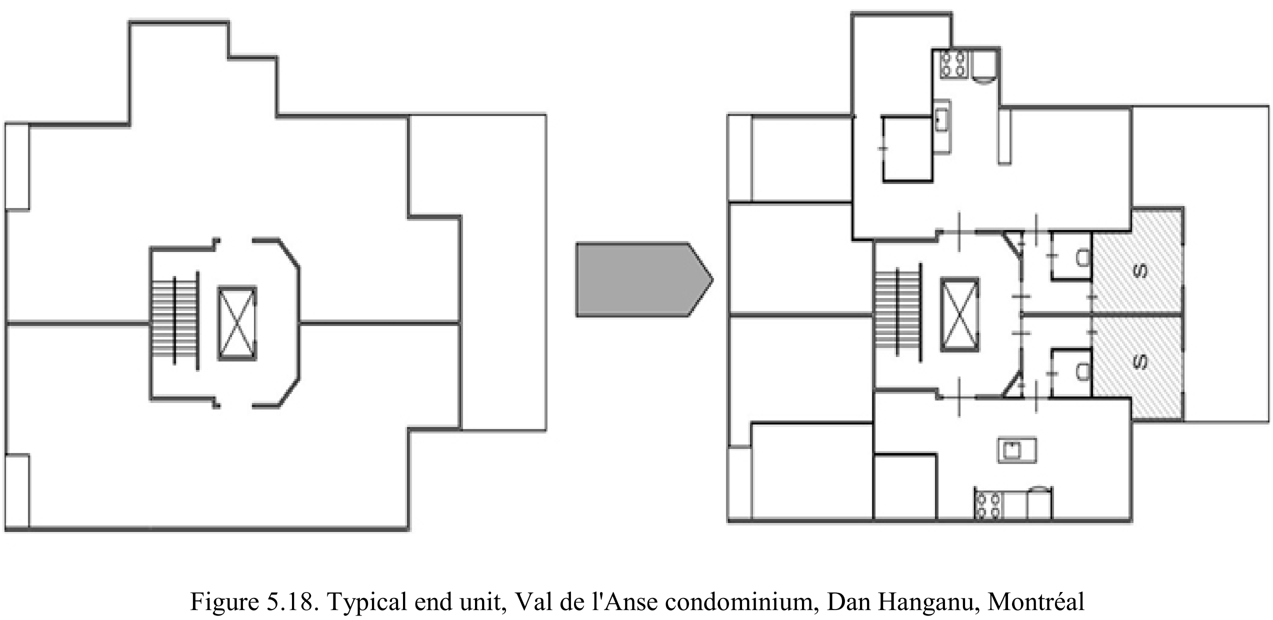

Figure 5.18. Typical end unit, Val de l'Anse condominium, Dan Hanganu, Montréal

5.5.2 Free-Standing Tower (Single and Perpendicular Units around a Circulation Core)

In this housing type, the units are arranged around the elevator core and the building's staircase. This arrangement is common, similar to plenty of free-standing towers in Canada in which some of the units offer a perpendicular orientation and others a single orientation (F. Schneider & Heckmann, 2004a). It offers perpendicular units at the corners and single orientation units in-between them (Figure 5.19).

The Evolo2 is a 30-storey tower project also on Nuns' Island in Montreal. The units are arranged around the vertical access ("Waterfront condo with an urban beat," 2012).

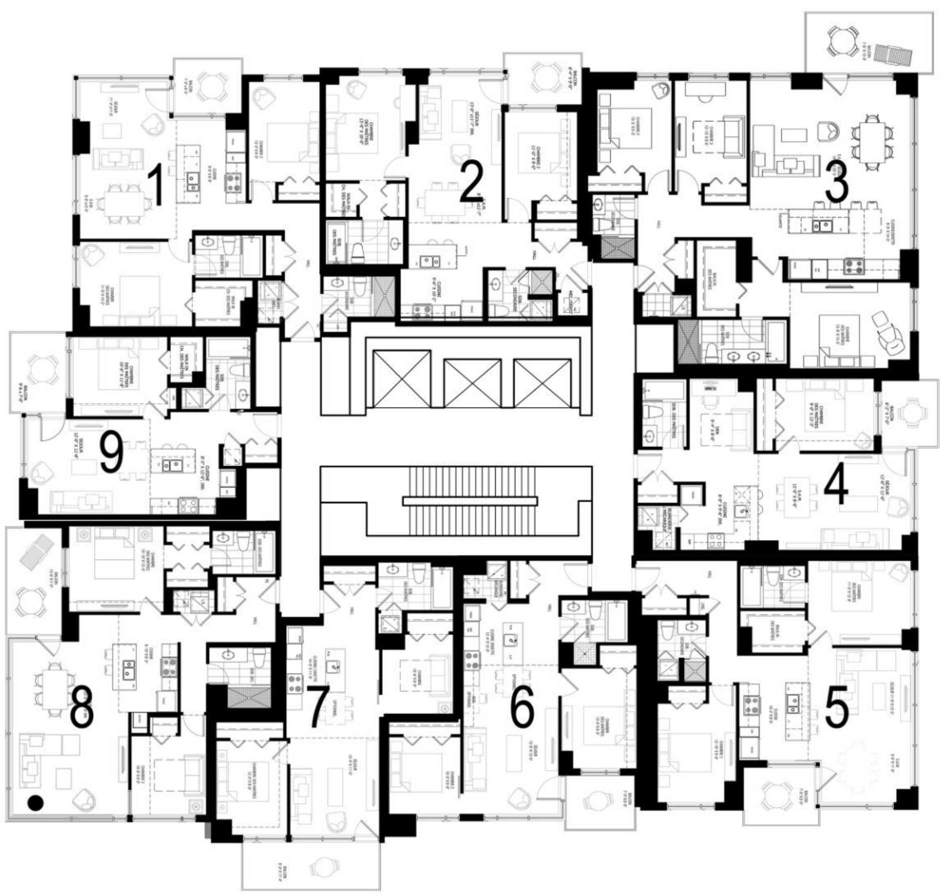

Figure 5.19. Evolo2 project, Montréal (Waterfront condo, 2012)

Units 1, 3, 5, and 8, which have similar floor plans, can implement a supplementary space since they are corner units. The implementation of supplementary space into Unit 3 (135 m2) can be seen in Figure 5.20.

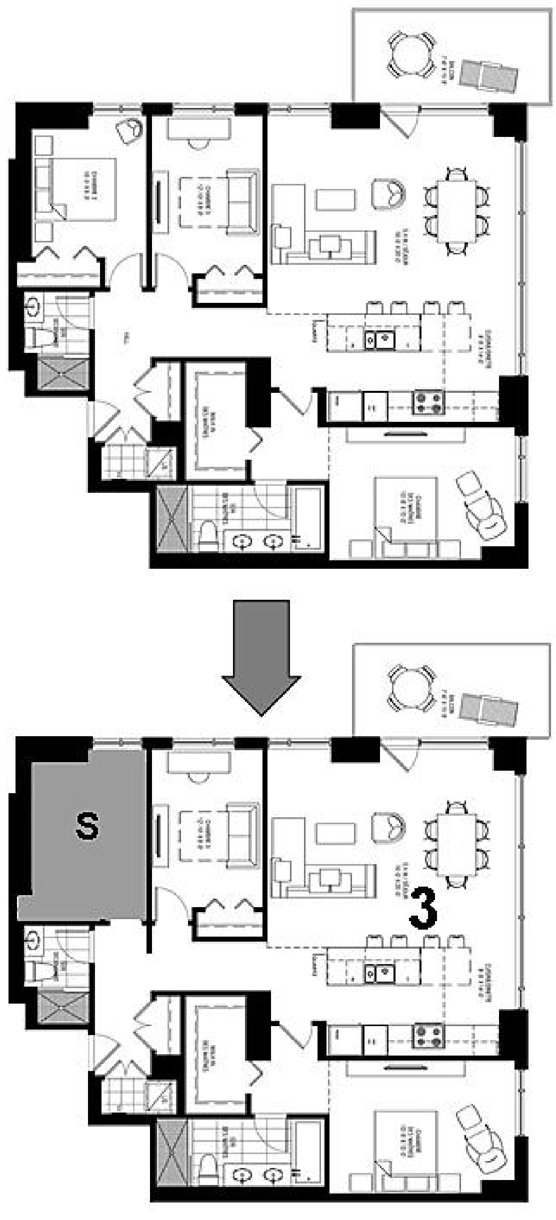

Figure 5.20. Evolo2 project, city of Montreal, original plan and supplementary space (Waterfront condo, 2012)

5.5.3 Horizontal Access (Single-Level, Maisonette, Split-Levels)

In the horizontal access buildings, the apartment groups are along the passageway through the common horizontal access axis (F. Schneider & Heckmann, 2004a). This access axis could be in a double loaded corridor or along an external alleyway/gallery.

External access gallery: Buildings with exterior alleyway access have existed for a long time in Southern Europe, where the weather allows. This type of access has an economic advantage: the ratio of unit spaces to the access spaces is significantly larger when compared to buildings with closed corridors (Figure 5.21). In bigger projects with more units, the units could be extended to several stories (F. Schneider & Heckmann, 2004a). However, privacy is a problem with this building type, as the privacy of the portion of the unit facing the access gallery can be intruded upon when other residents walk to their units. High level or recessed windows can be used as solution.

In warmer climates the external access gallery is common, whereas in Canada, this arrangement is rare. Of course, the external gallery does provide some of the advantages of the double orientation.

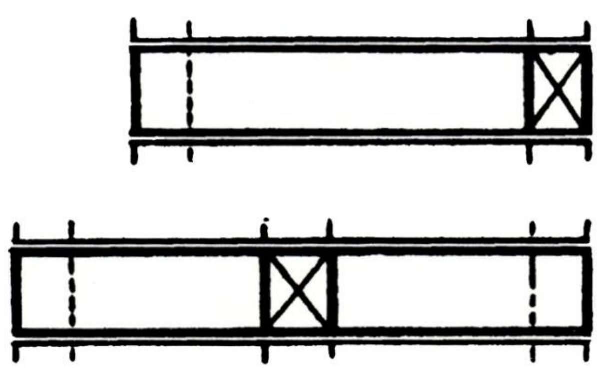

Figure 5.21. Single-story units with horizontal axis (F. Schneider & Heckmann, 2004a)

Double-loaded corridor: it is the most common building type in Canada. The example selected for this housing type is the MUZ condominium housing project in Montréal (Figure 5.22). It is a 10-storey mid-rise project completed in 2015 ("MUZ condominium", 2013). Units 1,2, and 3 have greater potential to implmenet supplemnatry space.

Figure 5.22. Floor layout ("MUZ condominium", 2013)

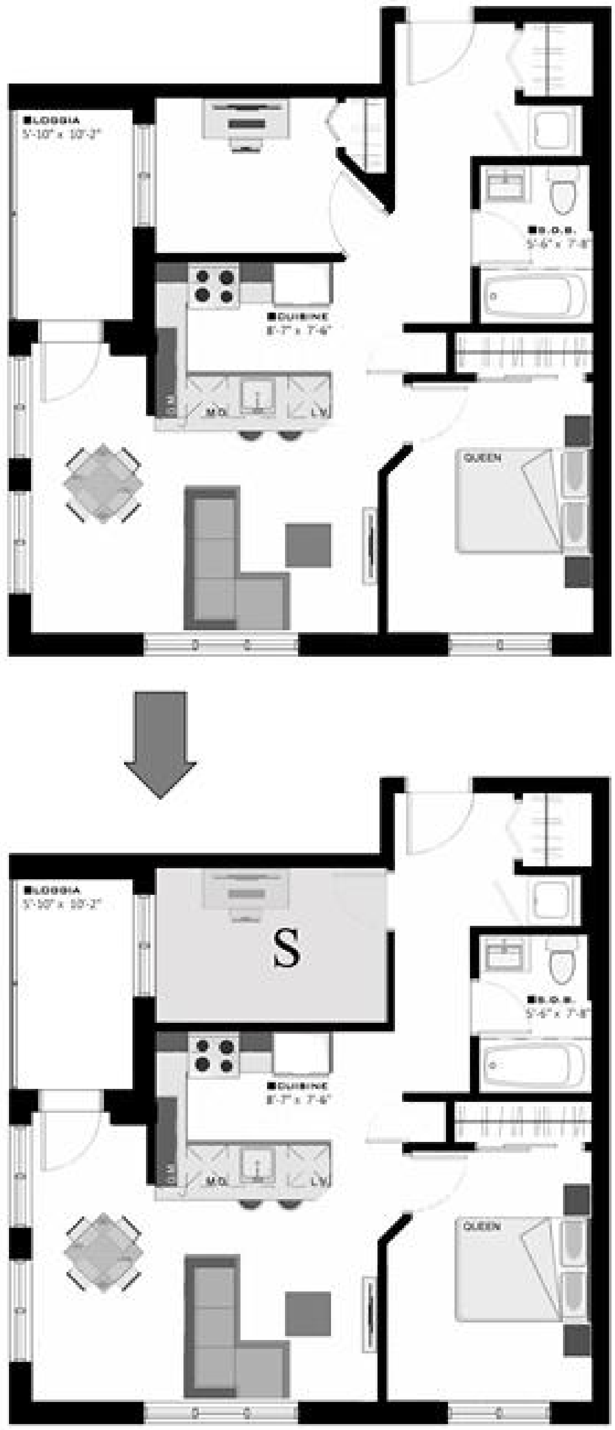

Figure 5.23. MUZ condominium project, Montréal. Floor plan with the implementation of "supplementary space" ("MUZ condominium", 2013)

5.6 Multi-Level Transversal Unit Types

In horizontal access buildings, residents have easy access to the entrance and other building amenities. The size of the access unit varies, depending on the number of floors, the number of units, the specified building code, and other factors. According to the orientation, classification, and configuration of horizontal access units, two variations can be classified, as follows:

- Two or more storey units that are often referred to as maisonettes; they could have interior or exterior access.
- Split-levels units, in which the floor levels are staggered; they could have interior or exterior access.

5.6.1 Maisonettes

Buildings with access for two or more story units are within the maisonette arrangement. This type of apartment group can be organized in many ways. Although it saves access space, the problem of alternating room utilization remains (e.g., the kitchen over the bedroom) (Figure 5.24). (F. Schneider & Heckmann, 2004a, p.40) In general, this building type is uncommon in Canada since the means of egress is an issue and must be accommodated in accordance with the code.

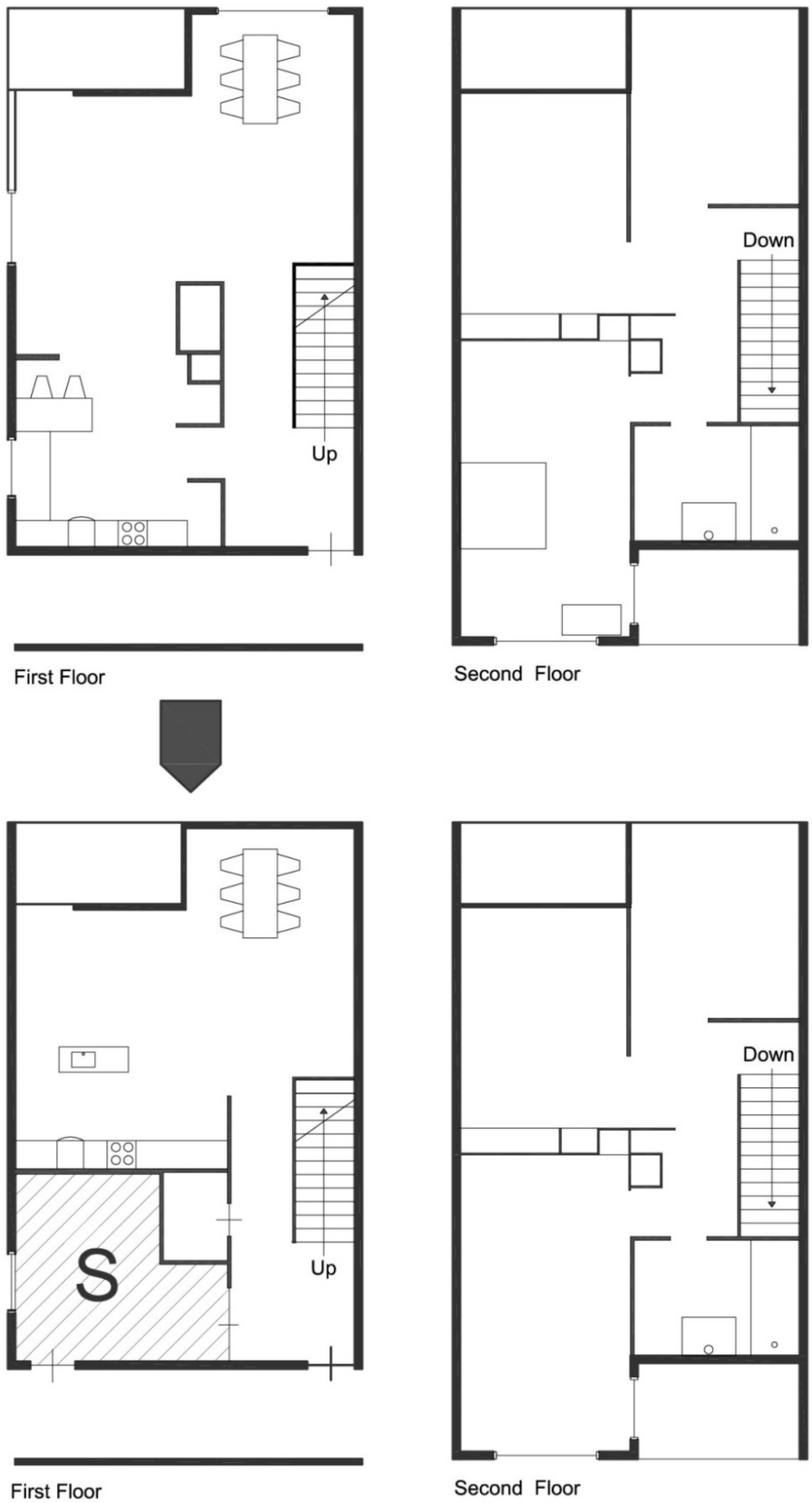

Figure 5.24. Top: Maisonette floor plan, Bennett project, London, 1971 (Sting, 1975), Bottom: Implementation of supplementary space

5.6.2 Scissors Maisonette

Another category, which could be classified under the split level category, is the scissors maisonette. One example is the Corringham apartment building in London, designed by Kenneth Frampton. Most of the scissors apartments are in the United Kingdom. The Scissors maisonette layout has different advantages, such as the ability for natural ventilation, direct daylight, two exits for each unit that could be used as means of egress (meeting the Canadian building code). However, due to additional construction costs for extra staircases, this layout is uncommon in Canada.

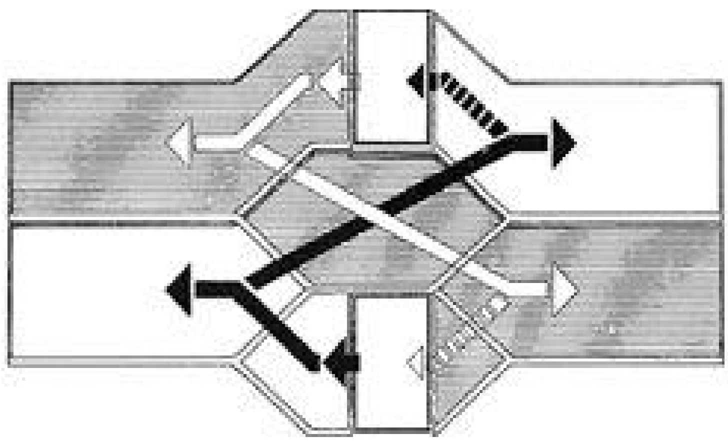

Figure 5.25. Scissors maisonette layout (Tirion, Cruchley, & Creighton, 2006)

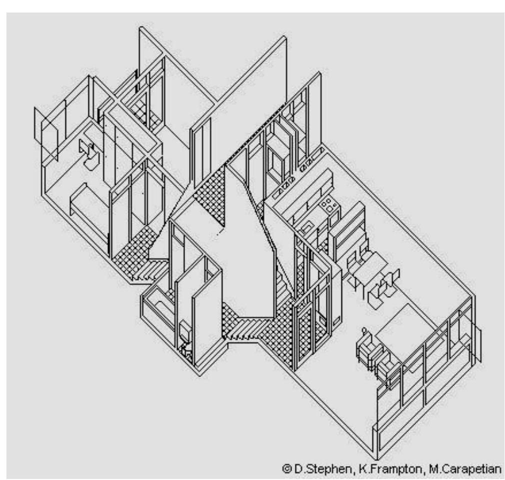

Figure 5.26. Corringham apartment layout (Tirion et al., 2006)

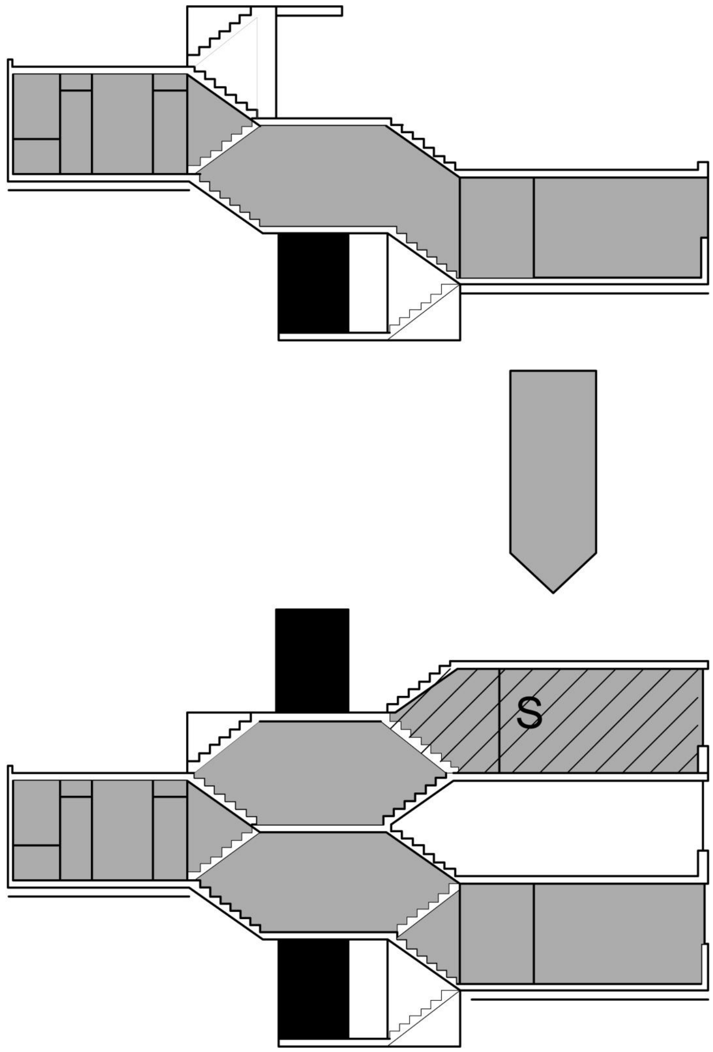

Figure 5.27. Scissors units, supplementary space hatched (Tirion et al., 2006)

5.6.3 Split-Levels

The split-level housing type allows for "living in several levels", with more choices of living in different areas. By partially dividing the levels into half a story (or splitting the unit in ratios of 1:3 and 2:3), a more desirable dwelling communication atmosphere is created (F. Schneider & Heckmann, 2004b). The number of levels ranges from one to four. The present research investigates the potential of supplementary space in buildings with two to three split-levels. However, due to the additional financing required for the construction of half-floors, this layout is not usual in Canada.

The best example of two-level split-levels is the Hansaviertel housing project in Berlin, designed by Van den Borek (Figure 5.28). In this example, there are two types of units, two-level units and one-level studios.

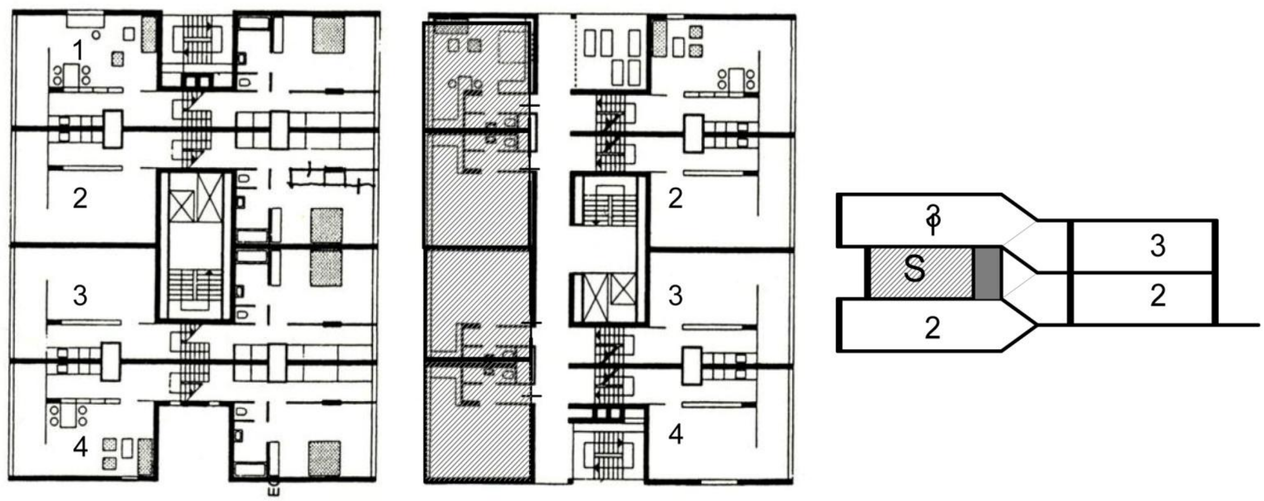

Figure 5.28. Split-level units offering corridor level supplementary space (French, 2006)

In this case, the small independent single-level units along the corridor can be allocated as supplementary space to the occupant of the split-level ones, which means the supplementary space is not inside the dwelling unit but is next to it instead.

5.7 Chapter 5 Findings

There are three general orientations of units: single, perpendicular, and transversal. Each orientation is justifying a basic generic model in order to fully respond to the criteria of the supplementary space. The accesses are either vertical circulation core including elevator and staircase or horizontal i.e. mainly along the corridor. Different provisions for horizontal access are possible; such as maisonettes, split-levels, and scissors maisonettes.

6 Building Systems to Materialise Supplementary Space

Whereas the feasibility of the supplementary space generic models can be validated through conventional construction, industrialized building systems are providing the relevant technology to accommodate change without demolition through the design for disassembly (DfD) approach.

Industrialised building systems usually include five sub-systems: Structure, Envelope, Partitions, Services, Equipment. They rely on four strategies to provide individualized layouts: flexibility of the product, flexibility of the tool, multi-purpose frameworks, and combinability.

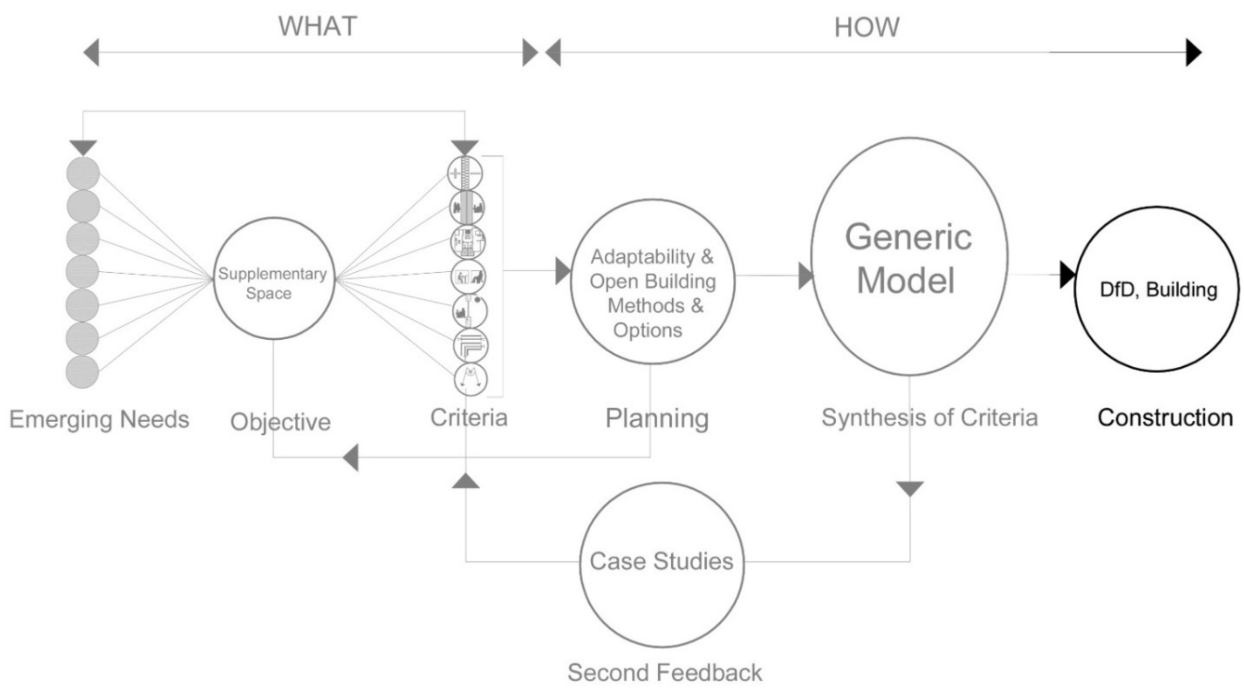

Figure 6.1. Map of research, materialization of model into building systems

6.1 The Conventional Building Industry and Industrialised Building Systems

When it comes to the potential of space to accommodate various activities through the lifespan of building, conventional housing design envisions a single determined usage for each space, making it difficult to modify a dwelling to accommodate users' emerging needs. Because most dwellings are destined for destruction or major modification, renewal, or replacement, such building practices rely on diminishing construction materials and energy resources and generate unnecessary waste at the end of a building's life.

In industrialised housing, the main products are building systems. A building system consists of sub-systems that correspond to the main functions of a building. There are usually five sub-systems:

- STRUCTURE
- ENVELOPE
- PARTITIONS
- SERVICES
- EQUIPMENT

Sometimes, sub-systems are combined to minimize costs and simplify operations. For instance, a modular closet kit could be used to partition two rooms , as long as sound-proofing measures are implemented.

It is logical for building factories to simplify the process of on-site installation. Therefore, industrialized systems can easily become flexible and demountable.

- In renovation or reconfiguration, all components can be easily dismantled or switched due to their flexibility.
- Since the system is demountable, the building can potentially be reconfigured instead of demolished.

Industrialised Flexible and Deountable (IFD) systems precisely achieve the aim of design for disassembly (DfD), which is discussed later in this chapter.

- **User engagement:** Designers cannot forecast the exact needs, desires, and tastes of a homeowner at a particular time and place.

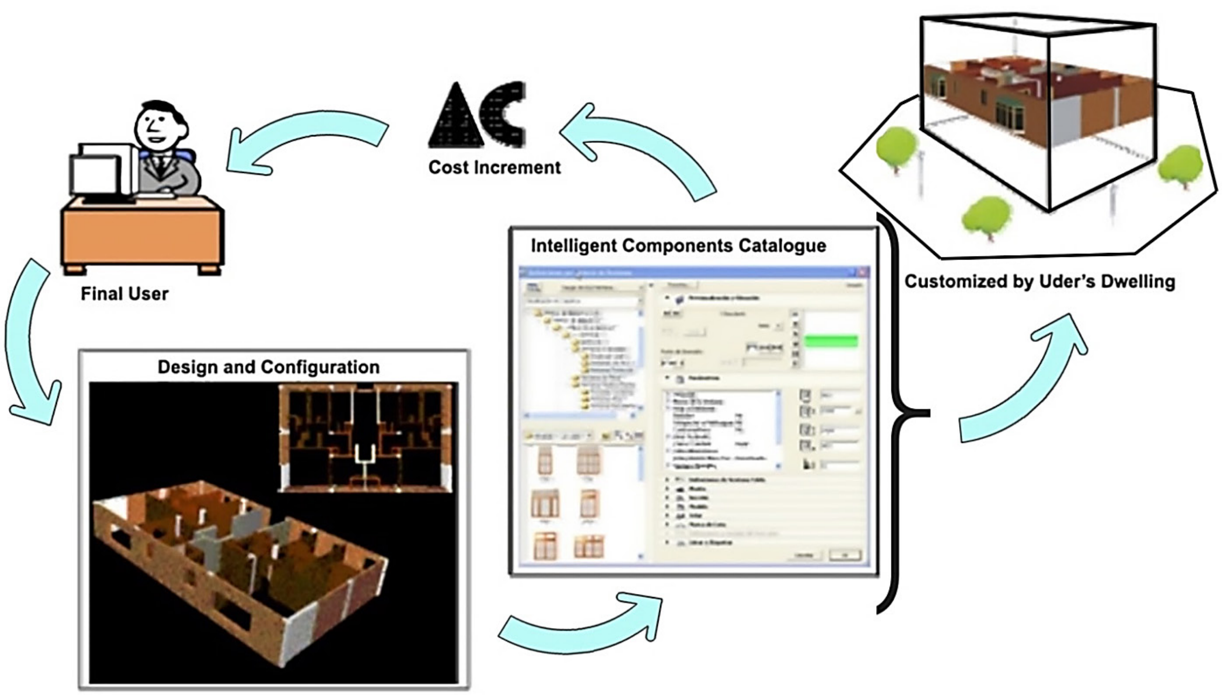

Figure 6.2. Dwelling configuration loop (Lucksiri, Miller, Gupta, Pei, & van de Lindt, 2011)

Two options are available for acquiring new components once the building has been developed:

- Demanding that the manufacturer offer a "service centre," which is a standard procedure in Japanese house construction (Lucksiri et al., 2011);
- Sharing the respective components publicly and widely with independent distributors, which is known as the IKEA approach .

6.2 Individualization

According to the principle of individualization, a product should be able to adopt many configurations to accommodate the needs of its users.

The purpose of individualization, in the context of buildings, is the capacity to alter the usage when new user demands arise. Incorporating adaptable features can help the building be individualized more easily, not only in terms of space but also in terms of use throughout its lifetime. The presence of a supplementary space is a typical situation where adaptable features are relevant.

According to Richard (2010), four strategies can be extrapolated from industries that provide individualized products:

1 Flexibility of the product

2 Flexibility of the tool

3 Multipurpose frameworks

4 Combinability

From the four strategies mentioned above, the flexibility of the product, a multipurpose framework, and combinability will contribute to the materialisation of the supplementary space, at one level or another (Richard, 2010).

6.2.1 Flexibility of the Product

Once a dwelling unit is completed by the builders, Flexibility of the Product occurs whereas one or several components allow reorganising the layout to respond to the life scenario of the occupants. These components notably include the partitions, the equipment (kitchen, washroom, etc.), the services distribution and sometimes the envelope. Product flexibility is being introduced in various factory-made partitions that are:

- Demountable: Consists of removable panels connected with notched studs;
- Movable: Responds only to a ceiling channel and can be dismantled in a single operation;
- Mobile: Consists of a series of hinges connecting lightweight panels;

Figure 6.3. Demountable wall partition office (Navarre, 2005)

6.2.2 Multi-Purpose Framework=Open Building

A multipurpose Framework is ± a skeleton built to host various options. According to Richard (2006), these options are:

- "The addition of specialized components or
- The introduction of secondary modifications on the production line." (Richard, 2006, p.83)

The multi-purpose framework is in full correspondence with the Open Building approach mentioned in chapter 4. It is equivalent to having a "SUPPORT STRUCTURE" that is open to different "INFILL" that can be adjusted at any time, depending on the requirements and resources of the occupants.

As mentioned in sub-chapter 4.2.3, the Kodan Skeleton & Infill (KSI) approach proposes a raised-floor circulation of utilities to every section of the unit from a collective service channel. Consequently, movable dividing walls can be incorporated and the position of the bathroom and kitchen can be altered, offering complete adaptability (Figure 6.4).

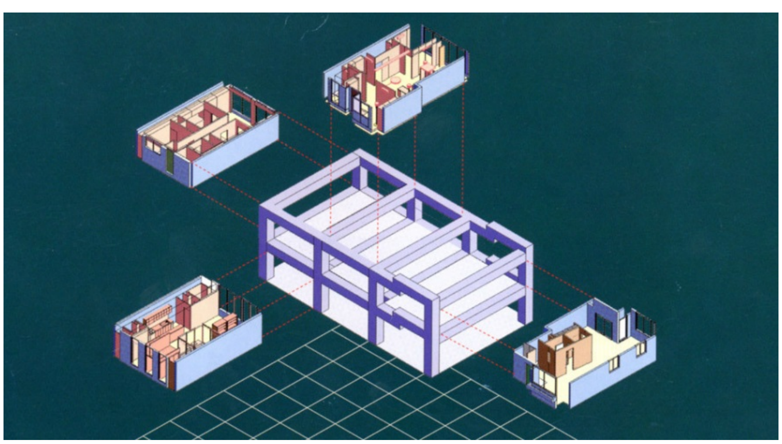

Figure 6.4. Multi-purpose framework KSI (Kodan Skeleton & Infill) (Urban Renaissance Agency 2003)

6.2.3 Combinability

Combinability occurs when a very limited number of components can generate a large number of variations. This approach is characterized by demountability. It is similar to the Meccano kit, where nuts and bolts provide the basic fixings through pre-set hole layouts that act as preconditions (Figure 6.5) (Richard, 2006).

- One example is the Meccano kit method adopted by Otto Steidle for the Munich-based Genterstrasse housing development, in which 1½-storey or split-level rooms are incorporated through each half-storey at standard column intervals in addition to a corbel.
- Another example is a composition of two typical beams, one diagonal and the other orthogonal, which can create a few columns for rooms.

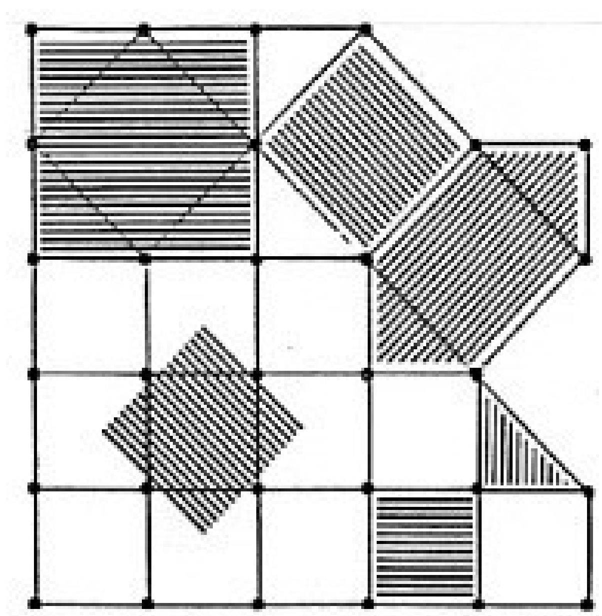

Figure 6.5. Variations generated by an orthogonal beam and a longitudinal one (Richard, 2007)

6.3 Design for Disassembly (DfD) in Buildings

Design for disassembly (DfD) is a growing concern in the manufacturing industry as greater attention is being devoted to the management of products' end of life. DfD can be applied to buildings to facilitate future change and eventual dismantlement (in whole or in part) for the recovery of systems, components, and materials. This process includes developing the assemblies, components, materials, construction techniques, and information and management systems to accomplish this goal. DfD in buildings enables flexibility, convertibility, addition, and subtraction of components, helping to avoid the demolition of entire dwellings. In his book, *Ecodesign: A Manual for Ecological Design* (2006), Ken Yang explains how the reduction of waste products has led to an increase in the demand for labour in the disassembling, arrangement, and recycling processes. This methodological approach can be described as a form of "service-and-flow economy" and entails a transformation from the use of natural resources to human resources (Yeang, 2006). Yang outlines the general concepts related to design for disassembly:

- DfD enables the manufacturer to disassemble the products easily or pull them apart to rearrange and reconfigure the raw materials. The most successful products or built systems are those that are designed with a small number of material types and whose components can be disassembled easily, rearranged, and reused. These principles form the basis for DfD (C2CNews, 2017).

- Products in the built environment should be designed to be very durable and to last long enough that there will be little or no need for disposal or replacement. In the DfD service-and-flow economy, the interest of both the manufacturer and the customer lies in establishing long-lived products while employing minimal energy and materials.

- DfD in buildings should provide features for environmental reintegration. This is done by preserving all the items manufactured by humans within the metropolitan ecosystem through the processes of recovery, recycling, and reuse. Rather than dumping these items into the natural environment, they should be constantly reused.
- According to DfD, designing a system for reuse is preferred over designing one for recycling, as the latter requires more energy. An example is the recycling of iron, which takes almost as much energy as it does to produce the iron itself.

6.3.1 Spatial Adaptability and DfD Potential

Buildings are purposely designed to last for 50-75 years. However, in most cases, the economical duration of one phase in the use of a building is less than its components' technical life span. With each new phase of building use, new requirements and spatial organisation issues arise, which necessitates building changes.

Figure 6.6 depicts the life cycle of a building with regards to sustainable design. It is dependent on repetitive sequences, from materialisation to reconfiguration and disassembly. Increased spatial adaptability is due to the greater potential of DfD and reconfiguration ability of floor plans. In simple terms, once the floor plan containing the supplementary space has greater potential of disassembly and reconfiguration, it will have higher propensity for spatial modification. Therefore, spatial adaptability is interconnected with the potential of disassembly, reconfiguration, and flexibility of physical levels (building elements and systems). The supplementary space would become more meaningful once the physical levels have potential flexibility through reuse, reconfiguration, and disassembly.

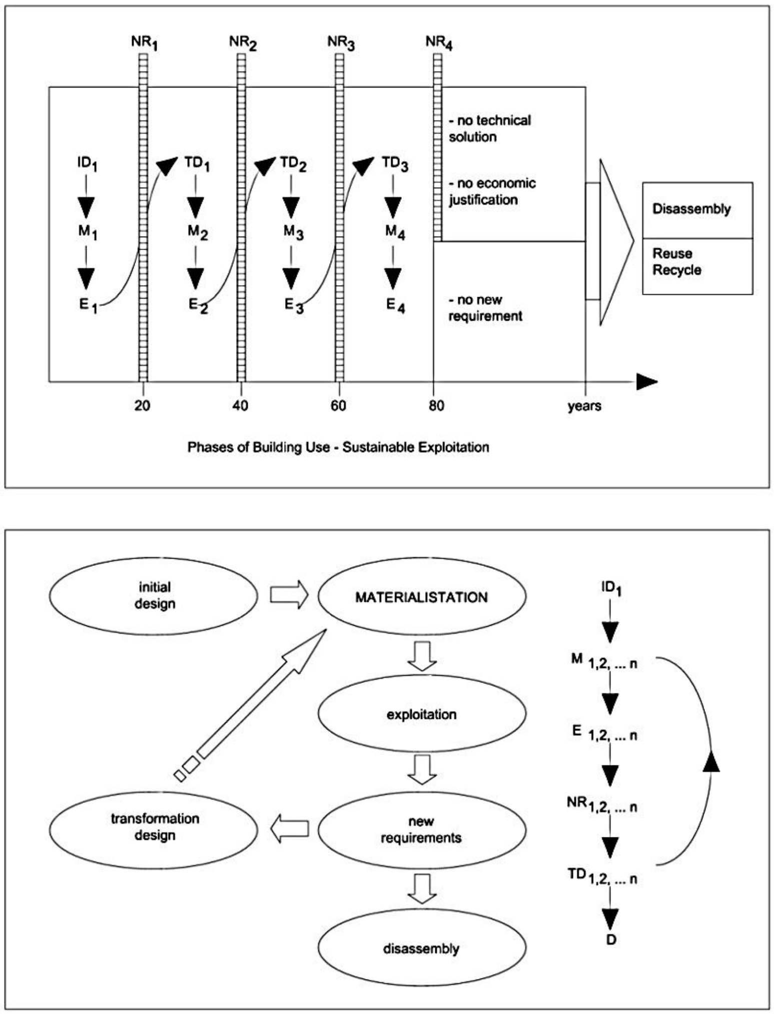

Figure 6.6. Number of sequences in building use (Durmisevic, 2006)

6.4 Supplementary Space Model for DfD

Figure 6.7 presents the hierarchical organization of building components. The proposed figure is based on the maximum flexibility of building components. The independent time level is recognized with regards to the hierarchy of building components. Supplementary space primarily depends on the mechanical and partition sub-systems, and therefore, they will be the ones that are mainly focused on in this paper. Furthermore, the fit-out and façade sub-systems are less influential.

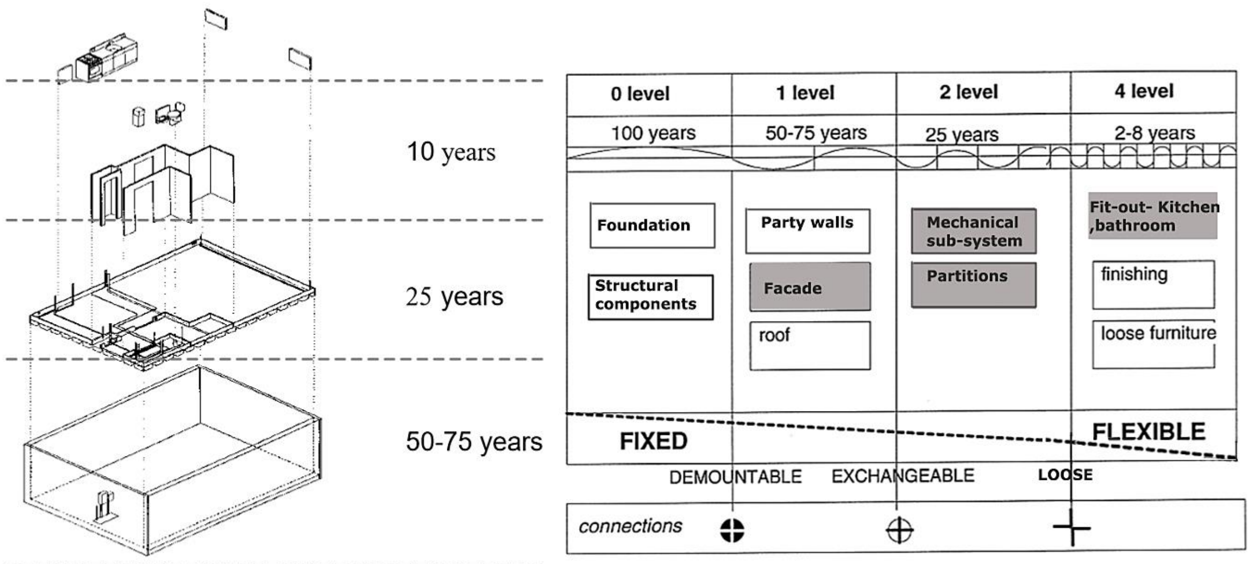

Figure 6.7. Building systems interfaces according to life cycle (after Durmisevic, 2012)

The partition and mechanical sub-systems arrangements can be modified once the change in scenario happens (change of wall locations, modifying mechanical sub-systems). When a fundamental change is required, such as relocating the kitchen to create a larger space, or the addition of a bathroom or small kitchenette in the supplementary space, it necessitates modifying the fit-out sub-system.

6.4.1 Building Components and DfD: Mechanical ("Dry") Joints to Allow for Recycling, Dismantling, and Reconfiguring

The adaptability provided by mechanical "dry joints" can be implemented at each sub-system level. Disconnecting components is a major factor in the on-site disassembly process and calls for access, readability, and simplicity in terms of the required tools and actions. The number of connections is an important determinant of whether manual labour can be used and whether transportation is affordable. While fewer components of larger size will minimize the number of connections and hence the labour to assemble a building, the flexibility of smaller components will facilitate reuse and recycling.

The application of mechanical joints (bolting, splicing, locking, etc.) versus wet joints (mortar, welding, bonding, etc.) remains a key assembly concern (Richard, 2010). Bolted connections allow for disassembly without demolition. The accessibility of connections also assists in easier disassembly (Richard, 2013)

6.5 STRUCTURE Sub-System

The Generic Models are generated based on the specific criteria of the Supplementary Space and their relationship with the dwelling unit. Notably, neutral access (circulation that is independent from that of the living room area and the bedroom areas), gradient of intimacy of the spaces, soundproofing, etc. are the more significant criteria. The same relationship applies when the Generic Models are to be materialised at the sub-system level.

First and foremost, the Structure plays an important role. Since the model represents a segment of a multi-tenant building and such buildings have parking level(s) at their base, the usual parking grid of 6.0m to 7.2m becomes a governing necessity.

There are three types of prevailing structures in Canadian multi-family buildings: point-to-point (post and beam), linear (cast-in- place walls and prefabricated panels) or volumetric (BOXES) (Richard, 2017).

1- Post & Beam, cast in situ or precast is a typical point to point structure.

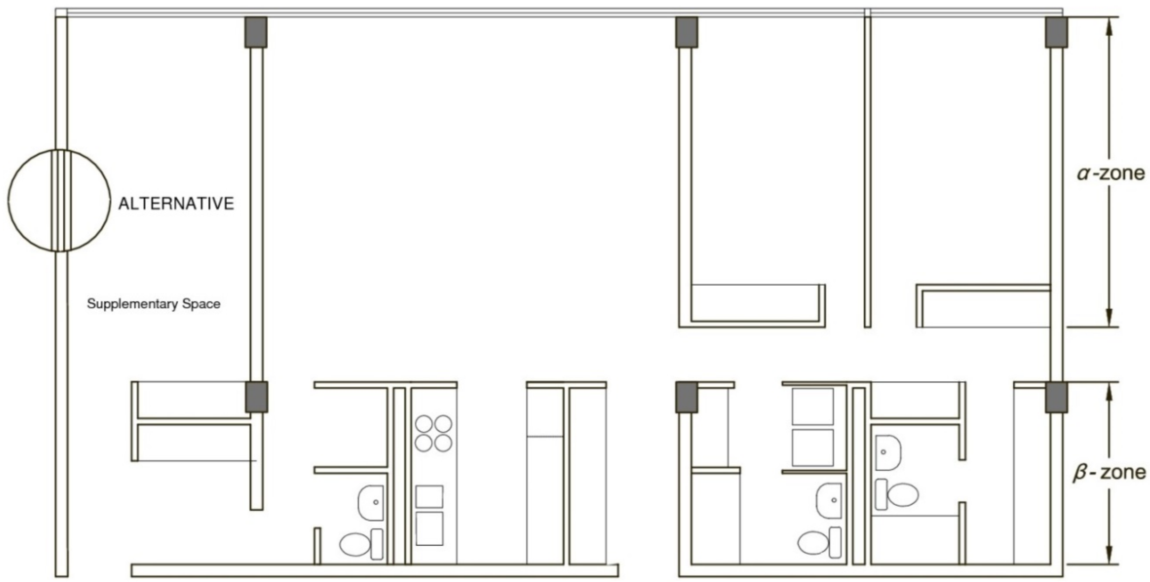

Figure 6.8. Post and beam structure in a longitudinal unit

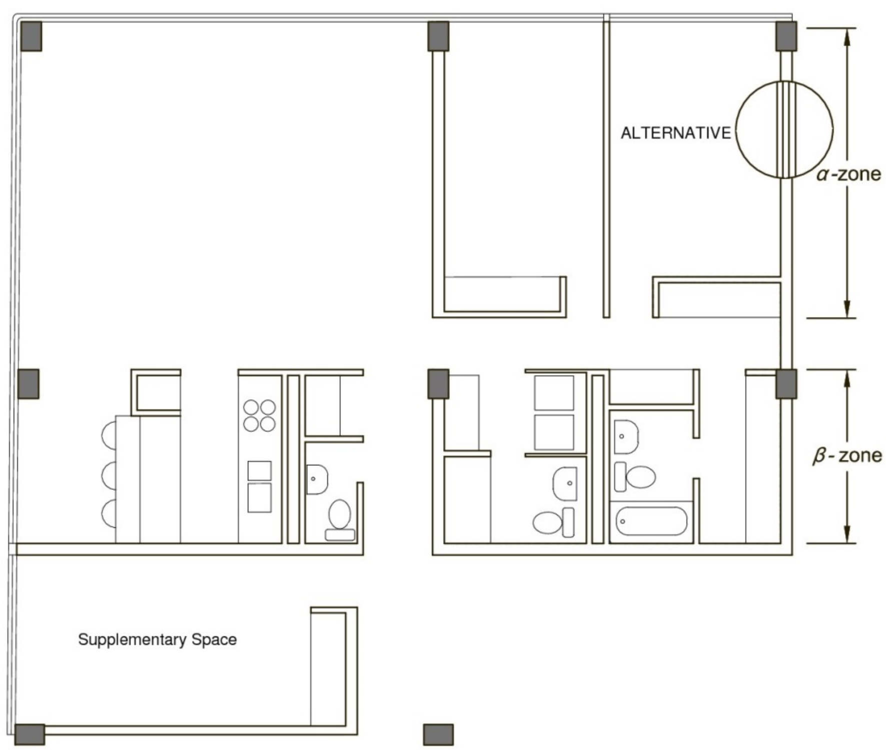

Figure 6.9. Post and beam structure in a corner unit

The same structural grid is also applicable when pre-engineered wood components are used but, for optimisation purposes, an additional component will be inserted on one axis. The alternative double-partition wall provides additional soundproofing, insulation, fire-resistance rating (FRR) and reduces thermal bridging between units.

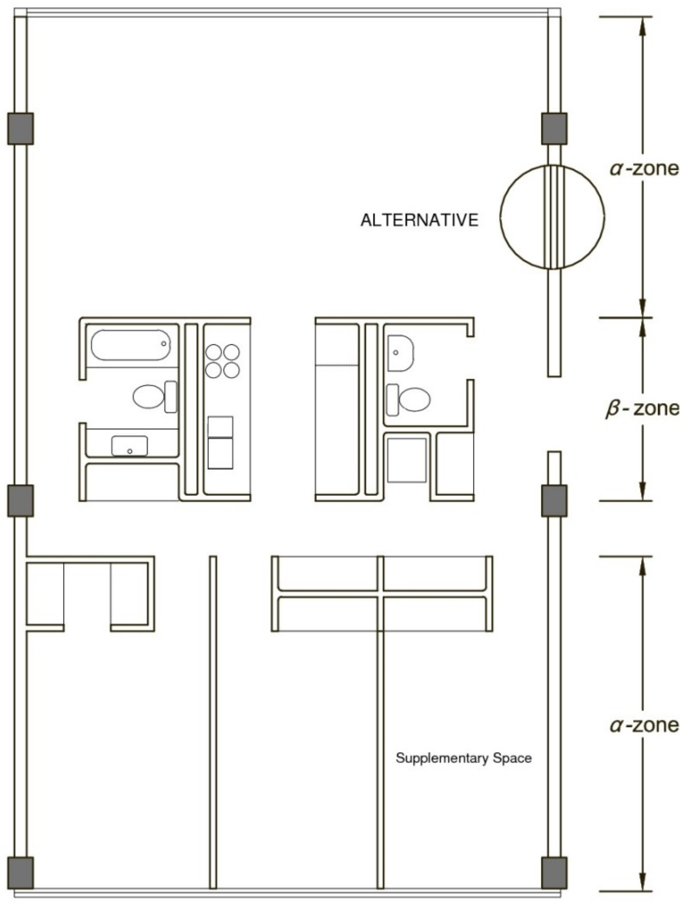

Figure 6.10. Post and beam structure in a transversal unit

2- Linear cast in situ load-bearing walls or precast concrete panels. The walls that are hatched in orange represents structural panels.

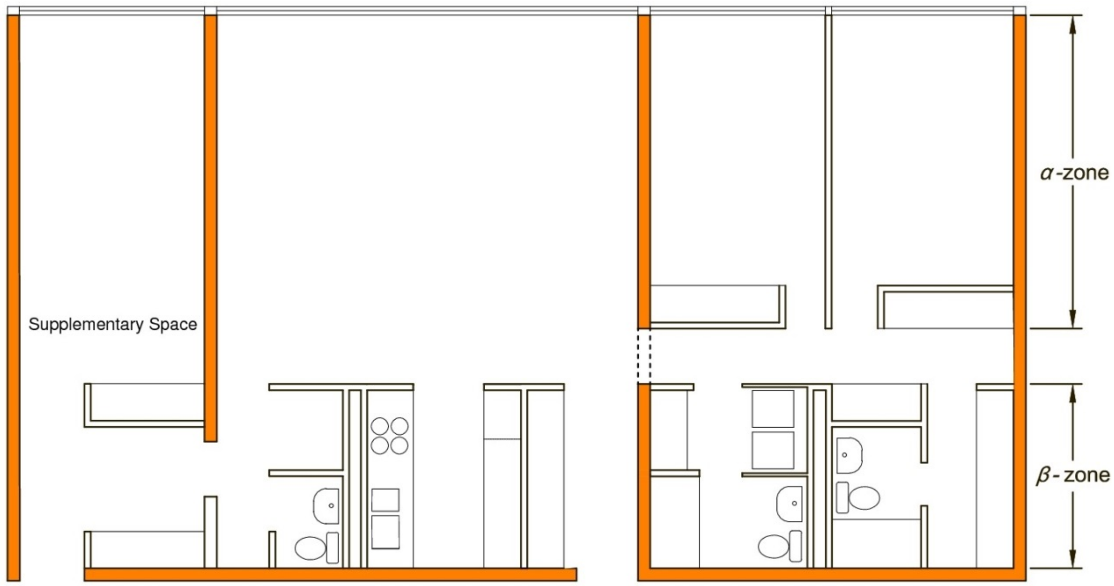

Figure 6.11. Linear structure in a longitudinal unit

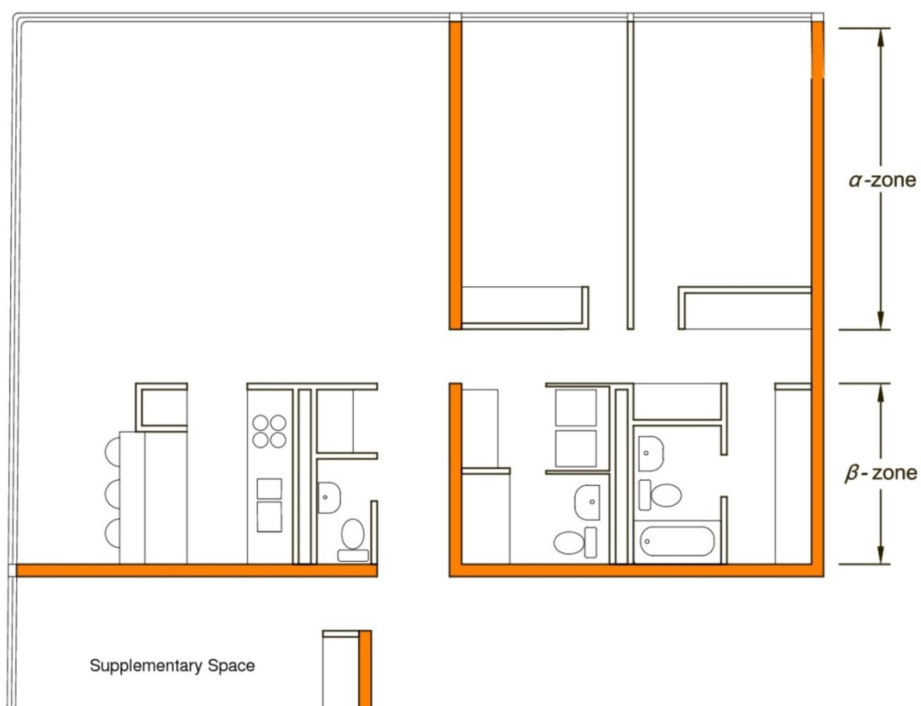

Figure 6.12. Linear structure in a corner unit

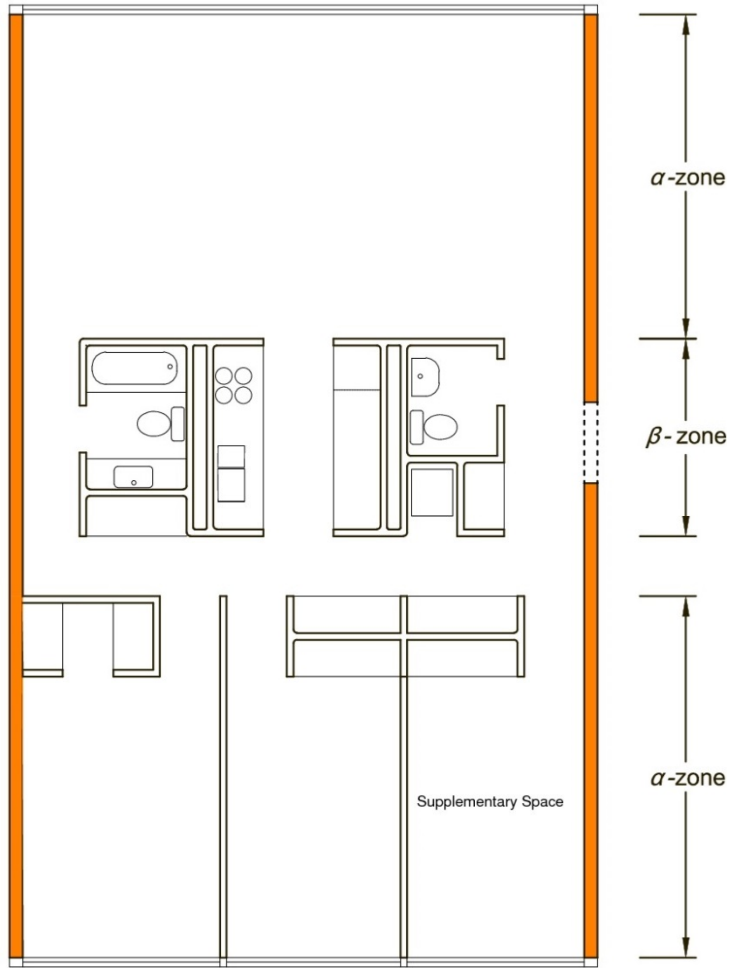

Figure 6.13. Linear structure in a transversal unit

A split-levels alternative is provided below. All the transversal units provide cross-ventilation.

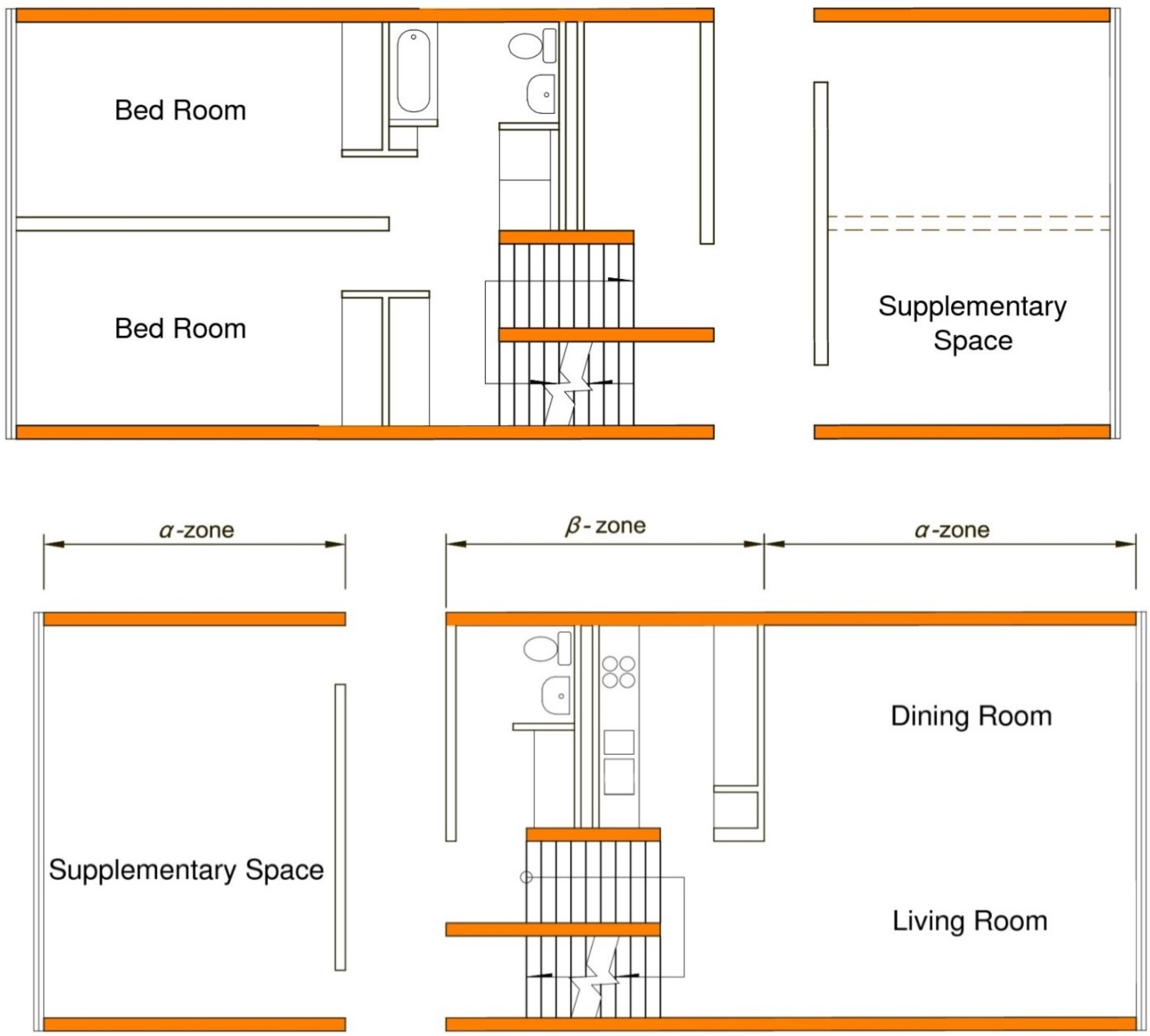

Figure 6.14. Option for a level split-level alternative

3- Hybrid volumetric & panel pre-engineered wood system. This solution combines framed volumetric service modules for the service areas and CLT panels for the living areas.

Figure 6.15. KLEIN Amsterdam School laminated wood framed modules, SeARCH

In the following figures the green hatched walls represent CLT walls, and the brown hatched walls symbolize laminated timber volumetric service modules.

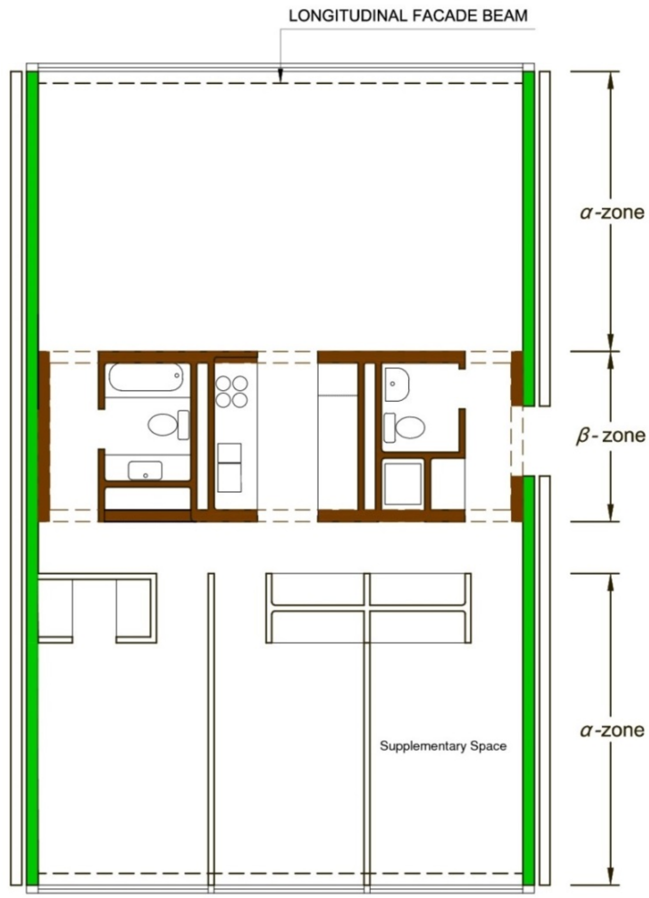

Figure 6.16 Hybrid volumetric and panel system in a transversal unit

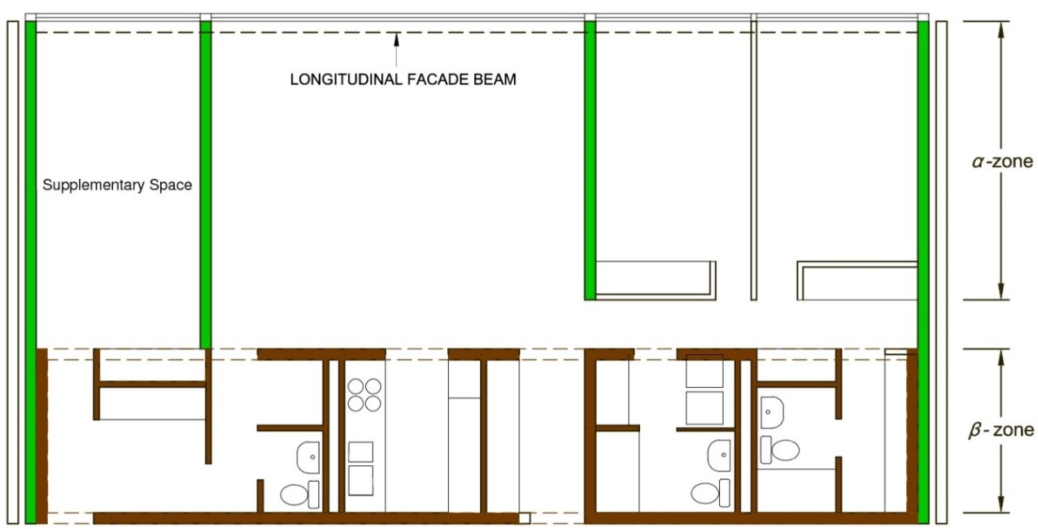

Figure 6.17. Hybrid volumetric and panel system in a longitudinal unit

Figure 6.18. Hybrid volumetric and panel system in a corner unit

6.6 ENVELOPE Sub-System

Although the supplementary space needs direct contact with the outdoors, there are no specific design requirements. However, the possibility of modifying the façade with a dry-joint curtain-wall sub-system allows for a more personalised envelope. The NEXT21 prototype has provided numerous independent physical levels to ensure greater adaptability, and has led to the development of an external envelope using movable frames that are encased in aluminium strips. To reconfigure the façade system, door or window openings can be moved or added.

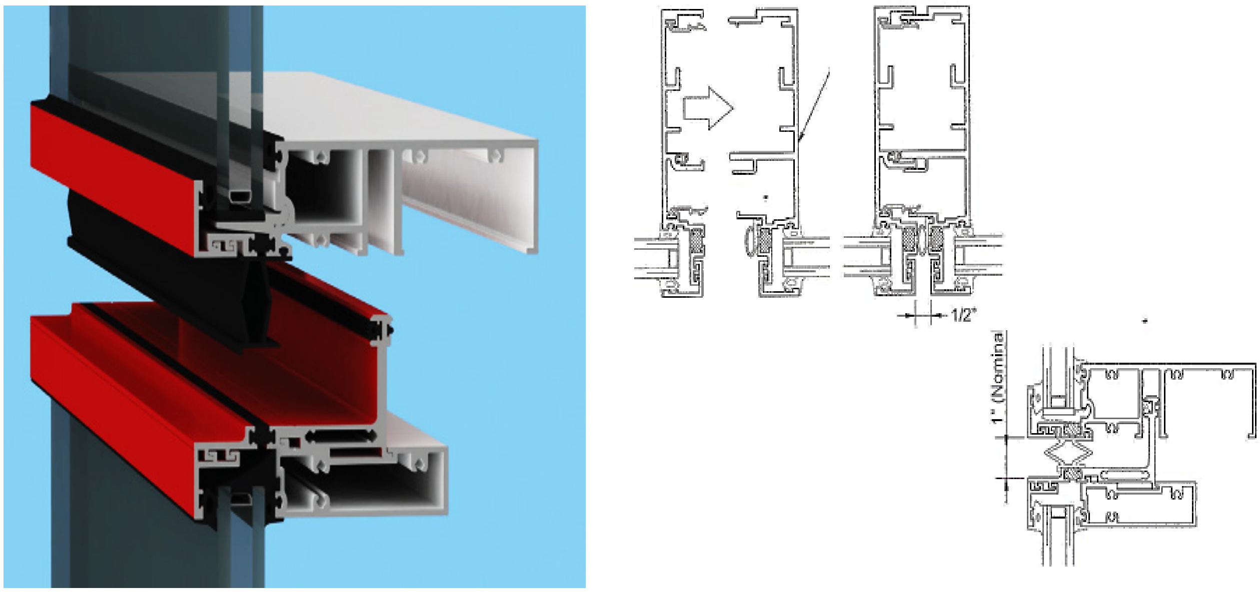

Figure 6.19. Y.K.K curtain wall dry-jointing, YKK AP Company (Laplante, Rockar, & Stegeman Jr, 1991)

In order to respond to the variable room sizes provided by the movable partitions described in sub-chapter 6.7 hereafter, corresponding mullions need to be available. That involves the series of pre-set mullions with ability to match the desired room widths or a flat, vertical curtain-wall element covering the foreseen range of widths. Otherwise, the whole panel will have to change each time a different width is needed (Richard, 2011).

6.7 PARTITION Sub-System

A few simple, easy-to-install, and movable partition sub-systems are available, especially for integrating the electrical cables that run within the baseboards of the supplementary space. When higher soundproofing performance is required, a double set of partitions will usually be sufficient.

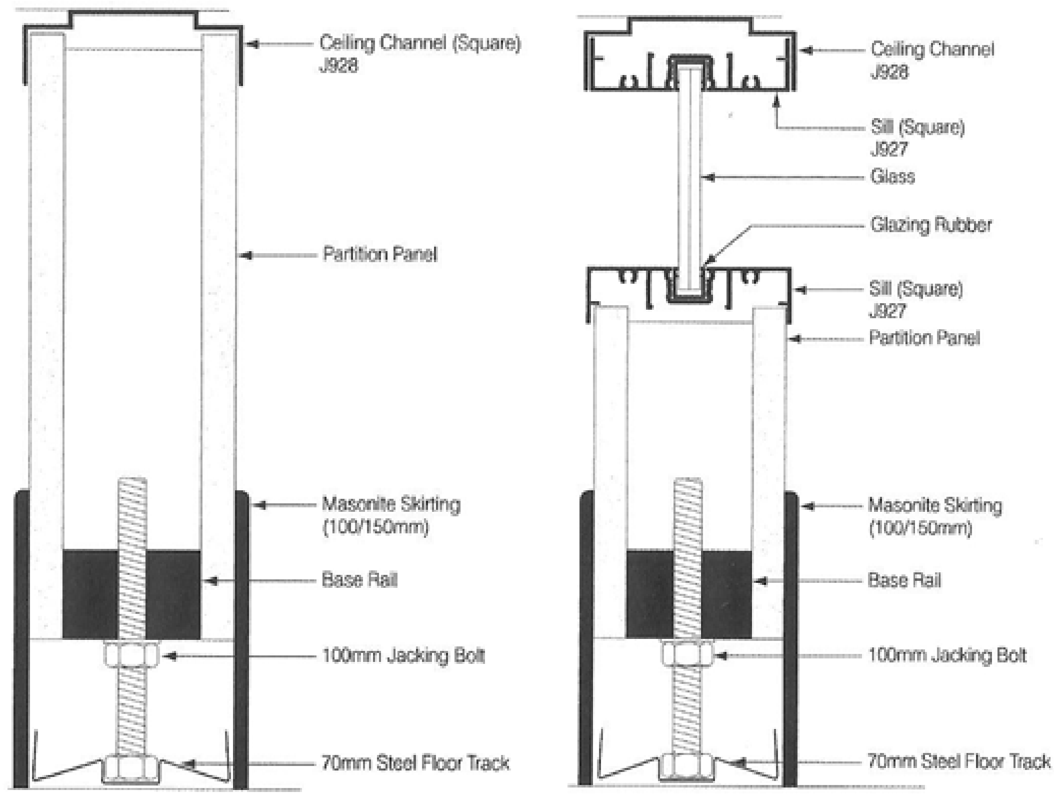

Figure 6.20 Movable partition, Clestra Hauserman approach

Movable partitions accompanied by movable closets are available to adjust the widths of both the bedrooms and the supplementary space; in a trade-off based on the needs of one another.

The options are limited when the building has a linear structure, but more options are available when a post & beam structure is offered.

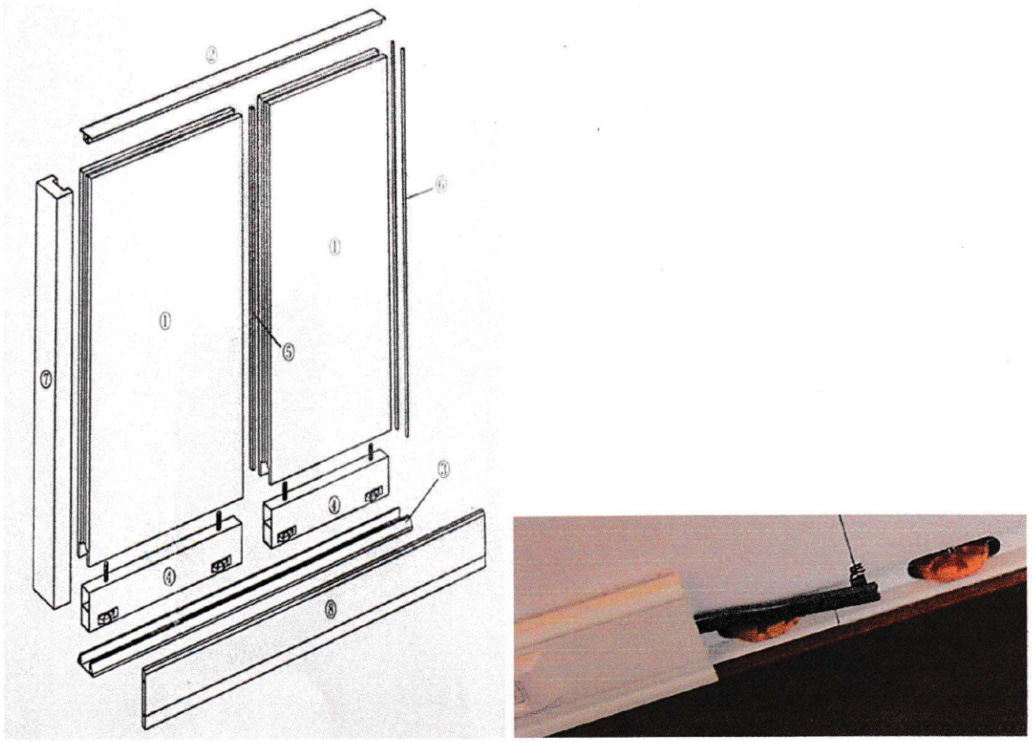

Figure 6.21. KSI movable partitions

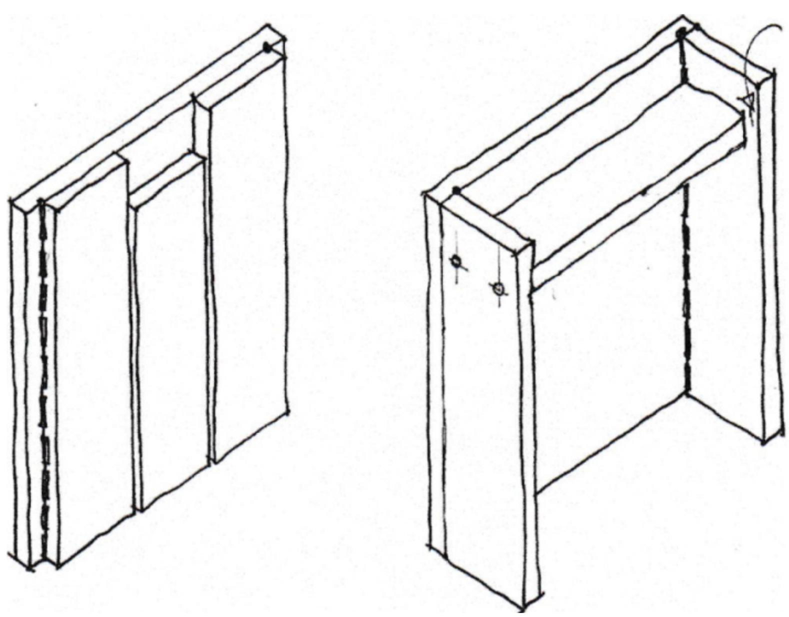

Figure 6.22. Movable closet concepts to go along the movable partitions (Richard, 1990)

Figure 6.23. Movable walls and closet in a longitudinal unit

Figure 6.24. Movable walls and closet in a corner unit

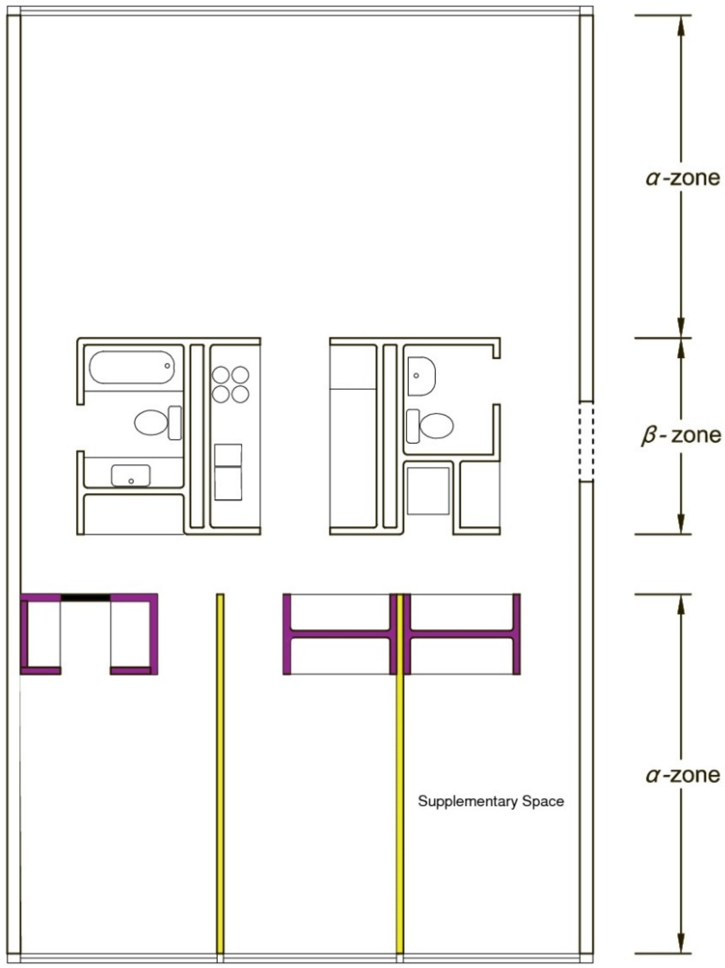

Figure 6.25. Movable walls and closet in a hybrid volumetric transversal unit

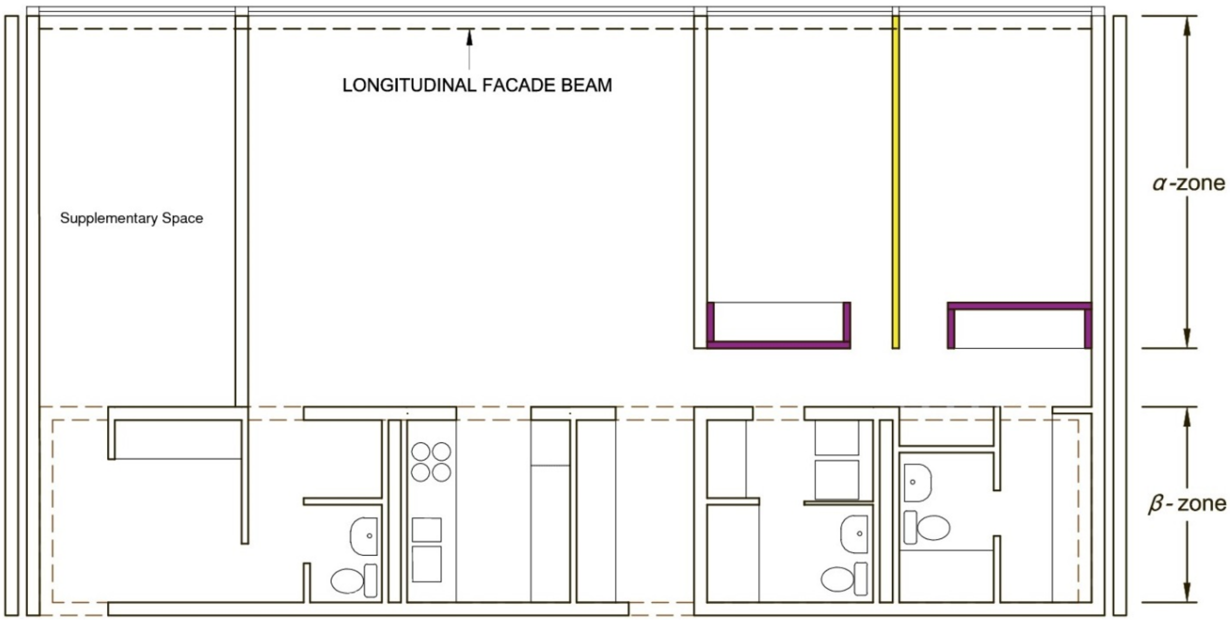

Figure 6.26. Movable walls and closet in a hybrid volumetric longitudinal unit

6.8 MECHANICAL SERVICES Sub-System

The position of the service spaces and cores are a determinant for the configuration of DfD. Service units can be governed by the structural system or they can be designed separately. They comprise of "access units" on the scale of both the building and the apartment, and they are the infrastructure that determines the location of "wet spaces" (Kendall, 2017).

6.8.1 Vertical Distribution

The traditional vertical distribution of services through a shaft is an inflexible element, as far as its location concerned. However, it could be entirely assembled in a factory, ready to be installed on the site and to serve the plumbing units.

Besides the conduits, the vertical shaft could integrate double water heating coils, which take less space than a tank, and need energy only when hot water is required (Juan & Cheng, 2018).

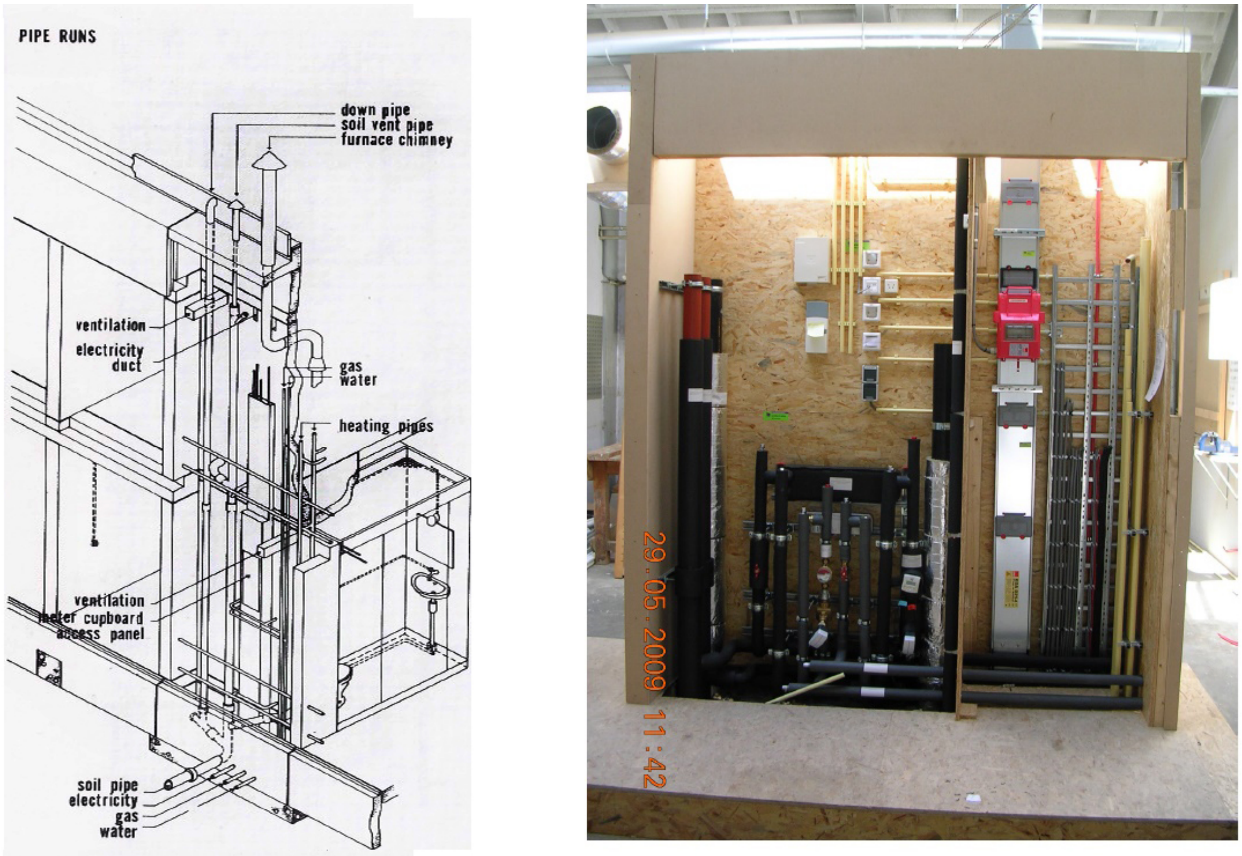

Figure 6.27. Plumbing shaft, common parts of vertical distribution (Kendall, 2017)

The vertical plumbing shaft can be designed to accommodate different geometries and functions: an entire kitchen and bathroom placed back-to-back in a compact arrangement or perpendicular bathrooms/powder room/washer dryer, as illustrated in the generic longitudinal model.

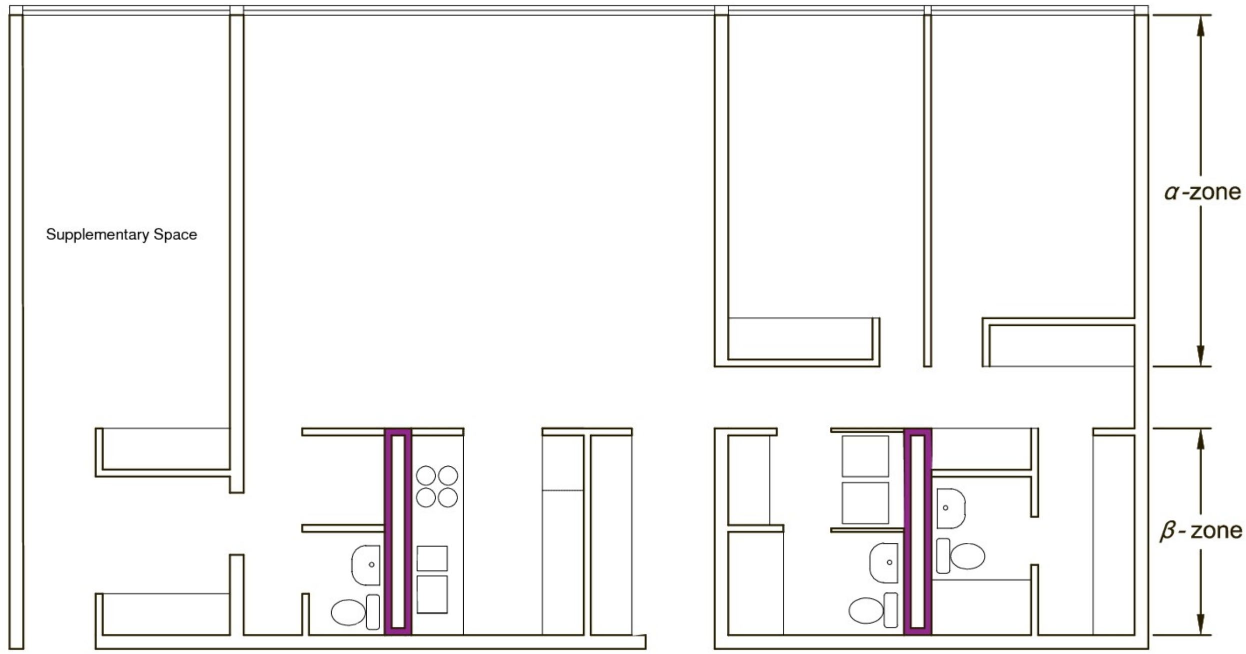

Figure 6.28. Different functions served by the vertical plumbing shaft in the generic longitudinal model

6.8.2 Horizontal Distribution (Raised Floor)

One of the techniques that has been effective in flexible projects is distributing services horizontally (Kendall & Teicher, 2010). In this method, the floor is raised, and pipes, wires, and ducts are placed beneath it, providing the potential to easily change the location of the kitchen and bathrooms. In this scenario, a supplementary space could be facilitated as the services are movable.

Figure 6.29. Kikou SUPPORT & INFILL (KSI), raised floor

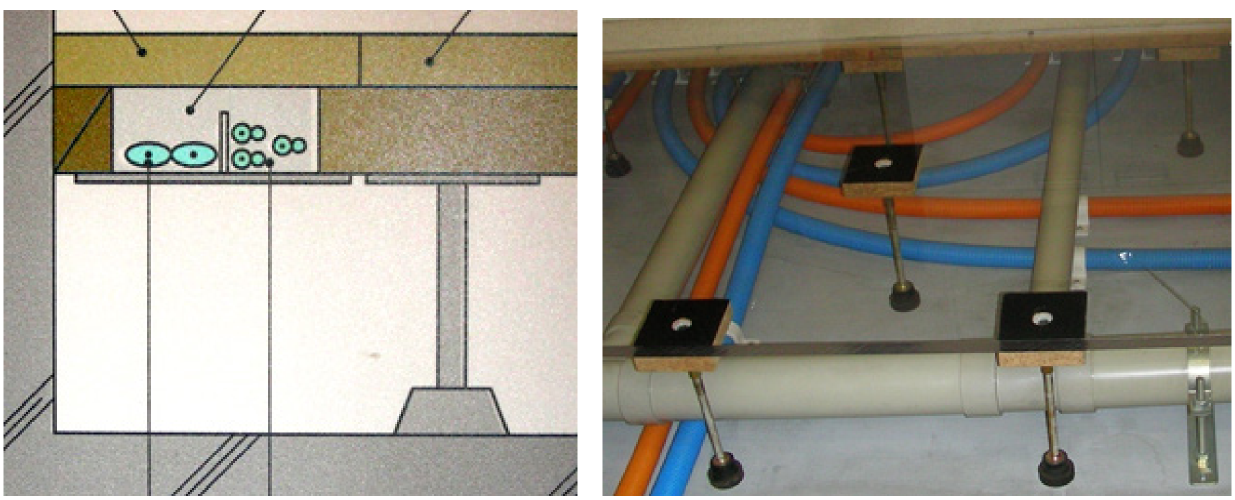

Figure 6.30. Kodan SUPPORT & INFILL (KSI), raised floor components, Tokyo, Japan

The matrix tile system (Figure 6.31) is made from medium-density polystyrene and applied on top of the SUPPORT (base building), with the tile thickness being 4 inches. Matrix tile systems provide rapid piping installation that allows for a variety of floor plan alternatives. The “tile” is covered with a one inch fireproof floor layer. The lines, conduits, services, hot and cold water, floor heating, and gas pipes are distributed horizontally within it (Li, Li, & Li, 2019).

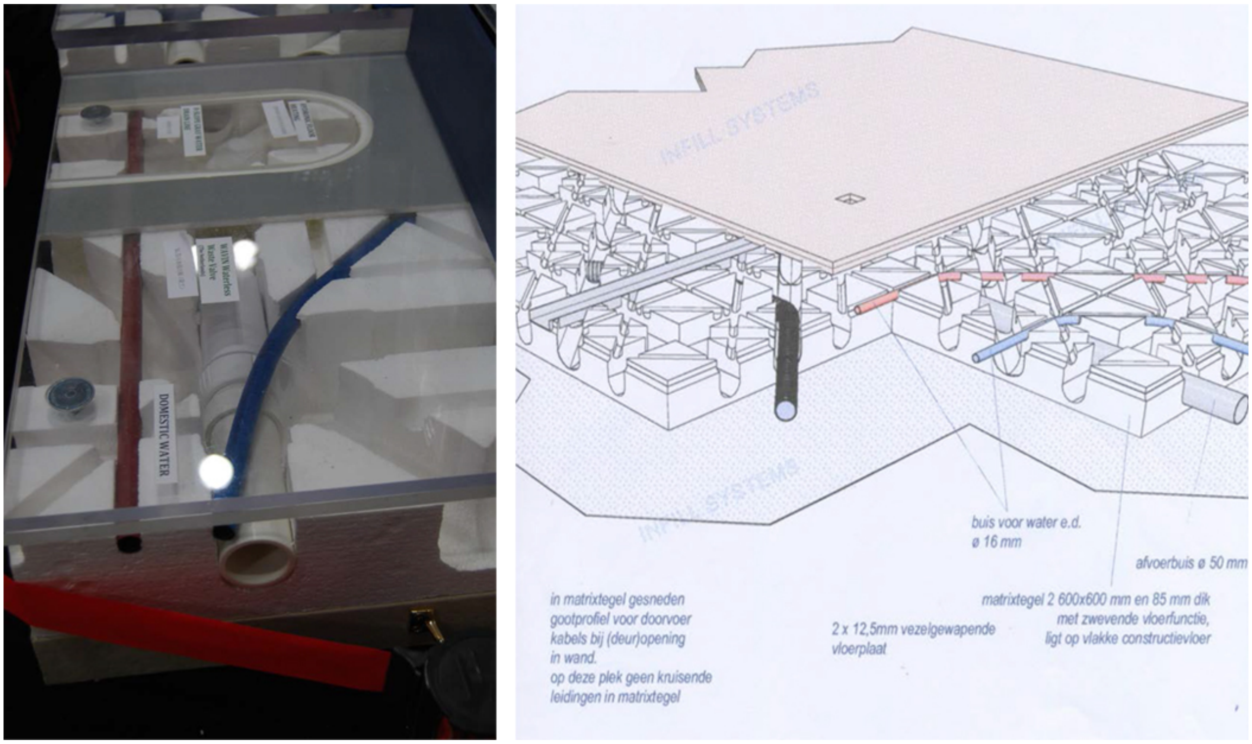

Figure 6.31. Matrix tile system (horizontal distribution to units) (Li et al., 2019)

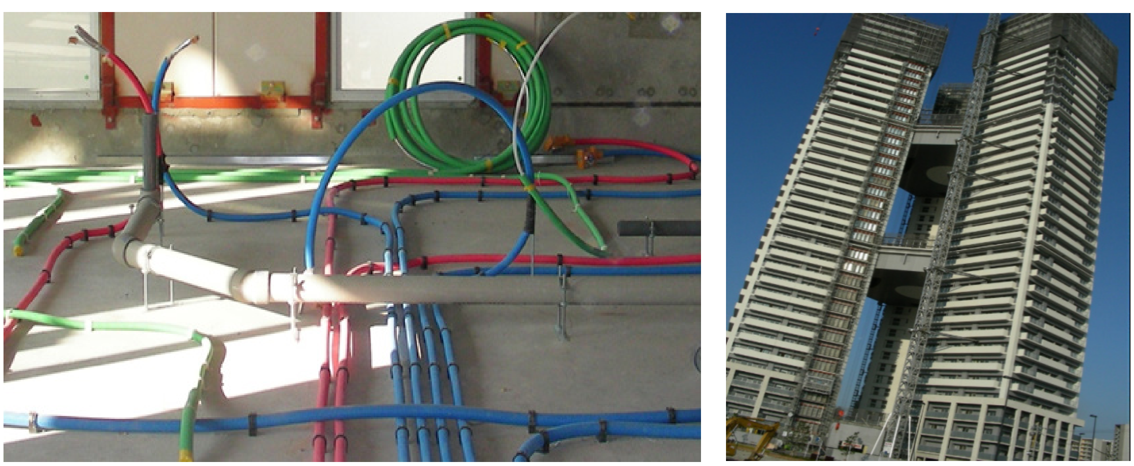

Figure 6.32. KSI application at Fukuoka Island Tower, Japan, 200

As demonstrated in NEXT21 prototype, the horizontal distribution will enter the dwelling unit from the collective circulation zone and will be limited to the « β » zone once inside (Figure 6.33 & 6.34). Therefore, a lower structure in the « β » zone will allow for the raised floor to level with the « α » zones. Depending on the type of structure, the lower part could allow for a drop-ceiling in the unit below. One of the other key advantageous of this horizontal distribution is to avoid floor-to-floor noise often carried with vertical mechanical shaft.

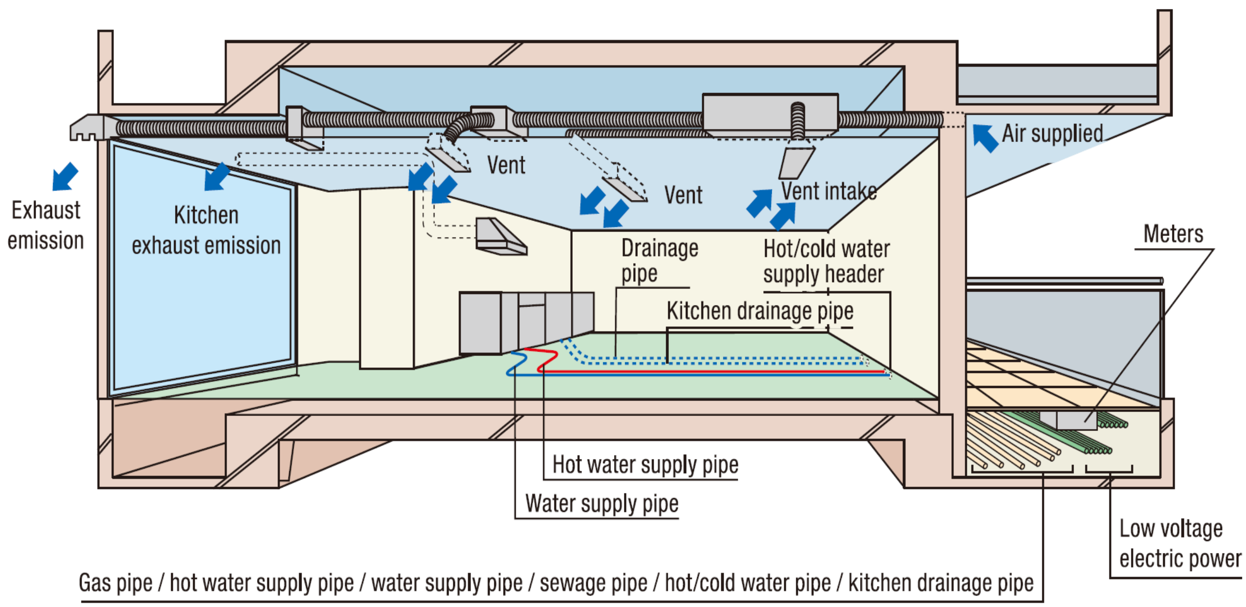

Figure 6.33. Adaptable services at NEXT21 (Osaka Gas, 2013b)

Figure 6.34. Horizontal distribution along the corridor (NEXT21) (Osaka Gas, 2013b)

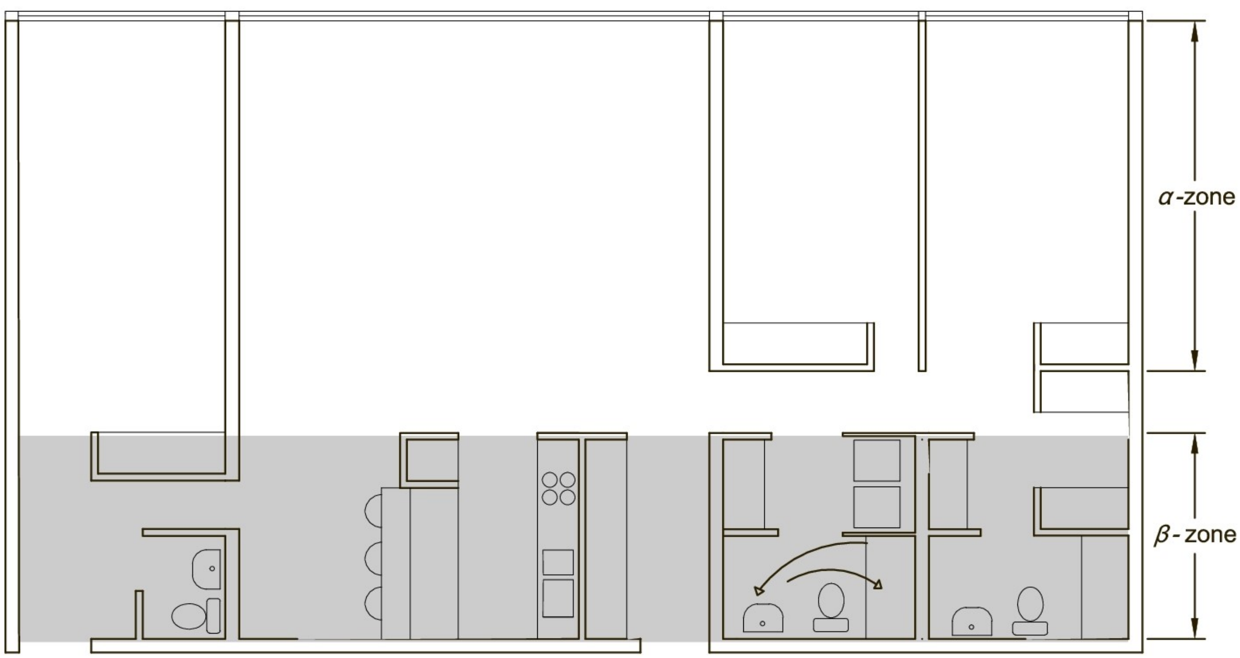

Figure 6.35. Horizontal distribution of services in the generic longitudinal model

6.9 EQUIPMENT Sub-System

The location of the service pods influences where the supplementary space will be placed in the floor plan (Albostan, 2009). Because the kitchen and bathroom are the most fixed elements in the unit, their position is a key element of the design process.

These pods have two main advantages:

a) They are fully factory-finished, and incorporate all the plumbing conduits and fixtures;

b) They are lightweight and therefore easy to handle whenever any layout modification is required, especially when the services are distributed off a raised floor.

In combination with the movable closets described in sub-chapter 6.6, the pods offer several adaptability options in the « β » zone.

Figure 6.36. Integration of services pods in the " β "' zone of the longitudinal generic model

Factory-made bathrooms and kitchens are not new phenomenon, as the idea was originally proposed by Buckminster Fuller (Figure 6.36). Other factory-made bathroom and kitchens module options are available in the market which can be used in any unit with supplementary space (Figures 6.37 & 6.38).

Figure 6.37. Dymaxion bathroom, R. Buckminster Fuller (Brennan, 2017)

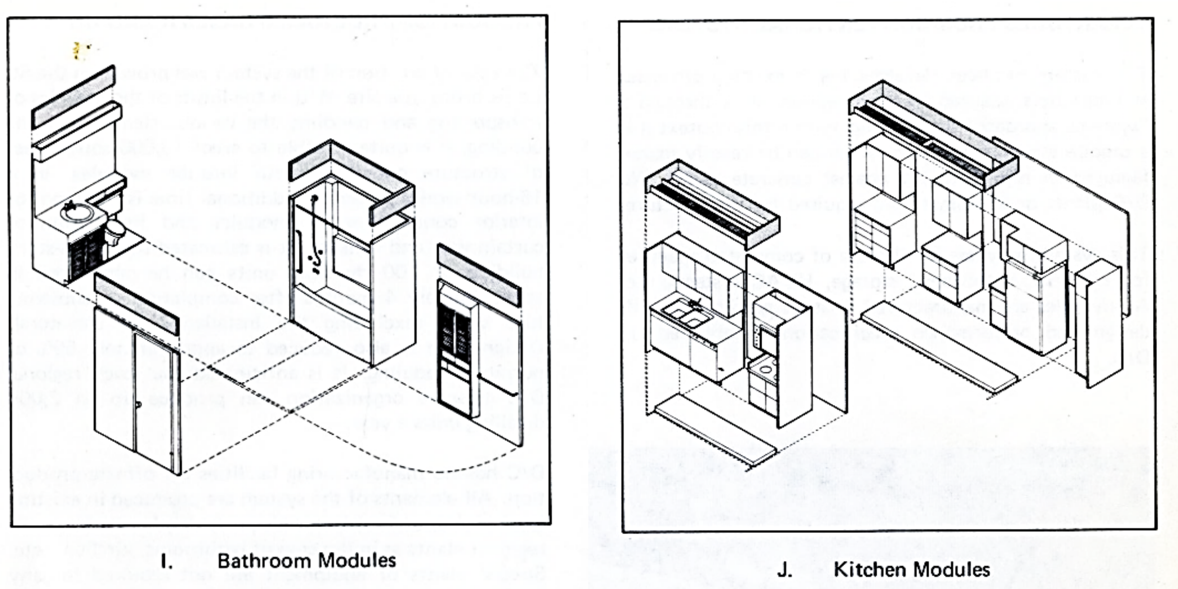

Figure 6.38. Descon system bathroom and kitchen module

Figure 6.39. Parmarine bathroom module

One of the advantages of such modules is the possibility of offering a powder room that is connected to the supplementary space as well as the potential of moving the bathroom in the future.

6.10 Conclusion

The simulation of the following sub-systems technologies was successfully applied to materialise the three supplementsry space generic models.

- Structure: post and beam (skeleton), continuous wall (out of panels or boxes) and hybrid.
- Envelope sub-systems: curtain walls.

- Partition: movable partitions or closets.

- Mechanical: vertical shaft or horizontal distribution (i.e. raised floor).

- Service sub-systems: service pods.

7 Conclusion

The six previous chapters have elaborated a series of research highlights contributing to theory and practice as well as announcing future studies related to the emerging needs in housing. The contributions to theory and practice shows how the deductive design approach can be used to generate both theoretical and practical guidelines, not only for the challenges of working from home but also for other housing issues. Furthermore, the resulting models can be used not only by professionals during the initial design of housing, but also by future occupants to alter their dwelling based on their shifting needs. The future studies section elaborates on other research that can be conducted in the future in the realm of this research.

7.1 Research Highlights

The issue of change in housing is the main theme in this research. The shifting demographics, life cycles and lifestyles are creating a demand for alternatives to conventional housing design in order to respond to the emerging needs.

Emerging needs in housing appear basically require new spaces which have different characteristics from the traditional spaces in the home (e.g. living room, bedrooms, and service areas). Emerging needs involve different scenarios, such as working from home, adult children or elderly parents moving back home, the arrival of a live-in nanny, or a member of the household needing full-time healthcare. Such a space exists in single-detached housing (primarily the basement). Therefore, the research focused on multi-family buildings. The study argued that incorporating emerging needs in the early design stages would extend the lifespan of the household and delay obsolescence of the building. The early stages in the design process are when the costs of introducing adaptability are the lowest and the influence of design efforts is the greatest.

According to various research and surveys in the North American context, a separate room can be used as an office and for other future emerging needs. This new entity is called "supplementary space" and its purpose is to accommodate emerging needs. Such spaces must be distinct and preferably independent from the rest of the household. Actually, certain housing projects have unintentionally deployed supplementary space in their designs.

The focus of this thesis is on the characteristics of the supplementary spaces in multi-family housing. The supplementary spaces can be modified to address different scenarios based on the occupants' future spatial needs. Among those scenarios, working from home is one of the most common and most demanding. More than 80 condominium projects in the city of Montreal were assessed and only 3% offered some kind of supplementary spaces.

Research through Design (RtD) was used as the methodology for this research. Accordingly, the design question proposed: how can supplementary space be incorporated at an early design stage in multi-family housing? This led to the following research question: what is a possible theoretical model for supplementary space? The answer is a generic model in the form of floor plan guidelines, incorporating a Design for Deconstruction (DfD) approach. To identify the relevant criteria, this study applies the system approach, a deductive methodology starting from existing knowledge and using it to generate the new knowledge meeting the objective pursued.

When dealing with uncertainty related to the future needs of a household (as is the case when considering supplementary space), scenario design is a technique for forecasting different potential future uses. for a product. Due to its importance, notably enhanced by governmental policies related to the COVID-19 pandemic, the basic scenario chosen for designing the supplementary space in this study is the need to work from home. Once the scenario is specified, the stakeholders of the system must be identified. The stakeholders involved in the supplementary space for working from home are as follows:

- The user of the supplementary space (direct)
- The other residents of the household (direct)
- Visitors to the supplementary space (indirect)

The research looked into the criteria for working from home, based on the above stakeholders. The ten criteria deduced, based on the criteria sources, are as follows: housing types, acoustics comfort, thermal comfort, provisions of growth, dwelling unit zones, natural light, dimensional comfort, spatial and visual privacy, entrance neutral access, and air quality.

When dealing with uncertainty in the household, “adaptability” becomes a solution. An adaptable dwelling unit can accommodate changes throughout its life cycle and as a result, delays its obsolescence. The most relevant theories and principles of adaptability are based on the Open Building approach developed by Niklas John Habraken. He identified the role of users as active participants in the housing design process. As such, he proposed the principle of SUPPORTS and INFILLS. The lifespan of an INFILL is 10 to 20 years, while the lifespan of a SUPPORT is over 100 years.

In simple terms, generic models for supplementary space must be materialized within flexible building components. There are five sub-systems within a building: STRUCTURE, SERVICES, EQUIPMENT, PARTITIONS, and ENVELOPE. Design for disassembly (DfD) facilitates future changes and eventual dismantling of a building, and is increasing in popularity. In the materialization of the supplementary space, different Open Building principles and industrialised building systems are incorporated, mainly at the Services, Partitions and Equipment levels.

The implementation of the above mentioned criteria (in particular neutral access and spatial/visual privacy) did govern the integration of the supplementary space in the following generic models (Figures 5.14, 5.15 and 5.16):

- In a single-orientation unit;

- In a perpendicular unit;
- In a transversal unit.

7.2 Contributions to Theory and Practice

7.2.1 Lifestyle Changes and the Notion of Emerging Needs in Housing

Underpinning this research are the socio-economic and lifestyle changes in the household that have occurred since the 1960s. It is important to note that emerging needs are imposed not only by internal family factors (such as the co-residence of parents), but also by external factors such as COVID-19, which forced people to work from home. Therefore, the emerging needs will become more common in the future and these changes are bound to be reflected in the household.

7.2.2 Research through Design as Methodology Dealing with Practical Design Problems

Conventional research methodologies (quantitative and qualitative) are sometimes incapable of responding to design questions where the outcome has both theoretical and practical components. In these cases, part of the research answer is envisioned within the design process itself. These questions cannot be resolved only with deductive or inductive research methods; rather, the designer's expertise and talent will play a role in reaching the answer. This thesis uses the research through design (RtD) approach. The objective of RtD is not to design a building, but to gain knowledge of various possible design outcomes.

7.2.3 Scenario Planning in the Scope of Housing

RtD is dealing with the problem of predicting needs in uncertain conditions. As such, it requires methodological support of scenario planning to forecast uncertain future. To address future uncertainty in housing, scenario planning can be utilized to create a context for research. In this thesis, various scenarios were predicted for the supplementary space, including a home office, a teenager's bedroom, and a co-residence for older parents. New scenarios may arise in the future based on emerging housing demands. The scenario chosen for this research was working from home, which has become an important phenomenon in the past decade. With the emergence of COVID-19, up to 30% of employees are now working from home, emphasizing the relevance of having access to a supplementary space for this purpose. Once the scenario is built to accommodate the stakeholders, the key criteria can be extracted as it is the case with the 10 criteria indicated hereabove.

7.2.4 From the Knowledge Model to the Generic Model

The thesis synthesized the criteria to achieve the objective and allow for options in the floor plan design. The outcome resulted in a knowledge model that systematically integrated the criteria and options, which was then used to create a set of three generic models acting as practical guidelines for the home-office scenario.

7.2.5 User Engagement in the Model

The scenario behind the generic models is dynamic and can change throughout the life of the occupant, so that the space now used for work may become a co-residence for parents or teenagers. Different parts of the research, such as creating scenarios, generating knowledge models, etc., can be **involving the user**. The user's ability to play an **active role** in creating his/her future space is integral to the Open Building approach. User engagement in refining the supplementary space is an important feature of the model. The designer has an initial role, mainly in drafting the floor plans in the early design stage, but the rest of the work can be done by the user.

When the Open Building approach applied, the SUPPORT part of the supplementary space is intact, the user can govern the implementation based on his/her needs without the designer's involvement. This means, as long as the position of the structural and common mechanical elements (such as columns or vertical mechanical shafts) of building are not changed, the INFILL can be adjusted by the user. For example, when converting a home office into a parental co-residence unit, the user can govern the lighting arrangements or interior partitions independently.

7.2.6 Contributions to Design Practice

The three generic models proposed in this research (single orientation, perpendicular orientation and transversal) were initially created for the scenario of a home office and their purpose is to serve as guidelines which the designer could use in the early planning stages. Once the supplementary space is designed as a home office, it can easily be adapted to accommodate the other emerging needs.

7.2.7 From Spatial Adaptability to Technical Flexibility

Spatial adaptability can be envisioned through technical modifications, as changes in space can be linked with a building's physical components. Accomodating change can be challenging when the physical components are programmed for a specific purpose and are not intended to be changed. Hence, the design should contemplate the adaptability of the physical components. This is considered a critical aspect of sustainable design.

Industrialized sub-systems and components that allow for disassembly, reuse, and recycling are available to facilitate spatial adaptability, leading to sustainable building construction. The technical flexibility of physical components and spatial adaptability are intrinsically linked and cannot be separated. This means that changes will affect the building's physical components and vice versa.

This study focused on designing supplementary space as the tip of the iceberg. Emerging needs are already a necessity in housing. However, the nature of emerging needs will change with time; as demographics, lifestyles, and life cycles change. Therefore, complete adaptability in housing must be demonstrated to deal with new demands appearing in housing. As mentioned in chapter 6, the application of the Design for Disassembly (DfD) approach allows for complete adaptability in architecture and housing.

7.3 Future Studies

The potential of future studies could be addressed at four levels:

1- **Replication of research sequence:** the sequence of research applied in this thesis could be replicated to deal with other issues in multi-family housing. Once there is more than one stakeholder and the goal is to meet specific objectives, the process is pertinent. Design problems in the built environment can follow the same deductive process to propose a generic model reaching a similar objective.

2- **Proposing other emerging needs:** the same model can be used for other emerging needs in housing. For instance, in the case of co-residence, the research objective remains the same (supplementary space), but a new set of criteria and a generic model could be generated. Such a model could be used for future unknown scenarios affecting our lives in the future. Today there is COVID-19, tomorrow there may be something else.

3- **Generating user's guidelines:** out of this thesis, a series of guidelines can be created for the user (in an Infill user's manual fashion) to customize the components of the supplementary space; including technical issues such as wall customization, lighting customization and HVAC adjustments.

4- **Application of "design research" methodology in housing research:** most housing research on economic factors and the environment uses quantitative methodologies. On the other hand, in most scholarship on the quality and social aspects of space, qualitative methods are the norm. A third approach would focus on the "design research" methodology in housing. Such a methodology is definitively distinct from the quantitative and qualitative methodologies regularly used in the social and natural sciences.

In the meantime, the generic models proposed herewith are available as guidelines in the early design stage of multi-family housing: that is their ultimate goal.

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