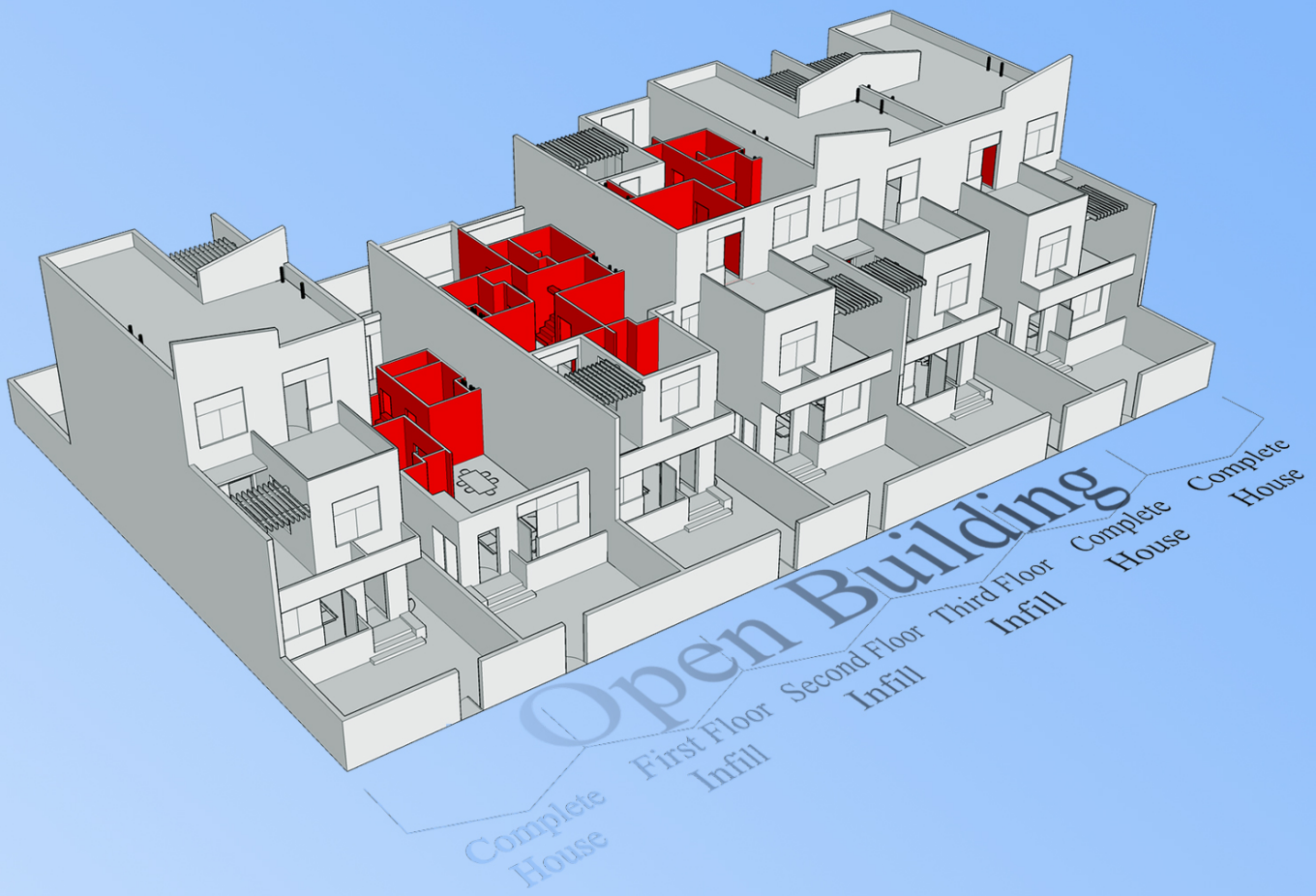
MASTER OF ARCHITECTURE THESIS

OPPORTUNITIES FOR OPEN BUILDING TO SUPPORT CHINA'S URBAN HOUSING PRODUCTION OPERATING ON A MARKET MODEL



ZHONG HONG

BALL STATE UNIVERSITY MUNCIE, INDIANA

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ABSTRACT

THESIS: Opportunities for Open Building to Support China's Urban Housing Production Operating on a Market Model

STUDENT: Zhong Hong

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As China's economy continues to grow, the problem of meeting urban residents' diverse housing requirements has become more and more important for government, housing developers, and architects. In western countries, especially in European countries and Japan, the "open building" concept is increasingly recognized as an alternative to the conventional approach in the housing sector, and many projects have been built. This thesis asks whether changing the housing process in the market-based urban housing production system in China can provide new and profitable opportunities for those business types which already set the stage for open building implementation in selected parts of the Chinese urban housing market.

The thesis first studies China's urban housing development history and the current housing market. The changing roles of housing consumers and the characteristics of the market-based urban housing production system indicate that the open building process might be useful at least in some parts of the Chinese housing market.

The second focus of this thesis is a study of a townhouse, one of four popular housing types in China. A townhouse in the market is chosen as a reference to demonstrate the principles of the open building process, showing the design and technical possibilities for this method in that context.

The third focus is the study of an existing decoration company with successful experience in residential projects and an attempt to show that the open building approach is a possible outgrowth of an already operating process.

In conclusion, the thesis seeks to demonstrate that open building will not only benefit companies and housing consumers in China's urban housing sector, but also promote the development of sustainability in the residential sector.

CONTENTS

Chapter I

Introduction

I – 1: The motivation for this thesis

The motivation to examine the relevance of open building for part of the Chinese housing market comes from more than eight years' professional experience in design firms in China, and the experience as a graduate assistant in Building Futures Institute. Studying the basic principles of open building in relation to the US market, and reading about the application of these principles in other countries have led to questions regarding their applicability to the current huge housing market in China. The thesis asks whether changing the housing process in the market-based urban housing production system in China can provide new and profitable opportunities for those business types that already set the stage for open building implementation in selected parts of the Chinese urban housing market.

I – 2: Multiple family types and dynamic living styles in China

Affected by western culture, the traditional three-generation-living-together family type in the old days has been gradually changing to different types. It has become

popular for people not to live with their parents. The emergence of small size families pushes the society to build more housing with different types to accommodate them, and gives housing developers and architects new tasks.

As technology developed and people's living standard increased, housing conditions become an important part of people's living quality, and more and more people like to give their houses a new face every few years. One of the problems in current approaches to housing and planning is how to let people have satisfactory living environments over time. This has been studied for many years and many measures have been implemented. For example, in the first half of the 1990s, *anju* projects (economical housing projects) provided housing for low-income urban employees such as teachers who were waiting for housing. But it only solved the housing problem temporarily because those buildings were designed to meet the strict criteria of matching the building floor area, which those residents originally had in their old houses. Housing developers often asked architects to change the floor plan for the accuracy of the unit building area (the accuracy was usually within +/- 1 m^2), and therefore, some very poor unit plans had to be adopted. Furthermore, in order to control housing prices, those buildings were designed only to meet the basic requirements. Later, the electricity capacity in those units became a big problem after several years when residents added more electronic products. These problems also happened in other projects. Many small size housing units --- with unreasonable floor plans and little possibility for residents to adapt them in the future --- were largely left vacant, especially in the mid-1990s, while many residents were still living in their old dwellings and were waiting for new houses. For those people who moved into those "inflexible" dwelling units, they had to adjust to the existing spatial

layout and could not make any changes except for changing the interior wall color.

Kangju projects (elite housing projects) provided various housing choices for high-income households, but also did not do much in housing space flexibility even though it focused on advanced technology applications and building process industrialization.

Although housing design and construction have changed from the old days when government aimed to maximize housing floor space with limited investment, to the late 1990s especially after 2000, when the external housing environment (green areas, trees, parks, walkways, etc.) and spatial conditions within the neighborhoods are also considered to be important in addition to the interior layout, the housing capacity to fit the changing life styles of urban Chinese households has not increased much. For example, Eastern Coast Residential District developed by Vanke Company in Shenzhen, China won the "International Garden Residential District" in the *No. 8 International Garden City Competition* held in June 1994 (Shenzhen special zone newspaper, Nov. 12, 2004). It was successful in its site planning based on sustainability design principles, but the individual buildings did not have many capacities for future changes.

In the late 1990s, this problem drew investors' attention and some measures were taken to solve it. Investors began to pay much more attention to residents' opinions when they developed new housing projects. Some measures carried out at that time were similar to the principle of the open building process. Housing developers built many houses only with enclosure space for bathroom and provided more flexibility in the room arrangement within the unit. The residents could decide what kind of space they wanted to create in order to fit their living requirements, and what kind of material they desired

to use in the partition walls, the finishes, and the interior decorations. This trend has tended to be more progressive in recent years.

I – 3: Open building has potential to solve some housing production problems

Open building was started in the Netherlands, based on a book written by John Habraken about 40 years ago (Habraken, 1999). Parallel developments were taking place in Japan. Since then, many pioneering projects have been built in different countries around the world. A recent example in Japan is shown in **Figure I-1.**

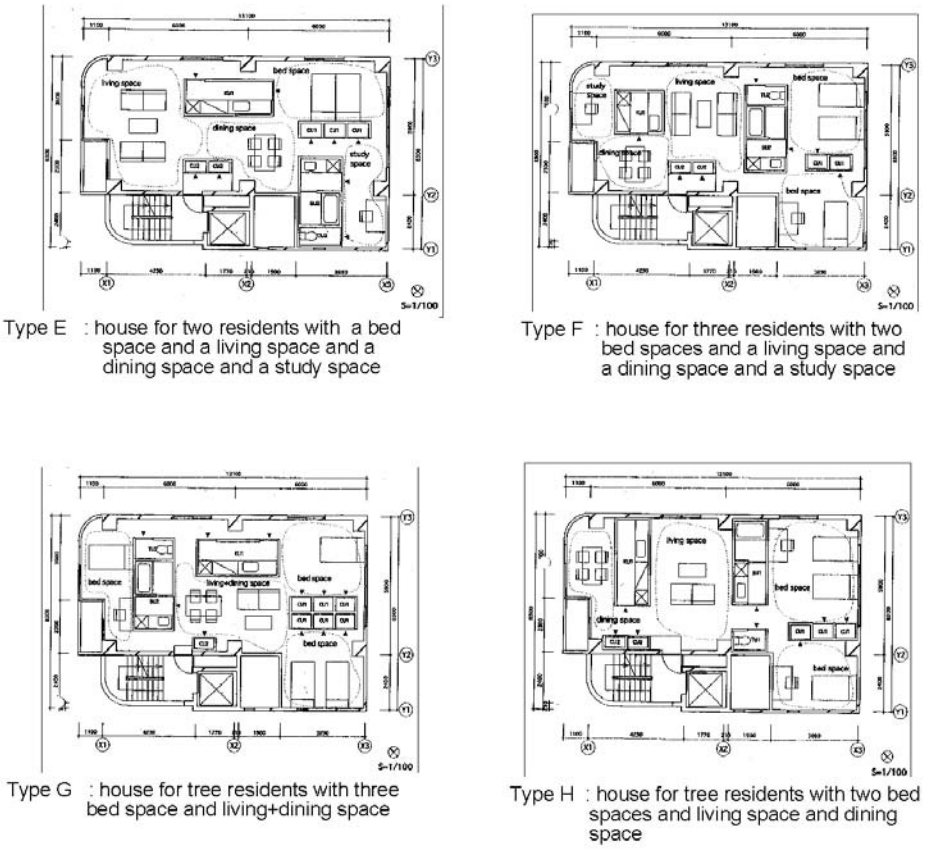


Figure I-1 Four Infill Variations

(Source: Serizawa, 2005)

The example shown in **Figure I-1** is typical of the application of the open building principles to the conversion of obsolete office buildings to housing in Japan. The drawings show several choices of interior layouts based on the same Shell in order to meet different residents' living requirements. Other examples are shown in Appendix I.

According to John Habraken, open building is the term used to indicate a number of different but related ideas about the making of environment. These include:

> **The idea of distinct levels of intervention in the built environment, such as those represented by 'base building' and 'fit-out', or by urban design and architecture.**
>
> **The idea that users / inhabitants may make design decisions as well as professionals.**
>
> **The idea that, more generally, designing is a process with multiple participants also including different kinds of professionals.**
>
> **The idea that the interface between technical systems allows the replacement of one system with another performing the same function. (such as different fit-out systems applied in a given base building.)**
>
> **The idea that built environment is in constant transformation and change must be recognized and understood.**
>
> **The idea that built environment is the product of an ongoing, never ending design process, in which environment transforms part by part.**
>
> (Source: http://www.habraken.com/html/introduction.htm)

Basically, the open building concept divides a building into two parts - Shell and Infill. The Shell is the configuration of physical elements and spaces that represents the more stable and long lasting "public" interests, while the Infill represents short-term "private" interests in the view of sustainable development and life cycle analysis, and it is decided by or for individual occupants. In principle, the Infill can be determined or changed without changing the Shell, but a change of the Shell will make the Infill change. That produces a hierarchical relationship between the Shell and Infill.

Open building principles are not associated with any specific building typology, but may have special relevance in more dense urban housing. This is because the potential for conflict between the “public” interests in the stability and permanence of housing and the “private” interests in personalization and change is greater in higher density housing types.

An important attribute of the open building process is that it can provide housing occupants more choices in the layout, finishes, equipment, and final cost of their housing units. This flexibility makes it possible for housing occupants to change the interior layouts within their existing units after years later, with far fewer constraints in contrast to conventional design and construction. Accordingly, the remodeling costs in an open building project will decrease since the occupants do not need to change everything that is connected to the part they want to change, especially the Mechanical, Electrical, and Plumbing (MEP) system which is a most difficult part in the remodeling process. For example, floor mounted rear discharge toilets are used. The drainage piping for one unit is routed above the floor and within the dwelling’s space, thus maintaining a strict separation between the systems of adjoining apartments.

The open building process may also benefit housing developers and property management companies. A good housing process can shorten the housing sale period, thus reducing investment cost and market risk. By distinguishing the Shell and Infill parts, responsibility for certain building parts is clearer, thus reducing arguments during the long-term housing management.

I – 4: Can changes in China's housing production system provide opportunities for open building implementation in China?

Since 1979, China's urban housing production system has changed dramatically from the old welfare-based model to a new market-based model. Does the present market-based model provide opportunities for open building to be widely adopted at least in some parts of the Chinese market? Facing this new situation, can ways be found to propel its application and to allow more people to benefit? This is the question asked in this thesis. This research topic is not only important for China's housing industry development, but also may have significance for sustainability debates around the world.

I – 5: The detailed objectives of this thesis

1. In specific market segments in China, is it possible for developers to efficiently provide more choices for consumers at a range of prices, while avoiding risk by systematic organization of the process?

2. Is it possible for an existing company --- already providing complete interior decoration services under single source responsibility --- to extend its market by adopting open building principles?

3. As China's economy continues to move toward privatization, with an increasing middle class, can open building meet the housing preferences of this segment of the Chinese market with appropriate consumer-oriented housing finance, real estate transactions, and service?

Chapter II

Brief History of the Urban Housing Development in China

II – 1: The old welfare-based housing production system

Between 1949 and 1979 in China, housing policy focused on providing basic shelter to urban residents. The welfare-based housing production system controlled the urban housing industry. Housing was not regarded as a commodity but a welfare benefit that was directly linked to employment. During that period, housing was actually in very short supply but people had little demand for it, because they were dominated by the magic spiritual satisfaction created by Mao Zedong, and were happy with satisfying mental needs instead of physical needs. The old Chinese saying “there are houses made of gold and silver, but I would rather stay in huts” best described the people’s attitudes towards the housing requirement at that time.

II – 1.1: How did the old system work from 1949 to 1978?

1949 – 1955: Housing market dominated by private interests

In the late 1940s, housing developers took advantage of the massive housing shortage, political chaos, and serious inflation, to conduct extremely speculative and

profiteering activities**,** thus making the housing rent unreasonably high. In order to make the housing market run properly, in August 1949, China's Community Party (CCP) announced a housing and property policy that expropriated the properties owned by anti-revolutionists and larger companies. Later in June 1950, CCP also announced *the Land Reform Act*, which stipulated that the land could not be transacted in the market either by rent or by sale. All land property was declared to belong to the government. In order to propel the national economy, both CCP and local governments cracked down on speculation and profiteering activities in the housing sector. (Zhang, 1997)

However, facing the severe housing shortage, private landlords still could charge relatively high rents. And most of the housing stock remained in the private sector in many cities in 1955: 66.0% in Shanghai, 78.0% in Jilin, 80.3% in Wuxi, and 86% in Xuzhou. Furthermore, private housing was controlled by a few large landlords (Huang and Clark, 2001). After all, the private interests still controlled the housing market.

1956–1966: Socialist transformation

From early 1956, CCP conducted three types of socialist transformation in the housing sector in order to control the private housing sector effectively. (1) The government took control of the allocation, rent, and daily management of private rental housing, and distributed some part of rents to those housing landlords, thus cutting the direct linkage between private landlords and tenants, and avoiding unlawful high rents. (2) CCP made full use of national businessmen's skills and experience, and accepted them to be a favorite force in this socialist transformation. Therefore, those private housing companies and large private landlords were allowed to run their rental housing business

as a partner of CCP during this transformation. (3) CCP set some rules and regulations to control those small private rental businesses, and force them to follow the government's policies.

This socialist reform transferred almost all private rental housing into government owned housing, and put the government in charge of the urban housing through local municipal housing departments or work units. Consequently, urban housing became a component of government welfare instead of a commodity**.** This transformation action ended with the Cultural Revolution in June 1966. (Zhang, 1997)

1966–1978: Government switched construction focus from urban to rural areas

During this period, two important events happened in China's modern history. They switched the government's policy focus from urban to rural areas. The first event is the break-up of the Sino-Soviet relationship, which increased the fear that World War III would break out in the near future. It pushed the government to build new industrial projects mostly in rural areas, as well as housing construction that was regarded as a non-productive investment. From 1966 to 1970, urban housing investment dramatically decreased nation-wide, and some cities even stopped it.

The second event was the Cultural Revolution (1966–76), which moved this anti-urban campaign further forward. In order to reduce the inequality of the living standards between cities and the countryside, poor materials and low techniques were widely adopted in the urban housing construction. Furthermore, the Red Guard largely impounded and occupied the private urban housing. The percentage of private housing ownership in some cities was less than 4% much lower than 10% of national average

level. The central government had overall control of the urban housing sector by establishing a welfare housing system. It also adopted the *hukou* system in 1958 as an entry to the urban housing to reduce the housing pressure caused by potential massive migration. (Zhang, 1997)

Since liberation, the central government has adopted a number of measures to stop the private housing market in the urban area: (1) controlled the urban land available for housing construction; (2) expropriated large size housing properties and turned most of them into government owned properties; and (3) controlled the housing rent and made private landlords' investment in housing rental unprofitable. The government became the only party responsible for urban housing provision.

Urban public housing was divided into three different categories. The first category was the housing directly provided by the government and distributed by municipal government housing departments. The second category was the houses built by government-owned work units and distributed to their employees. The third category was the houses built by collectively owned work units and distributed to their employees. According to *the First National Housing Survey in 1985*, work units owned 90% of public housing and the government only owned 10% (Zhang, 1997). Only the housing from the first category was funded by the government. All other housing investment (except for new industry) came from its own production surpluses.

New village housing type, including several multi-storey-buildings organized in groups, was considered the unique public housing form at that time because it was closely connected with socialist functions and symbolism. And the most successful village housing example was *Shaoyang Xinsheng,* built in Shanghai in 1951. The height

of housing building was 2-3 storeys in the early 1950s, 3- 4 storeys from 1954 to 1958, and 5- 6 storeys in the 1960s and 1970s. In the late 1970s, high-rise building became a popular housing type because it could solve the housing shortage problem effectively. Meanwhile, standard design and building components were widely used to speed up the housing construction as well as to reduce the initial housing costs. (Zhang, 1997)

Since urban housing had become a part of the social welfare system, and the rent was extremely low --- about 1% of an average worker's annual income and 0.71% of a household's total expenditure (Zhang, 2000) --- in addition to the *hukou* requirement, the government also set strict criteria for urban residents to choose their housing units. Normally the government set four housing categories based on floor space of each unit, and each category required specific qualifications including social status, political stance, or professional performance (diagram shown in **Figure II-1** on the next page). Only if their qualifications changed to a higher level could they get a larger unit. According to the central government's housing policy, working units had much power to decide the allocation of public housing (except the government housing) based on each person's working performance instead of their housing needs, thus accurately reflecting the socialist distribution principle of "to each according to his work" (*anlaofenpei*).

Housing standards (m^2 per housing unit)	Allocation requirements/Qualification
45–50	Staff in newly established enterprises/non-profit work units
50–55	Staff in old enterprises or large-scale work units
60–70	Officials at county level government bodies, and professionals with qualifications of engineers, or equivalent
80–90	Officials at provincial government bodies, and professionals with qualifications of senior engineers or equivalent

Source: Yunnan Construction Committee and Yunnan Planning Committee, *Notice on Tight Control of Housing Standards*, 1990.

Figure II-1 Housing Standard in China

II – 1.2: What challenges did the old system face?

In the old system, urban housing was regarded as a welfare benefit and was provided by the work unit or municipal housing bureau at low rental cost. This policy aimed to guarantee a basic living standard for all urban residents in the late 1970s. The deficiencies of this policy led to serious housing challenges.

Before 1978, all housing investment was from the central government. The highly subsidized rent was not enough to cover housing construction and maintenance costs, thus creating a heavy financial burden for the government and leaving many housing units poorly maintained. The government had to make an extra appropriation for housing maintenance and management in the urban housing sector (Gu, 2001).

Housing supply was not adequate. Overcrowding due to the population boom in Mao's era also became a common problem, thus making the housing situation worse. In addition, there were no housing types for people to choose (Huang, 1999).

Inequality in housing distribution existed among work units. Government-owned enterprises usually had better housing than collectively owned ones. Furthermore, corruption became a serious problem, resulting in some housing units remaining vacant while other families had no place to stay.

II – 2: The changes from the old system to the new market-based housing production system

In April 1980, China's paramount leader Deng Xiao Ping made a speech about urban public housing reform. It changed the long-standing policy regarding urban housing as social welfare, and began to allow and encourage urban residents to buy

houses. This housing reform introduced market mechanisms and households could choose among different types of housing and tenures. This speech guided the direction of the housing reform experiments in the following years.

Before July 1994, the housing reform focused on setting up a rental market and selling publicly owned housing to individuals by using government subsidies and other measures, just as World Bank economist George Tolley suggested that "divorce housing from work units**"** was a key to transition towards housing commercialization (Gu, 2001). Then, the housing market was gradually cultivated and eventually housing totally went into the market, with the government only acting in a balancing role in the housing market.

From 1979 to 1982 was the initial phase of the reform experiment. In 1979, Xian and Nanning conducted the first housing reform experiment, and they sold new houses to urban residents at the construction cost. By 1981, this experiment had been expanded to more than 60 cities and towns all over the country. This is the initial point of regarding housing as a commodity, but it was finally abandoned in 1982 for several reasons such as the new housing price was much higher than average income, the public housing rent was too low, and the payment method was not flexible. (Wang and Murie, 1996)

From 1982 to 1985, the second phase of the reform experiment was implemented. It was initially carried out in four cities including Zhengzhou, Changzhou, Siping, and Shashi, and then expanded to over 160 cities and 300 towns throughout the country by 1985. During this period, individual buyers only needed to pay one-third of the total housing price, and the rest were paid by the buyer's employers, thus reducing the family's payment dramatically. In 1985, about 200,000 housing units were sold.

However, widespread restrictions and complaints drew this experiment to an end in 1985. First, individuals could only get the housing subsidies for the qualified floor space. For the additional floor space, they needed to pay the full cost without any public subsidy. Second, the housing owner had no right to rent or sell their house in the market, even though they had housing property "right" certificates. Once they no longer needed their house, they must return it to the original seller and get a proportion of the original price back. However, they were allowed to pass on their house to their children by inheritance or family division. Third, employers complained that they had too much financial burden. (Wang and Murie, 1996)

From 1986 to 1993 was the third phase of housing reform experiments. In order to facilitate the nation-wide housing reform, at the beginning of 1986, according to the guidelines set by the State Council, the central government Housing Reform Steering Group was set up and Housing Reform Offices were also set up in cities.

The pioneer experiment was conducted in Yantai, Shandong province in 1987. This experiment successfully implemented the following aspects. First, it gradually commercialized the entire housing process from production to consumption by raising the rent and providing relevant subsidies, without substantially increasing households' housing costs and the government housing investment. Second, it switched the housing distribution method from material to monetary, thus cutting the direct housing link between employers and their employees, and making companies concentrate their full energy on production. Third, with different payment methods, public-sector workers only bought the houses they could afford and gave up their extra houses. And finally, it established independent housing service companies to provide services in each

neighborhood area at the property owners' cost. (Wang and Murie, 1996)

This successful experiment was expanded to the national level. In 1988, *the Ten Year Reform Strategy* was published, and urban residents were encouraged to buy their houses. At the same time, the Constitution legalized the existence of the private sector in the economy, and the paid transfer of the use right of government-owned land for a certain time limit. Different land uses had different time limit. The time limit for residential land use was 70 years. Furthermore, the time-limit contract could also be renewed by paying a fee. Nevertheless, the property right was still not available for sale. This new land system played an important role during the urban housing commercialization process. (Wang and Murie, 1999)

In **May 1991**, Shanghai's comprehensive housing reform program started and acted as a catalyst pushing this nation-wide reform forward. In November 1991, the State Council published very basic principles to guide some national common issues, and let local governments create detailed reform plans according to their economic conditions. However, the central government had to stop this housing reform at the end of 1993 because local governments or work units set housing sale prices too low. (Wang and Murie, 1996)

Until this time, even after many experiments had been conducted, the reform results were still not satisfactory for a number of reasons. First, rent income was insufficient. Second, housing prices were too low to recover the construction cost of the old houses. Third, loans remained rudimentary. And fourth, old houses were low quality and no one assumed responsibility for maintenance.

Drawing lessons from all the previous reforms, in **July1994**, the Third National

Housing Reform Conference was held in Beijing setting up the overall strategy, thus pushing the housing reform to a new phase. Several main points were addressed in this conference.

First, this new strategy changed the main housing investment source from employers to individuals. It required individuals to pay a major part of their housing costs instead of one-third as in the earlier years, and local government and work unit paid the remaining costs, while the central government was no longer the main housing fund provider and its role was changed to keep an overall balance within the country. There were some other investment sources such as bank loans, foreign investments, and a compulsory housing savings system. The compulsory housing savings system was nation-wide and was established to help people pay for the housing cost from down payment to maintenance. Every month, each urban worker was required to save a certain part of his/her salary to this long-term housing saving account, and the similar part should be distributed to this account by the employer. Meanwhile, housing insurance and mortgage systems were also gradually established in order to ensure that the housing investment system could be operated effectively in the market. (Wang and Murie, 1996)

Second, government aimed to increase housing rent in the public housing sector. By 2000, the housing rent would have been about 15% of a couple's total salary and covered all the cost including housing construction, repair, management, loan interests, and property tax. (Wang and Murie, 1996)

Third, the new strategy established a dual housing production system including the welfare-based housing production system and the market-based housing production system. The former refers to the economic and comfortable housing including *Jinji*

shiyong fang and *anju* projects that were built at reduced costs and sold to low- and mid-income households. The latter refers to the higher standard commercial housing that was developed at normal costs and sold to high-income households. This dual system aimed to produce more affordable housing and meet different housing requirements from both the rich and the poor. (Wang and Murie, 1996) For the policy-oriented social housing, after meeting the basic qualifications, individuals can buy it at three different prices including market price (*shichang jia*), cost price (*chengben jia*), and standard price (*biaozhun jia*) based on their economic conditions. Only those buying the house with market price could have full ownership, and they can sell or rent it in the market for profit. Otherwise, they only have a partial ownership, and can only have the right to use and succession instead of release in the market. (Huang and Clark, 2001)

Fourth, the new strategy pointed out that various commercial property development and management companies would be the housing providers and managers, not any government body (Wang and Murie, 1996). According to the report from *the Yearbook of China Real Estate Market in 1997*, "in 1996, there were 21,269 real estate development companies, of which 41% were state-owned, 22% collectively owned, 10% foreign developers and 10% overseas Chinese developers." (Zhang, 2000) According to the report from Shanghai Municipal Landuse System Reform Leading Group Office and Shanghai Municipal Statistical Bureau in 1997, "In Shanghai, market housing produced by development companies accounted for 66 per cent of total new housing supply in 1996." (Chiu, 2001) Obviously, commercial housing developers dominated the housing market.

The central goal of this new strategy was to commercialize the urban housing

sector, changing the welfare-based housing production system to the market-based housing production system. Substantial rental increase and the establishment of housing management companies to administer the housing stock with clear definition of ownership right and to corporate governance structure let housing occupants become familiar with what ownership means and gradually change themselves from renters to owners. According to the report, “In 1995, 53% of the housing area sold in the market in the whole country was purchased by individuals.” In addition, “It was reported that 52% of the saleable stock in Shanghai had been sold by the end of 1996, reaching a home ownership rate of more than 43%.” (Chiu, 2001) Meantime, the salary reform providing wage compensation for the cost of rental or buying house, and the establishment of a functioning mortgage loaning system making commercial housing loans possible for individuals propelled the commercialization process and pushed the housing reform forward.

Nevertheless, some problems still existed and required further reform, such as who paid for the house for those families who did not belong to government-owned enterprises; how to reduce monopolies and corruption; and how to strengthen the regulatory framework which lacked expertise in legal and regulatory issues --- even though the first major housing legislation, *the Urban Housing and Real Estate Management Act*, was issued in 1995**.**

In July **1998**, the State Council issued an important document *Deepening Urban Housing System Reform and Quickening Housing Construction* that took a bold step in the housing reform. As Eward X Gu (2001) quoted from *China Reform Newspaper, July22, 1998*, this document “comprised four major components: (1) ending the welfare

public housing allocation system by the end of 1998; (2) establishing a supply system of affordable housing for low-income families; (3) simplifying regulations concerning mortgages; and (4) developing a market for second-hand housing exchange." It aimed to boost the urban housing reform from the welfare-based model to the market-based model, and it also aimed to establish a healthy, standardized, and regulated market system for property exchange, repair, and management. Thus, both the rich and the poor could have access to the urban housing.

As the reform proceeded, housing cash subsidies started from December 1999 and reduced the unfairness and official corruption during housing allocation process, wages increase, and housing rent reform made people become more comfortable to buy houses using money from subsidies or other sources. As Peter Li (2003) quoted from *China Daily*, *Aug.21, 2002,* "figures released by the Ministry of Construction earlier this month show that four out of five households in urban areas are owner-occupied." He also quoted other data and pointed out that people went to secondary housing markets to buy and sell houses, especially in Shenzhen, China (Li, 2003).

By **2002**, many problems still existed in the urban housing sector. According to the report from *China Daily*, *Aug.21, 2002*, "1.56 million households still do not have enough living space." Economy housing in China was not economic because of the large unit size and high price. This happened anywhere in China not only in Beijing where 70% of people waited for houses under 300,000 *yuan* per unit and more than 90% wanted to buy housing unit with the building area less than 100 square meters. (Li, 2003)

With China's joining World Trade Organization and Beijing's successful bid to host the 2008 Olympic Games, China's economic growth rate remained high. In 2003,

the real estate sector accounted about 7% of the country's gross domestic products value, and the urban housing became the fastest growing part in real estate sector. Privately owned housing reached 80% in 2005, even though the urban population increased more than 40% from 1995 to 2005. (Rodman, 2005)

On the way to full urban housing commoditization, there are still many obstacles to be overcome. These include wage adjustment enabling people to afford the houses, or at least rent the houses; price adjustment showing a reasonable ratio of the rent and the sale price; financial system improvements making loans available for both housing constructions and house buyers; second-hand housing exchange market cultivation allowing people to get second-hand house at a reasonable price; and finally property right protection execution giving a sense of security to house owners. (Li, 2003)

II – 3: The differences between the old system and the new system in terms of housing ownership

In the old system, housing was regarded as a welfare benefit, and it was not profitable. Urban residents were allocated the subsidized rental houses with low rent through a point system according to their qualifications such as seniority, marital status, family size, and political performance. They could have the right to live in their house but no right to own their house or land. That is to say, they could pass their house to their children but could not sell it in the market. The government was the only one who was responsible for housing issues such as investment, distribution, and maintenance. Private production and management did not exist.

In the new system, housing is regarded as a commodity, and it is profitable.

People either buy a public housing unit from the government with governmental subsidies or buy a commercial housing unit from a housing developer with a loan from a bank. They not only have the right to live in their house but also have the right to sell or exchange it in the second-hand housing market (some restrictions apply if they bought public housing). That is to say, they are now house owners. Accordingly, they, instead of the government, need to take care of their house in every aspect. In addition, the land can be transferred for a fee within a certain time limit --- this time limit can also be extended by paying a fee later --- but still cannot be owned by housing occupants. This housing production system provides more job mobility for people. They do not need to worry about whether the future work unit can provide housing for them during their new job search. On the other hand, the housing will be gradually segregated by income level. This situation is different from the earlier work unit living compounds which were the co-residence of managers and workers.

II – 4: The differences between the old system and the new system in terms of housing consumers' roles

In the old system, housing consumers only had the right to live in the house distributed by the work unit. They could not change anything within the house such as the room size or the partition wall position. People who participated in the design and construction period were usually the leaders (*carders*) of the work unit and the people from the municipal government-housing department. The future housing occupants could hardly have a chance to participate during the building process. They could only accept the housing unit as it was provided.

In the new system, housing consumers' roles are totally changed. They can participate in the building process including design, construction, decoration, and later adjustment. They can modify anything within their housing unit as long as it will not cause unsafe conditions to their neighborhood and the whole building. Especially in recent years, more and more housing consumers like to participate in the design process and express their preferences to architects. As an architect, at least from my former working experience, he/she usually tries to meet their preferences within the constraints of building codes and regulations. After they buy the house, they like to choose different companies and compare various interior decoration schemes and costs. Some of them even participate in the material selections. According to the news published on http://www.sina.com.cn on September 13, 2003, on September 12 in the China Architectural Culture Center, Beijing Century Building Exhibition displayed eight integrated house models built in 1:1 scale as well as many kinds of building materials, decoration materials, equipment, and furniture. This exhibition demonstrated that future housing consumers could customize their housing unit --- no matter whether it was a detached house, walk-up unit, or high-rise unit --- by choosing favorite interior parts, such as high quality sound-proof partition walls improving privacy, high quality insulation material reducing the energy lost, and specific furniture and decoration materials creating different country style unit. On the other hand, they could just present their ideas to the developer and their new housing unit would be built at a reasonable price. After all, housing consumers have become the "real" owner and have many opportunities to participate during the entire process.

Chapter III

Current Market in China's Housing Industry

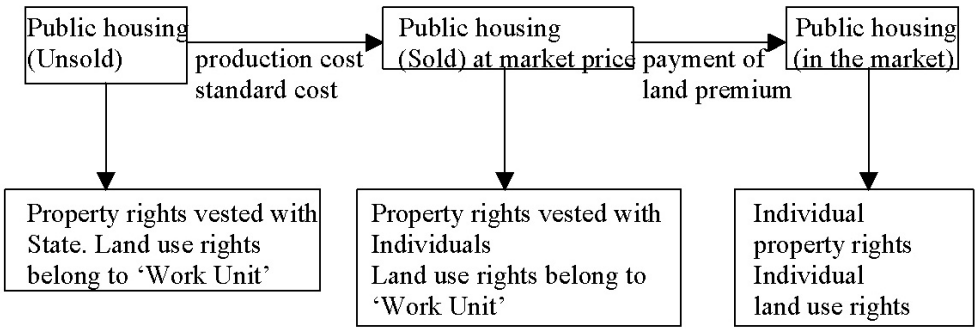
III – 1: What is the political housing goal set by the central government? How about the private housing property laws?

Due to the housing reform in China, per capita living space increased from 3.6 square meters in 1978 to 9.3 square meters in 1998. According to *the National Housing Survey conducted in 1996*, "about 47 per cent of Chinese urban households own their homes and another 46 per cent are renters in 1996". Even though the owner rate was lower than that of the US (64%), it had increased significantly compared to less than 20% at the beginning of the reform. (Huang and Clark, 2001) According to the goal set by the Chinese government Ministry of Construction, per capita building area in 2020 will be 32 square meters. Accordingly, new urban housing floor area should reach 14 billion square meters. (This data came from http://www.vankeweekly.com on Nov.6, 2004)

As the "shelter" period --- when mass housing was produced to meet the basic living requirement --- comes to an end, urban residents have more comprehensive requirements in addition to the unit size, orientation, and location when they choose their new houses. Today, more and more people, especially those in the middle-class, feel

unwilling to spend time and energy in “do-it-yourself” work where they can hardly have good results. The “skeleton” house will therefore gradually get out of the Chinese housing market, and the “ready-to-move-in” house will be a new trend. From this viewpoint, customer participation shifts to a more sophisticated form of decision-making.

Private housing goes directly into the housing market and house owners have clear property rights. Public housing is different. The diagram in **Figure III-1** shows the public housing property right transition from the old system to the new system. Full private housing property rights are possible if a secondary housing market is developed. However, it will take time to develop appropriate laws to protect it (Li, 2003)**.**



Source: Shanghai Fangdi 2002/3, p.23.

Figure III-1 Public Housing Property Chart

III – 2: What is the current housing production process?

In the new system, urban housing has been turned into a commodity and entered the market. Especially after December 1999, urban residents need to buy their houses instead of renting them with low rent. More than two decades’ development made the

current housing market more mature than ever, even though many problems need to be solved.

In order to profit from the new housing production process, housing developers need to pay attention to the housing market and housing consumers. The days when housing developers decided the production process no longer exist. Serving housing consumers has become their first priority and the consumers' satisfaction is critical for their business success.

Housing consumers will no longer have housing for free. They care more about their housing unit because the money they spend is much larger than their annual income. Consumers become more aggressive in seeking participation in the housing production process including design and construction, and they try to have their own ideas embodied in the final product. Thus, the balance between housing supply and demand shows its critical importance in the housing market. This is the reason why certain houses are easy to sell while some still remain vacant even years after being built.

Solving the housing problems in large cities has become an important task for the Chinese government. Both the central government and local governments actively show their support in promoting new technologies, making new rules, and enacting new ordinances and laws related to the housing industry.

III – 3: Four popular housing types

In China's current housing market, four types of housing are popular: high-rise multi-unit buildings, walk-up multi-unit buildings, townhouses, and detached houses or "villas". The pictures in **Figure III-2** show an example of each.

(a) High-rise Multi-unit Building

(b) Walk-up Multi-unit Building

(c) Townhouses

(d) Detached House (Villa)

(Source: http://www.villachina.com)

Figure III-2 Four Types of Housing in China

Most urban residents live in either walk-up or high-rise multi-unit buildings. Townhouses are widely occupied by middle- and high-income people, and the villa is occupied by very high-income people. Most townhouses and villas are occupied as "primary" living places while some of them are used for vacation or second homes.

Based on the specific social condition, the current urban housing goal set by the Chinese central government is to build enough housing units for low-income people, and build some high-end housing units for middle- and high-income people.

III – 4: The townhouse and the focus of the thesis on this type

Even though they will not be occupied by a majority of urban residents, townhouses still remain popular in China's housing market because this housing type not only improves the living quality by anti-urbanization --- which is widely adopted by western countries --- but also relieves people from the current urban living environment with high density buildings and population. With the improvement of infrastructure and transportation systems, townhouses will be widely expanded to suburban areas, benefiting people from the middle- to high-income class (Some already built townhouses in China are shown in the appendix II). After all, this housing type will benefit individuals, urban city development, and natural resource / sustainable development. Therefore, among the candidate housing types in China's current urban housing market, the townhouse is a suitable building type to study using the open building process. The people from the fastest growing segment of the Chinese market --- the middle-income class --- will be the main consumers. They are the most likely "early adopters" of this innovation because they have enough money to invest and enough interest to "maximum choice behind their front door". This is the primary reason I focus on this housing type and this income group in this thesis.

Building townhouse units using an open building approach requires comprehensive planning, including high quality technologies and labor skills. The initial

investment could increase costs compared to the housing units built in the traditional method. This must be carefully studied and the thesis has helped to set the stage for further detailed analysis. Experience in other countries where open building has moved into the market indicates that careful planning can make this new approach competitive with traditional methods and offer advantages that make the risk of implementing an open building approach attractive.

Even so, investments from various capital sources and/or subsidies and supports from governmental areas such as building regulation reform, finance, and changes in the law are needed.

Chapter IV

A Proposal for a Townhouse Based on the Open Building Principles

This chapter discusses how to design and deliver a townhouse using the open building principles. A townhouse type is used as a reference. It is familiar to builders and consumers, and many of this kind of housing have been built based on the conventions, regulations, and rules which developers, construction organizations, and regulatory bodies were familiar with. This proposal includes: Part 1: The reference townhouse; Part 2: Proposed design project; Part 3: Management complexity and choices; Part 4: Consumer decision process; and Part 5: Floor plan combination choices.

IV – 1: The reference townhouse

More than 50 townhouses, which were already built in Beijing, Shanghai, and Guangzhou, were studied before one was selected as the study example in this thesis. According to the open building principles, by adjusting some parts of the facade and floor plans from this reference building type which is already accepted by housing consumers, housing developers can have multiple interior layouts within the same unit enclosure and meet people's different requirements. The diagrams in **Figure IV-1** show the original

floor plans.

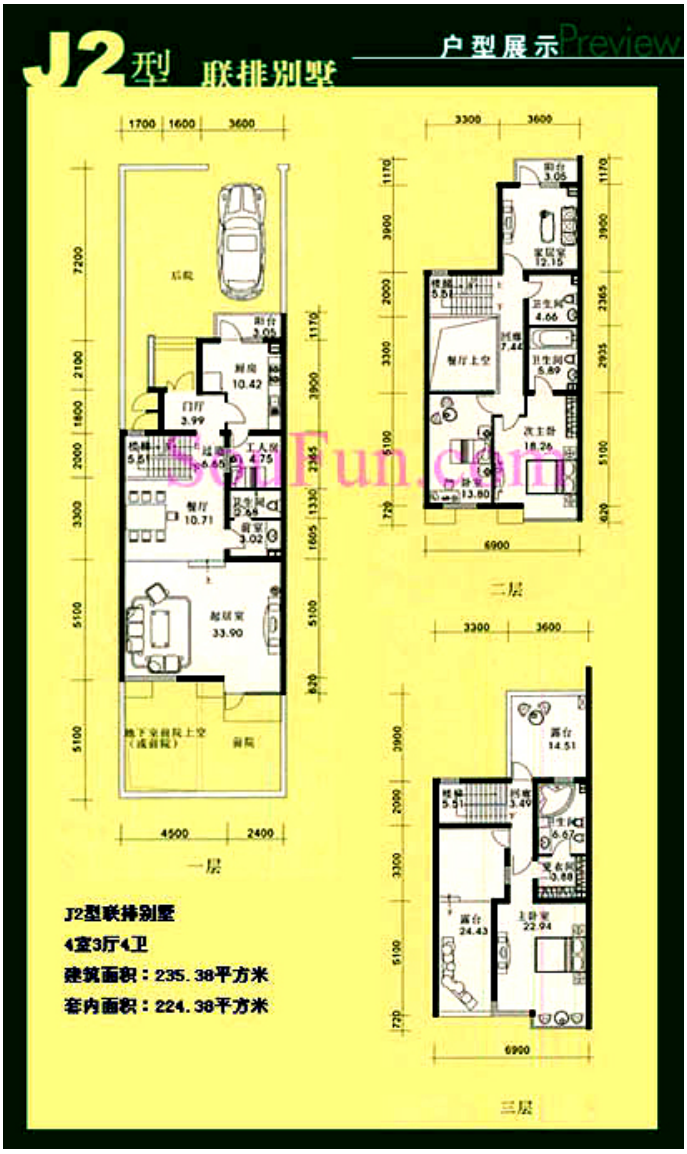


Figure IV-1 the Original Floor Plans

(Source:http://newhouse.soufun.com/housepic/1010017516_56946_%d4%c2%b9%f0%d7%af%d4%b0.htm)

The townhouse shown in **Figure IV-1** was built in Beijing in 2003. According to some market investigations, for example, Chen, Zhiping (2003) "Townhouse Becomes Popular", a townhouse with the building area between 180 m^2 and 260 m^2 is widely

accepted by middle-income urban residents. Based on my former design experience, and further "capacity analysis" conducted as part of the thesis study, the width and depth of this housing unit provide many possibilities for various interior layouts. Also, this housing unit has an appropriate footprint for reasonable urban design layouts. The reasoning for this assumption about the "urban design", however, will not be addressed in this thesis.

IV – 2: Proposed townhouse

Based on the original floor plans (shown in **Figure IV-1** on the front page), a series of "capacity analysis" studies were undertaken to determine how much adjustment of the basic housing shell would be needed to provide more layout options to homebuyers and developers, while keeping the construction efficient and within normal cost limits. The main study steps for the first floor plan are shown in the following. The simplified original first floor plan shown in **Figure IV-2** includes staircase, shafts in the kitchen and the bathroom, and the façade elements.

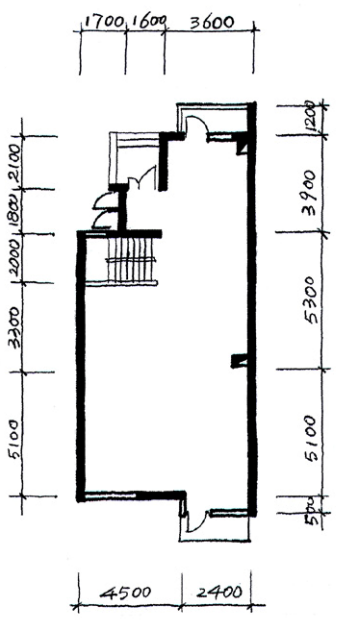


Figure IV-2

Simplified Original First Floor Plan

Step 1: move the existing staircase 3.3 meters in order to have less interior space without direct sunlight. The diagram is shown in **Figure IV-3-1**.

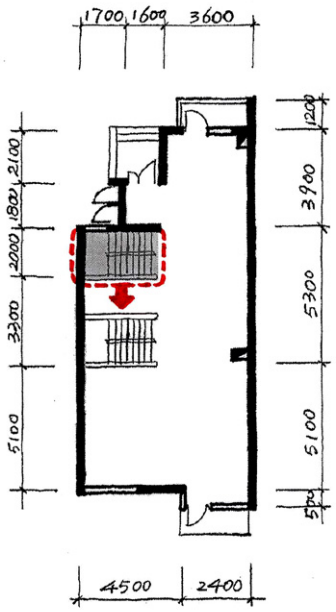


Figure IV-3-1 Step 1

Step 2: move the staircase a certain distance away from the exterior wall, and add a utility shaft between the exterior wall and the staircase. This shaft will connect the MEP vertical lines from different floors on the left side of the unit. The diagram is shown in **Figure IV-3-2**.

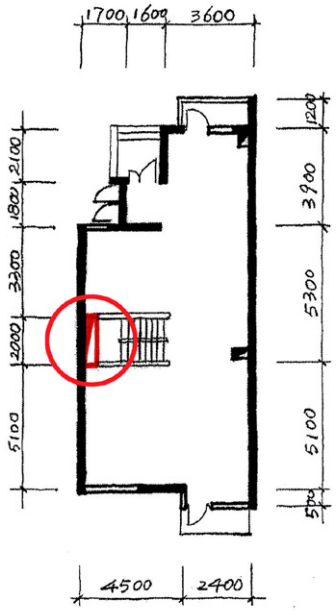


Figure IV-3-2 Step 2

Step 3: combine the original kitchen shaft and bathroom shaft to one utility shaft, and then locate this utility shaft next to the exterior wall and within the tone color area shown in **Figure IV-3-3** (like position A in the diagram). This shaft will connect the MEP vertical lines from different floors on the right side of the unit. This change also provides a short connection of the vertical MEP lines between these two shafts in the basement. Furthermore, this change avoids the shaft becoming an obvious form element if it is left alone without connection to any room.

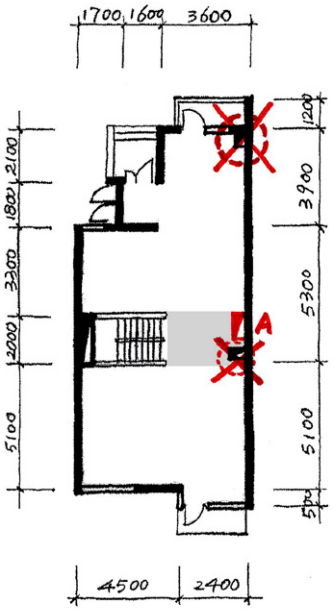


Figure IV-3-3 Step 3

Step 4: move the unit entrance 2.1 meters to create more possible interior layouts for this side of the unit. The diagram is shown in **Figure IV-3-4**.

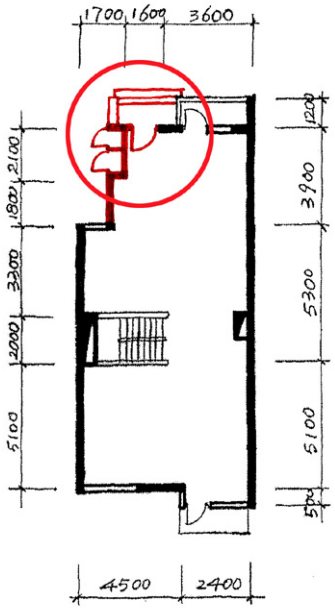


Figure IV-3-4 Step 4

Step 5: move the front side balcony and balcony door a certain distance, and expand the width of the balcony and the adjacent window in order not to have too wide space in the unit entrance. The diagram is shown in **Figure IV-3-5.**

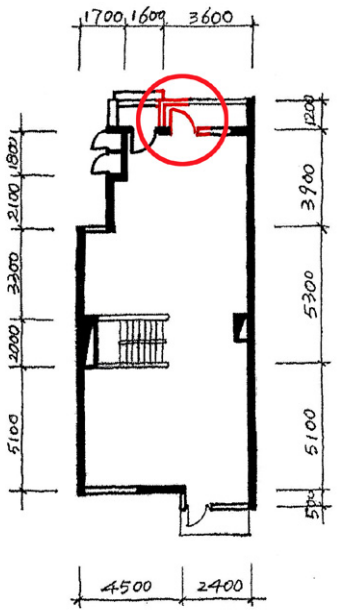


Figure IV-3-5 Step 5

Step6: move the wall adjacent to the back yard door 1.2 meters, and make the space in the lower-right part of the floor plan more useful. Also change the original out-swing door to a sliding door. The diagram is shown in **Figure IV-3-6.**

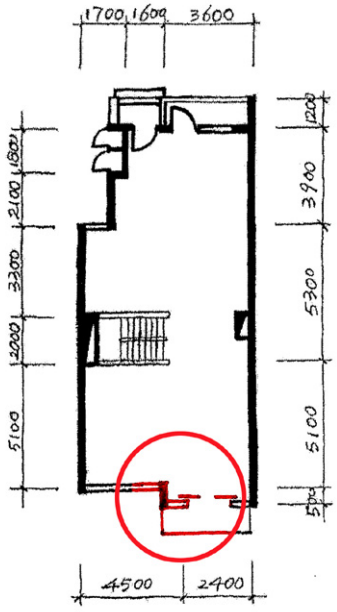


Figure IV-3-6 Step 6

Step 7: change the height of the dining room from the original two stories to one story.

The entire modification creates a new **Shell** that has clear capacity for Infill variations, initially and in the future. The diagram is shown in **Figure IV-4.**

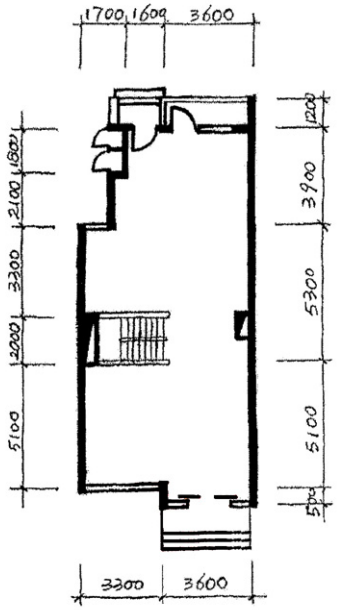


Figure IV-4 New Shell

As discussed in more detail later, the stair itself is considered as an Infill part in this study, but the hole in the floor is a part of Shell. This means that different stairs can be selected depending on the specific floor plan chosen. See diagrams in **Figure IV-5**.

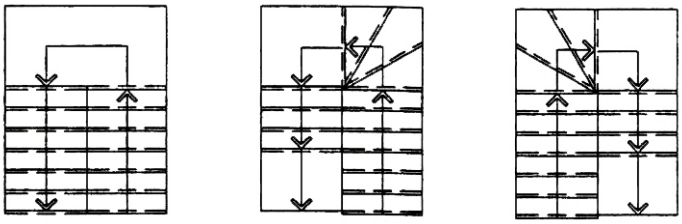


Figure IV-5 Stair Variations

(Source: Friedman, 2002: P96)

An open building process defines the hierarchy of the Shell and the Infill which make it easier for future adaptation and resulting maintenance. The following chapter gives more detailed descriptions of the Shell and the Infill including spatial layouts and MEP systems.

SHELL

1. A single unit:

The Shell includes the building structure, the exterior façade and roof, vertical utility shaft(s), main piping lines into and within the unit, and the common yard fence. In order to avoid pipes running across under the ceiling and to offer maximum ceiling height, two utility shafts (one of them is adjacent to the staircase) are adopted in this study. The only place that piping needs to run from one shaft to the other is in the basement, which is acceptable as the basement is only used for MEP facilities. Two utility shafts house all the Shell's vertical piping. The horizontal piping will be located in the Infill walls or under the counters (The piping system will be discussed later). The Shell (diagrams shown in **Figure IV-6** and **Figure IV-7** on the next two pages) is provided by housing developers. That is to say, in this study, housing consumers can only have an option to choose it or not to choose it, instead of providing their own preference. Of course, it is possible that part of the exterior of the housing unit is included in the Infill decision "package", but for this study that is not the case.

The diagram in **Figure IV-8** on page 40 shows a single unit without Infill part.

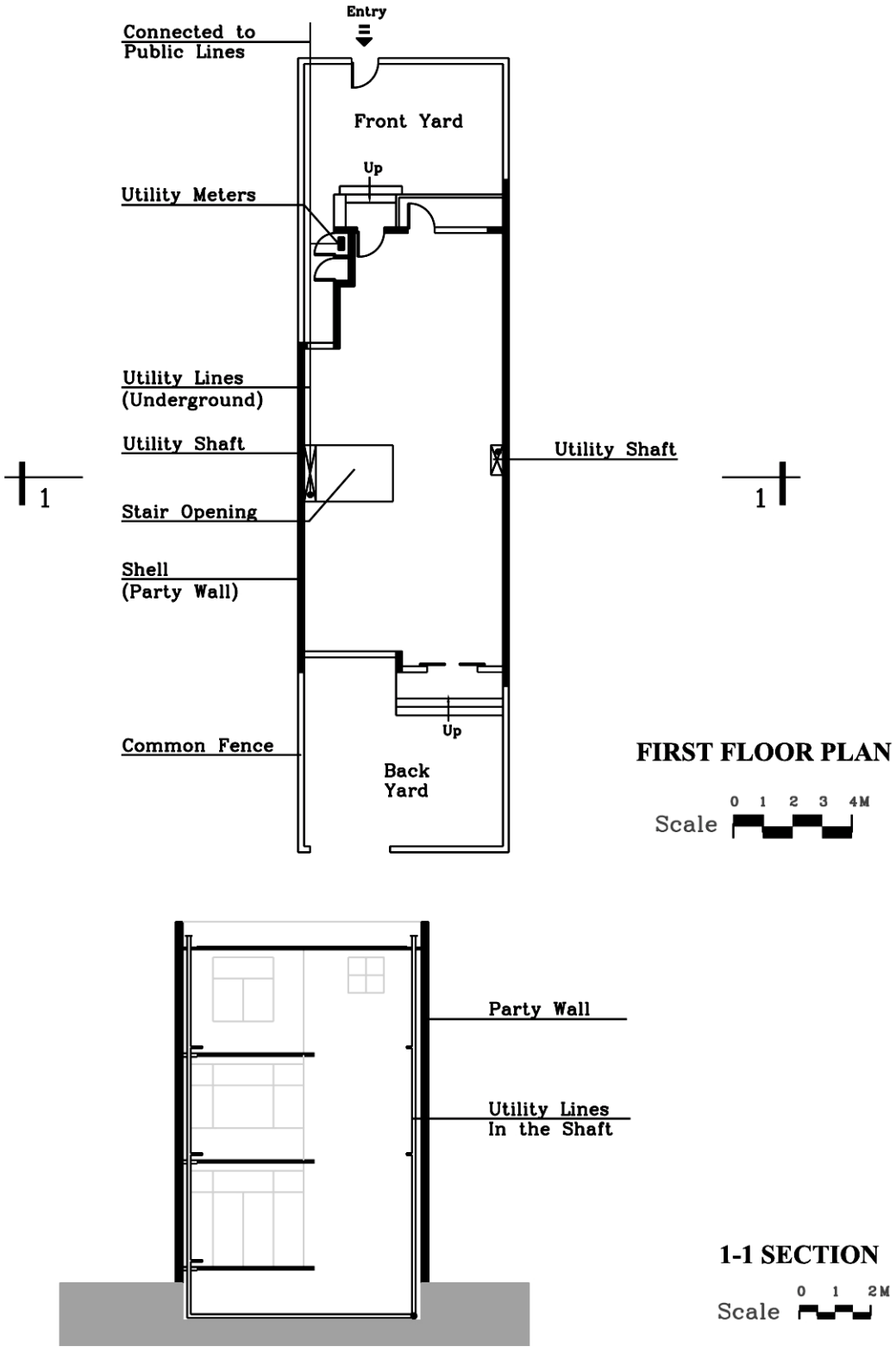


Figure IV-6 Single Unit Shell - 1

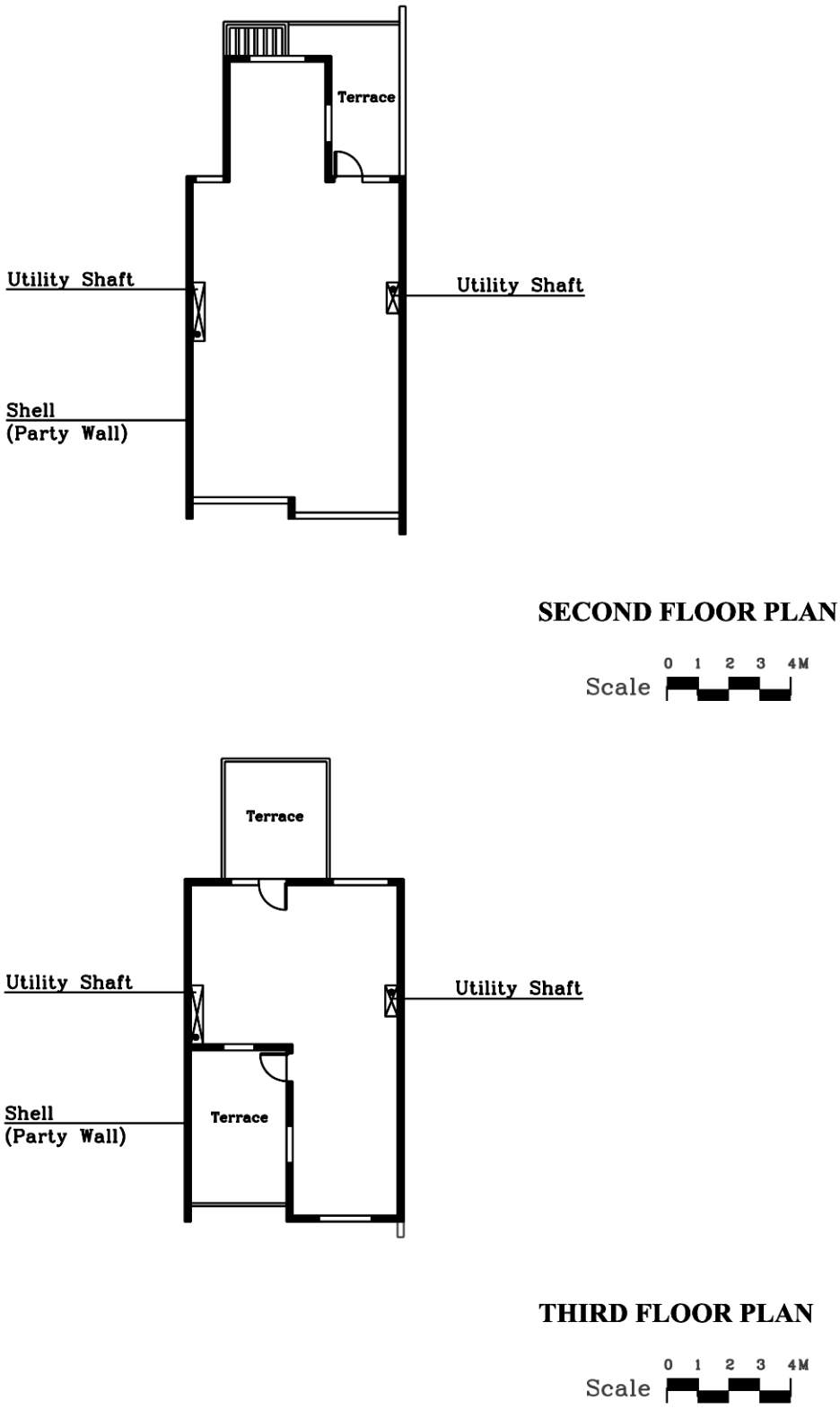


Figure IV-7 Single Unit Shell - 2

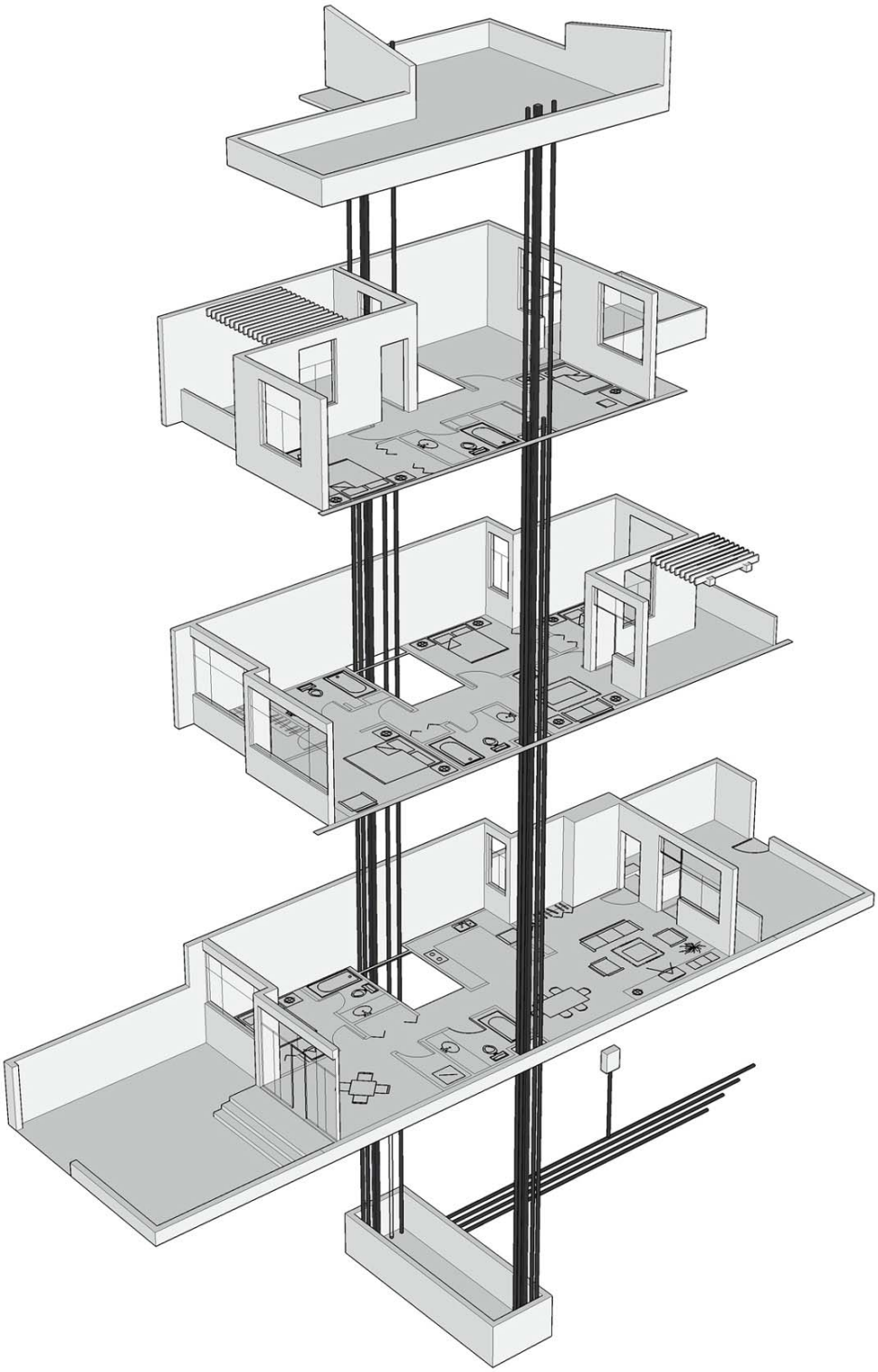


Figure IV-8 Single Unit without Infill

2. **Multiple units:**

The combination of single units can be different, resulting to various options of site plans. One option of the site plans for six units is shown in the diagram in **Figure IV-9** on the next page. The vehicle and the pedestrian movement are separated in order to create a safe living environment. Vehicles can not run on the road which is only for pedestrians. The children's playground provides a place for kids. It can also be used as a gathering place for seniors. The amount of guest parking should be decided according to the building code. In case of too many cars coming during a certain time period, the off street space can also be used as a temporary parking lot.

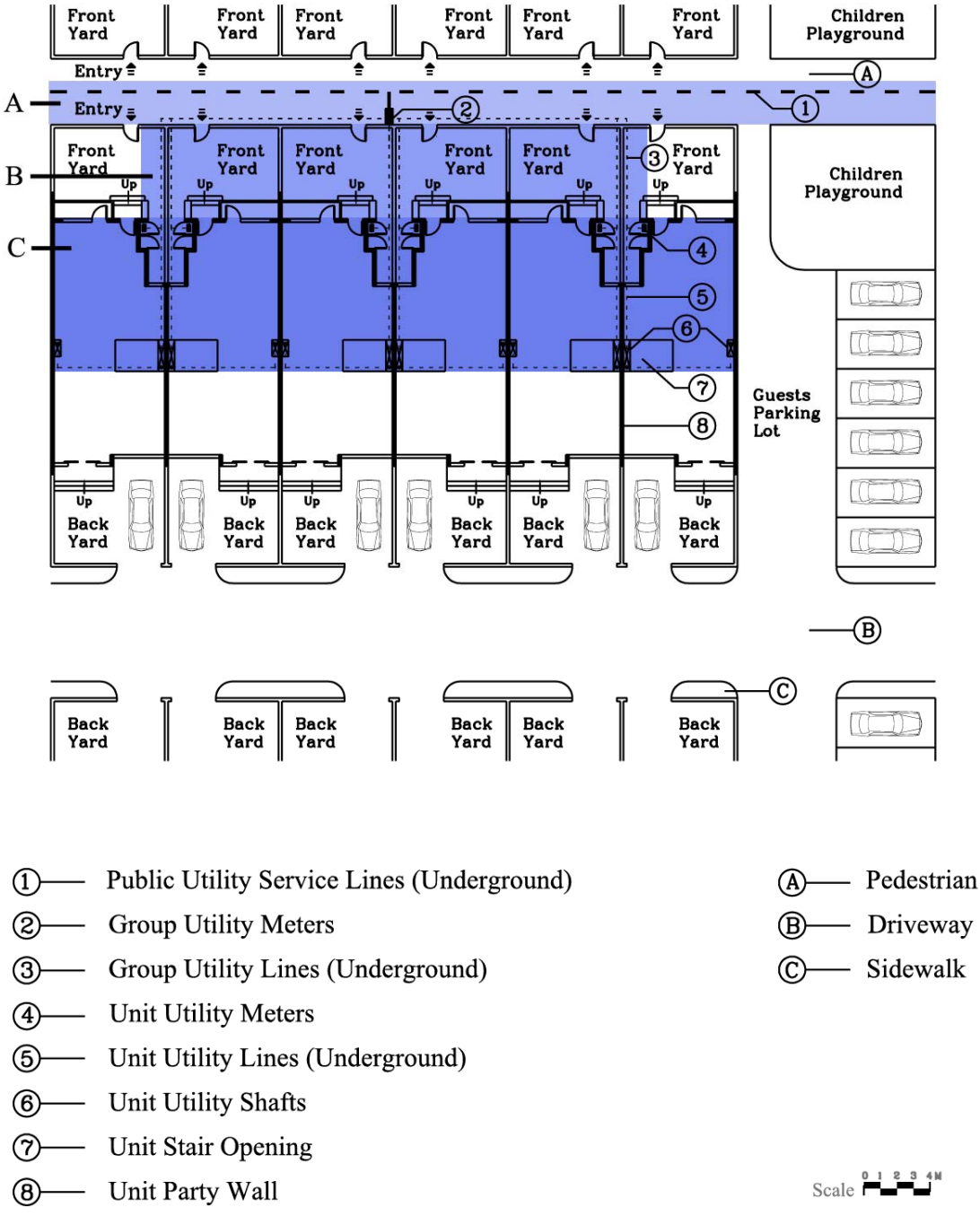


Figure IV-9 Site Plan (One Option)

In the diagram in **Figure IV-9** on the front page, three parts in different color tones show which part is controlled by whom. Utility companies will be responsible for part A, housing management companies will be responsible for part B, and housing occupants will be responsible for part C. This means responsibility for each part is distributed among a number of different players.

For each housing group, utility companies only need to check the group utility meters once a month. They are responsible for the maintenance of the group meters and the pipes connected from their companies to these meters. This is the major managerial method in today's Chinese housing market.

The housing management company needs to check both group utility meters and unit utility meters. If the sum from the unit meters does not equal to the amount of the group meter, the difference will be distributed evenly to each unit. That means each housing unit needs to pay for this extra cost; otherwise, the management company will pay for that. Which way will work is based on the contract between the housing management company and the housing occupants.

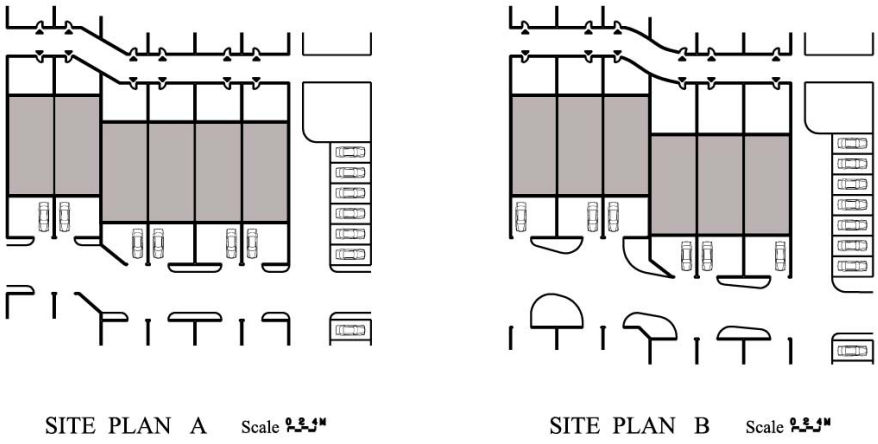


Figure IV-10 Different Site Plans

The diagrams in **Figure IV-10** show two other options of site plans for six units: Site Plan A and Site Plan B (tone color represents single unit).

The amount of the units in a row can also be different, but the total length of each row should not exceed the maximum length required by the local fire department.

The aerial perspectives in **Figure IV-11** and **Figure IV-12** (on page 45) show different views from the front yard and back yard of the six townhouse units. The part in red color is the Infill partition walls. The other part is the Shell that includes common walls, façade elements, and some parts of utility lines.

Figure IV-11 Aerial View from Front Yard

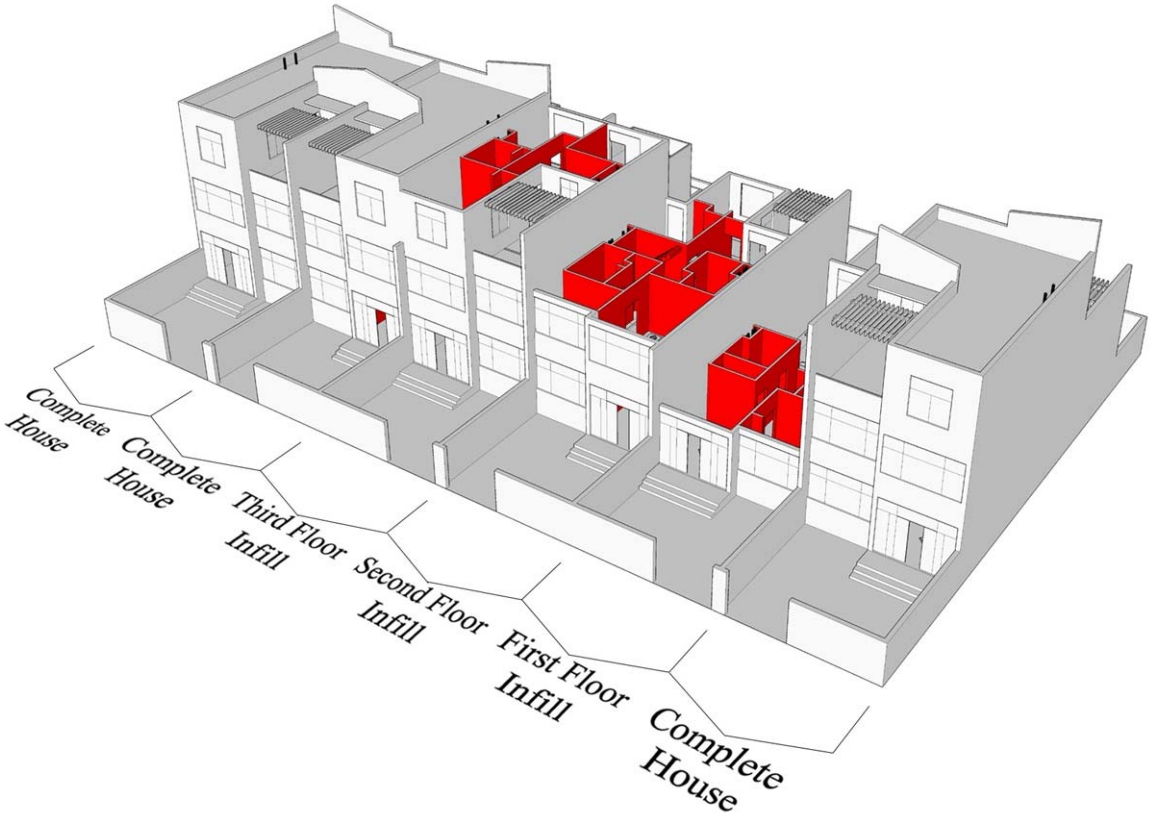


Figure IV-12 Aerial View from Back Yard

INFILL

1. Spatial variations

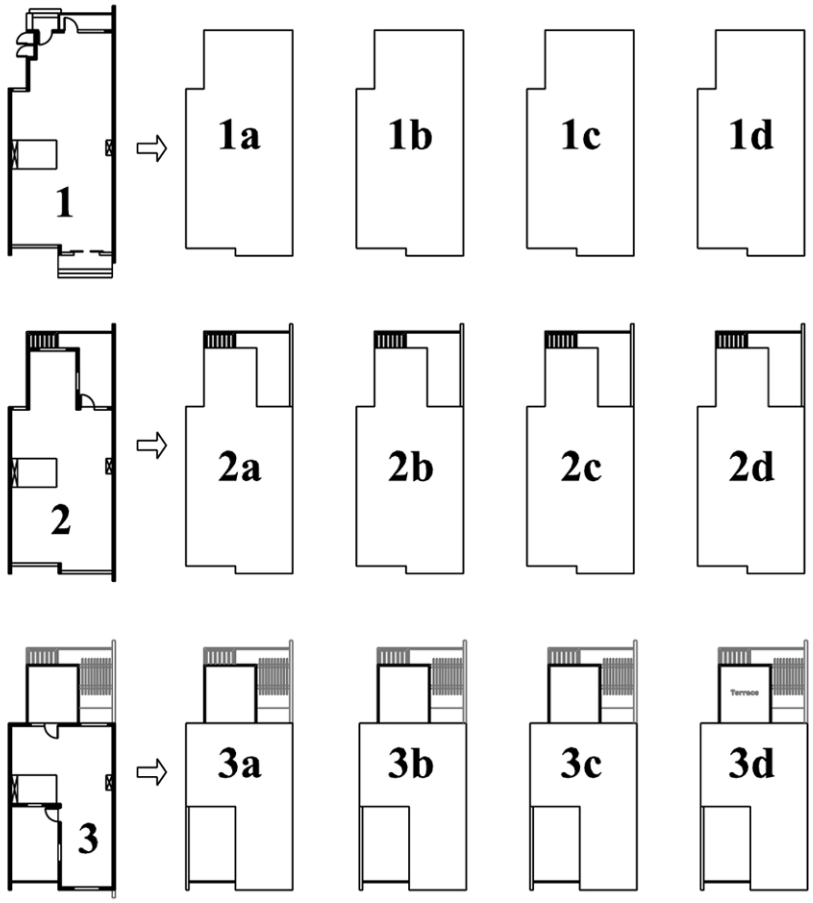


Figure IV-13 Spatial Variations Diagram

Based on the same Shell, many interior spatial layouts are possible. In principle, decisions of each floor plan are independent from any other floor plans. The diagrams in **Figure IV-13** show twelve variations for three floor plans in one unit based on the same Shell. 1a,1b, 1c, and1d are four variations for the first floor plan, 2a, 2b, 2c, and 2d are four variations for the second floor plan, and 3a, 3b, 3c, and 3d are four variations for the third floor plan. The detailed floor plans will be shown in **Figure IV-14** on the next page.

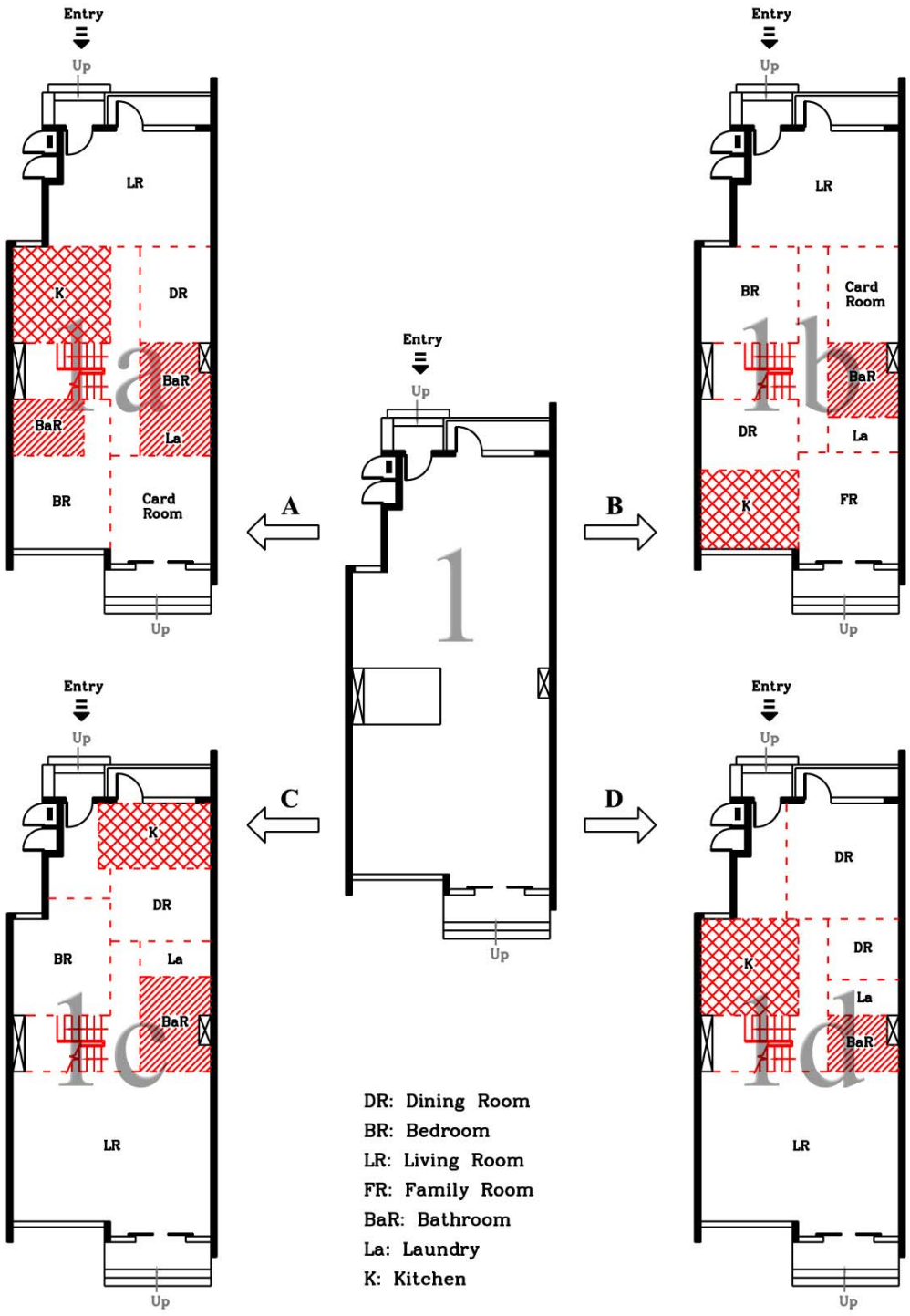


Figure IV-14 First Floor Plan Variations

The diagrams in **Figure IV-14** (on the front page) show four variations of the first floor plan based on the same Shell. Three of them provide convenience for senior people; this design idea has much significance because creating a suitable living environment for seniors has become more and more important in Chinese current society. In October 2000, the Chinese central government made a claim to the world that China had 132 million seniors aged more than 60 and had become an "old country"; the size of that population group kept on growing at 3.2% each year (Zhu, 2004). Also, according to the report from Shanghai Civil Administration Bureau and published on *Anbang Real Estate Research, Sept.20, 2004*, 50% of the city population in Shanghai will be seniors aged more than 65 in 2030. Detailed descriptions of the variations are shown in the following.

Variation 1a: A living room faces the front yard. A kitchen and a dining room are located in the middle part. A shared ½ bathroom with laundry machine inside it is on the opposite side of the staircase. A bedroom with its own bathroom and a card room all face the back yard.

Variation 1b: A living room faces the front yard. A bedroom is located on the position where the kitchen is located in variation 1a, and its opposite side is a card room. This bedroom does not have its own bathroom. A shared full bathroom is on the opposite side of the staircase and next to the laundry. A kitchen faces the back yard and a dining room is located between the kitchen and the staircase. A family room also faces the back yard.

Variation 1c: A living room faces the back yard. A shared full bathroom, with separate lavatory and water closet, is on the opposite side of the staircase and next to the laundry. A bedroom is located on the same position as that in variation 1b, but it has a

little more closet space. This bedroom does not have its own bathroom. A kitchen faces the front yard. A dining room is located between the kitchen and the laundry.

Variation 1d: A living room faces the back yard. A shared ½ bathroom is on the opposite side of the staircase and next to the laundry. A kitchen is located in the position where the bedroom is located in variation 1b. There is no bedroom in this variation. Two dining rooms are provided. The big one faces the front yard and the small one stays in the middle part and next to the laundry.

Among these four variations, laundry is always located on this floor in a separate space except in variation 1a. Without a bedroom or a bedroom with its own full bathroom on this floor, there is only a ½ bathroom available. The closet is provided as big as possible; more and more people in China like to hang clothes out instead of putting them in suitcases. All kitchens have natural light and ventilation directly from the outside --- even though this is not required by the building code in China, it has become a preference when people choose their house. In variation 1c and variation 1d, one side of the staircase can become a view from the spacious living room if hand-rails and stringers are decorated.

For the second floor plan (diagrams shown in **Figure IV-15** on the next page), four variations of interior layouts are based on whether master bedroom is on this floor or not. 1. When the master bedroom is on this floor, two variations are developed: **Variation 2a** with master bedroom facing the back yard and **Variation 2b** with master bedroom facing the front yard. Both of them have two additional bedrooms and a shared full bathroom. **Variation 2a** also has a family room facing the front terrace. The terrace in **Variation 2b** is used by the person(s) living in the master bedroom. 2. When the

Figure IV-15 Second Floor Plan Variations

master bedroom is not on this floor, two other variations are developed: **Variation 2c** with a family room facing the back yard and **Variation 2d** with a family room facing the front terrace. They both have three bedrooms and a shared full bathroom on this floor besides the family room. One of the bedrooms in **Variation 2d** has its own bathroom.

For the third floor plan (diagrams shown in **Figure IV-16** on the next page), four variations of interior layouts are based on whether the master bedroom is on this floor or not. 1. When master bedroom is on this floor, two variations are developed: **Variation 3c** with master bedroom facing the front terrace and **Variation 3d** with master bedroom facing the back yard. Both of them have a study room. The front terrace in **Variation 3c** is used by the person(s) living in the master bedroom. The front terrace in **Variation 3d** can be accessed through the study room. The back terrace on these two choices can be accessed through the staircase. 2. When master bedroom is not on this floor, other two variations are developed: **Variation 3a** provides two bedrooms, a small fitness room, and a public full bathroom. **Variation 3b** provides one bedroom with its own bathroom, and a big fitness room. The front terrace on these two variations is accessed through the fitness room while the back terrace can be accessed through the staircase.

Each master bedroom has a walk-in closet, no matter whether it is located on the second floor or the third floor, as well as facing the front yard or back yard. These different variations provide more choices for housing consumers in order to meet their diverse requirements.

For this study example, only four variations for each floor plan are developed. Many more variations can be developed if the study goes further to more detailed categorizations because each variation can have sub-variations and each sub-variation can

Figure IV-16 Third Floor Plan Variations

also have its own sub-variations, and so forth.

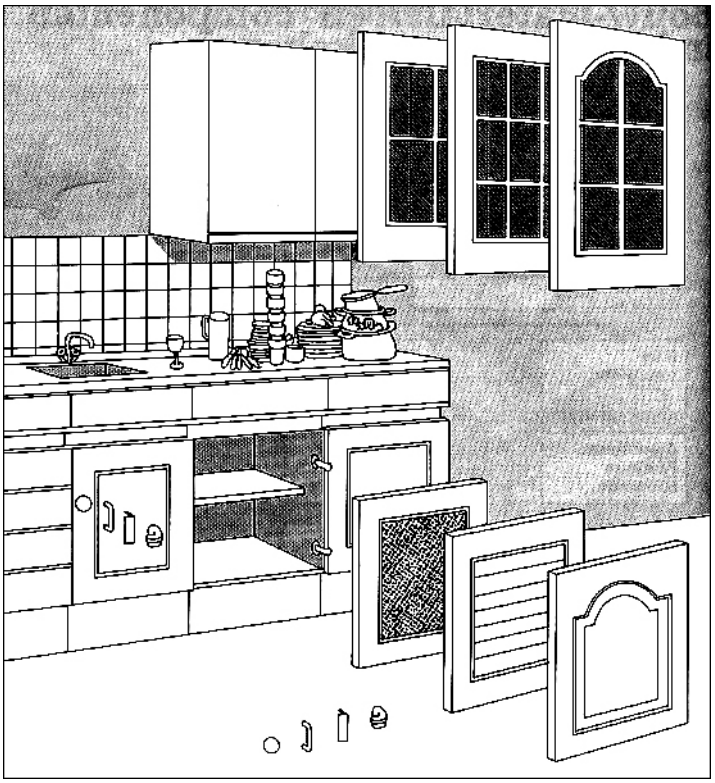


Figure IV-17 Variation Diagram

(Source: Van Randen, Age, 1989: P16)

The above diagram **Figure IV-17** clearly shows this relation. For example, in the same kitchen space, the layout of the sink, range, counter, and cupboard can be different. For the same cupboard position, the door of the cupboard can be different. For the same type of the door, the material can be different. For the same material, the color can be different, etc. All those constitute sub-variations, sub-sub-variations, etc.

2. Utility systems

The utility systems include piped systems, cabling systems, and a ventilation system. In the conventional building process, plumbing pipes penetrate floor slabs in “sleeves” (or floor slabs are drilled later) depending on each fixture’s position. In the open building process, pipes, cables, and ducts use a utility shaft as a dedicated channel to connect each floor. Within each floor, these parts are routed along the Infill walls or sub-floor and connected to the equipment, assuming no horizontal pipe will cross a doorway. The following will show the details.

2.1 Piped systems

The piped systems include water supply and drainage system, heating and air-conditioning system, and gas piping system. The perspective diagram of the Shell part of the piped systems is shown in **Figure IV-18** on the next page. The Infill part of the piped systems is developed according to the idea on this diagram.

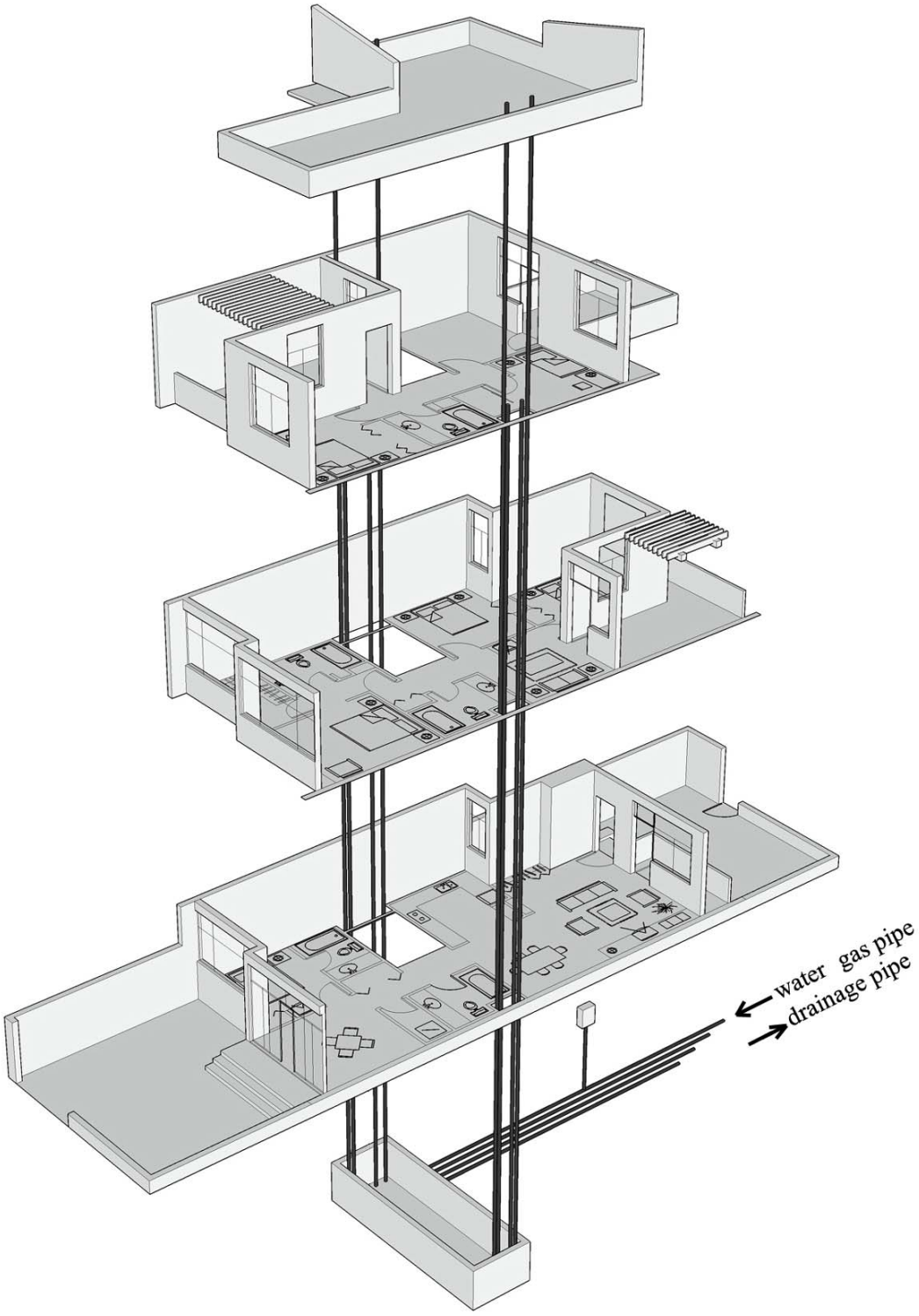


Figure IV-18 Shell Part of the Piped Systems in Single Unit

2.1.1 Water supply and drainage system

The water supply and drainage system (diagrams shown in **Figure IV-19** and **Figure IV-20** on the next two pages) includes water (cold and hot) pipes and drainage pipes. The unit cold water pipe is connected to the group cold water supply pipe by a unit water meter, and then connected to the city cold water supply pipe by a group water meter. The hot water pipe only exists within the unit, and is connected to the unit water heater which is located in the backyard of each unit.

The drainage pipe is connected to the group drainage pipe, and then connected to the city drainage pipe. The standard downward outlet toilet is replaced by the floor mounted rear discharge toilet. Open building criteria suggest that in general pipes serving one floor's equipment should not penetrate into the ceiling of the next lower floor. The bath tub or shower tub should be raised to a reasonable height in order to slope the drainage pipe above the floor to the vertical Shell pipe shaft.

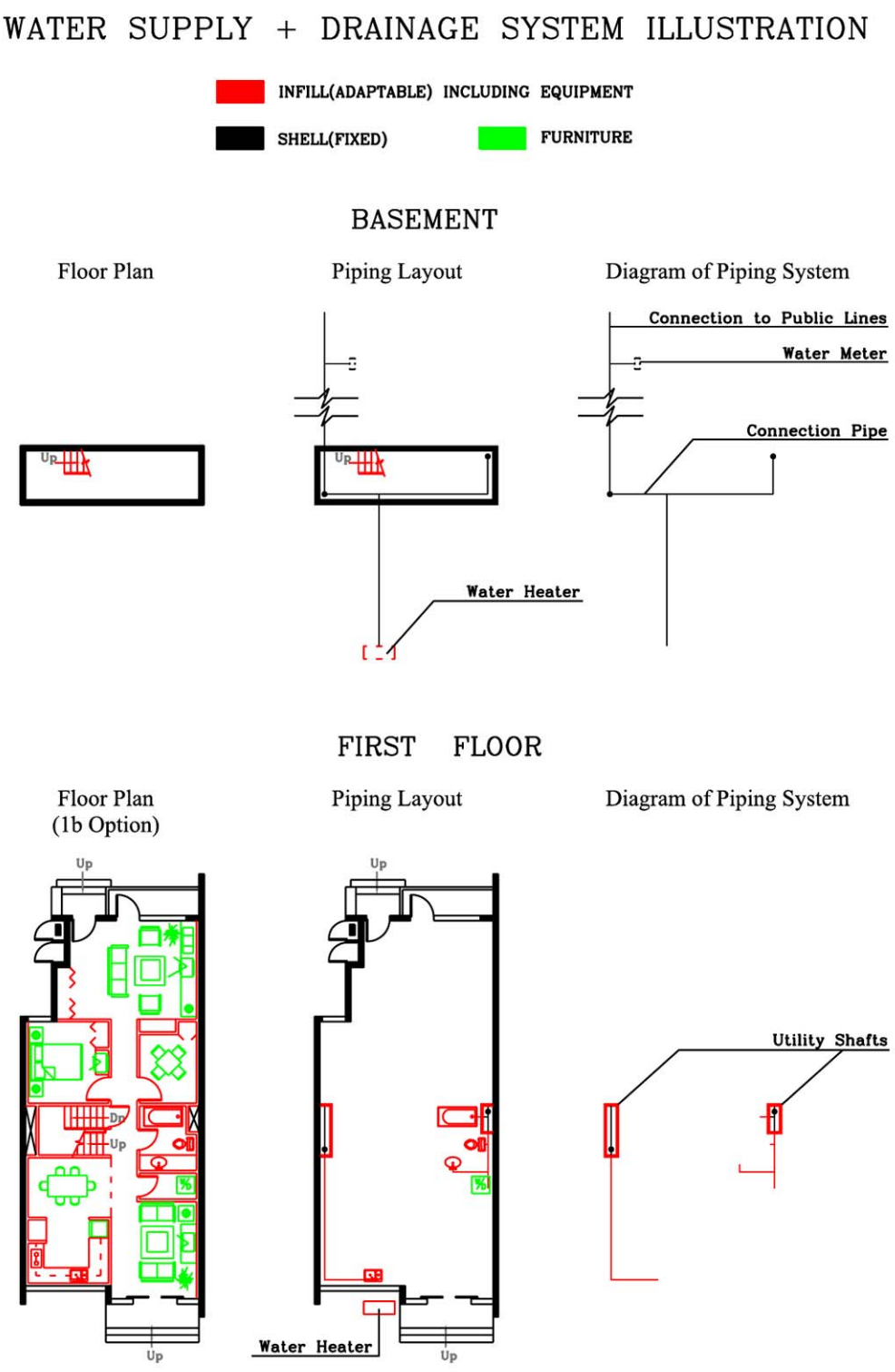

WATER SUPPLY + DRAINAGE SYSTEM ILLUSTRATION
INFILL(ADAPTABLE) INCLUDING EQUIPMENT
SHELL(FIXED)
FURNITURE
BASEMENT
Floor Plan
Piping Layout
Diagram of Piping System
Connection to Public Lines
Water Meter
Connection Pipe
Water Heater
FIRST FLOOR
Floor Plan
(1b Option)
Piping Layout
Diagram of Piping System
Utility Shafts
Water Heater
Up
Dn

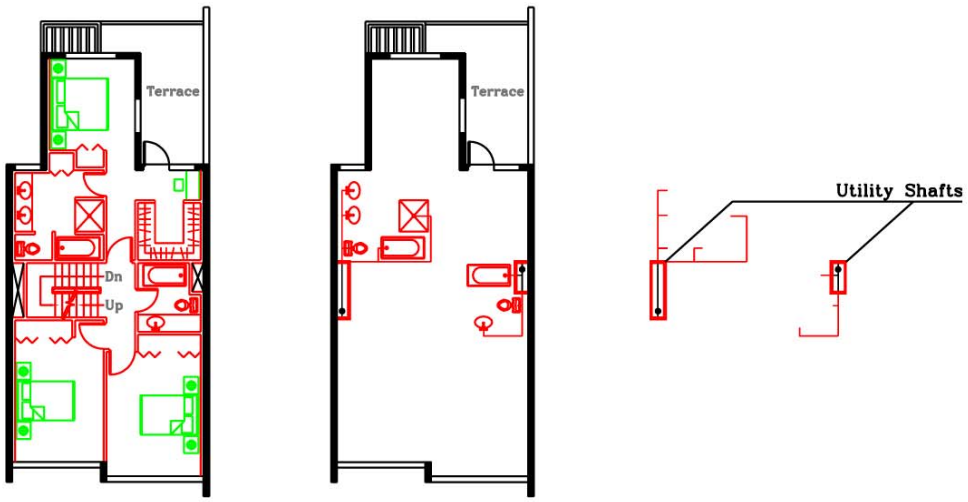
Figure IV-19

SECOND FLOOR

Floor Plan
(2b Option)

Piping Layout

Diagram of Piping System



THIRD FLOOR

Floor Plan
(3b Option)

Piping Layout

Diagram of Piping System

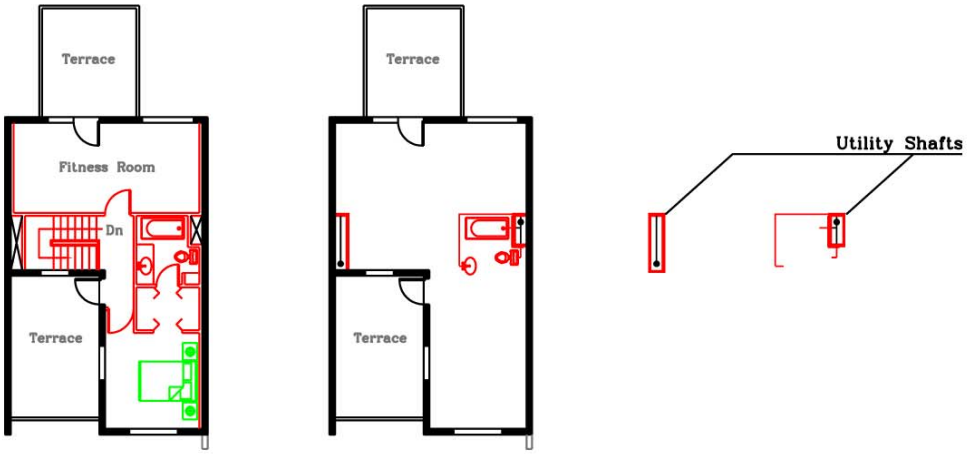


Figure IV-20

2.1.2 Heating and air-conditioning system

The heating and air-conditioning system refers to refrigerant piping system. The diagrams in **Figure IV-22** and **Figure IV-23** on the next two pages show the refrigerant piping and indoor unit locations in each room. Assume RFC160FX manufactured by MITSUBISHI HEAVY-Haier is adopted in this townhouse; the outdoor unit will be placed on the back yard and connected to the indoor units through pipes. According to the manufacturer's product specification diagram shown in **Figure IV-21**: 1. one outdoor unit can have up to sixteen indoor units; 2. the vertical distance between outdoor unit and indoor unit can be up to thirty meters if outdoor unit is placed on the ground level; 3. the vertical distance between indoor units can be up to eight meters; 4. various rooms can have different temperatures, and it can be adjusted by one control panel; and 5. one outdoor unit only occupies 0.72m x 1.35m floor space.

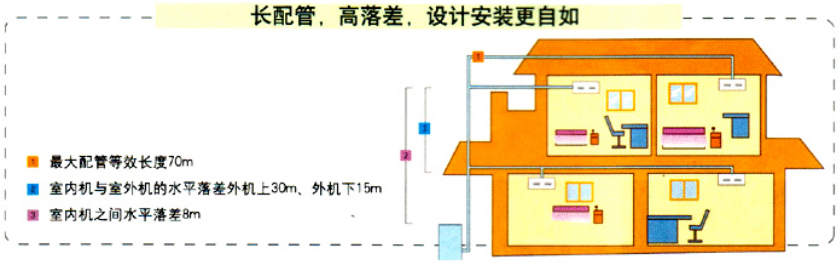


Figure IV-21 MITSUBISHI HEAVY-Haier air conditioning illustration

(Source: http://www.mhaq.cn/pro/cp5.htm)

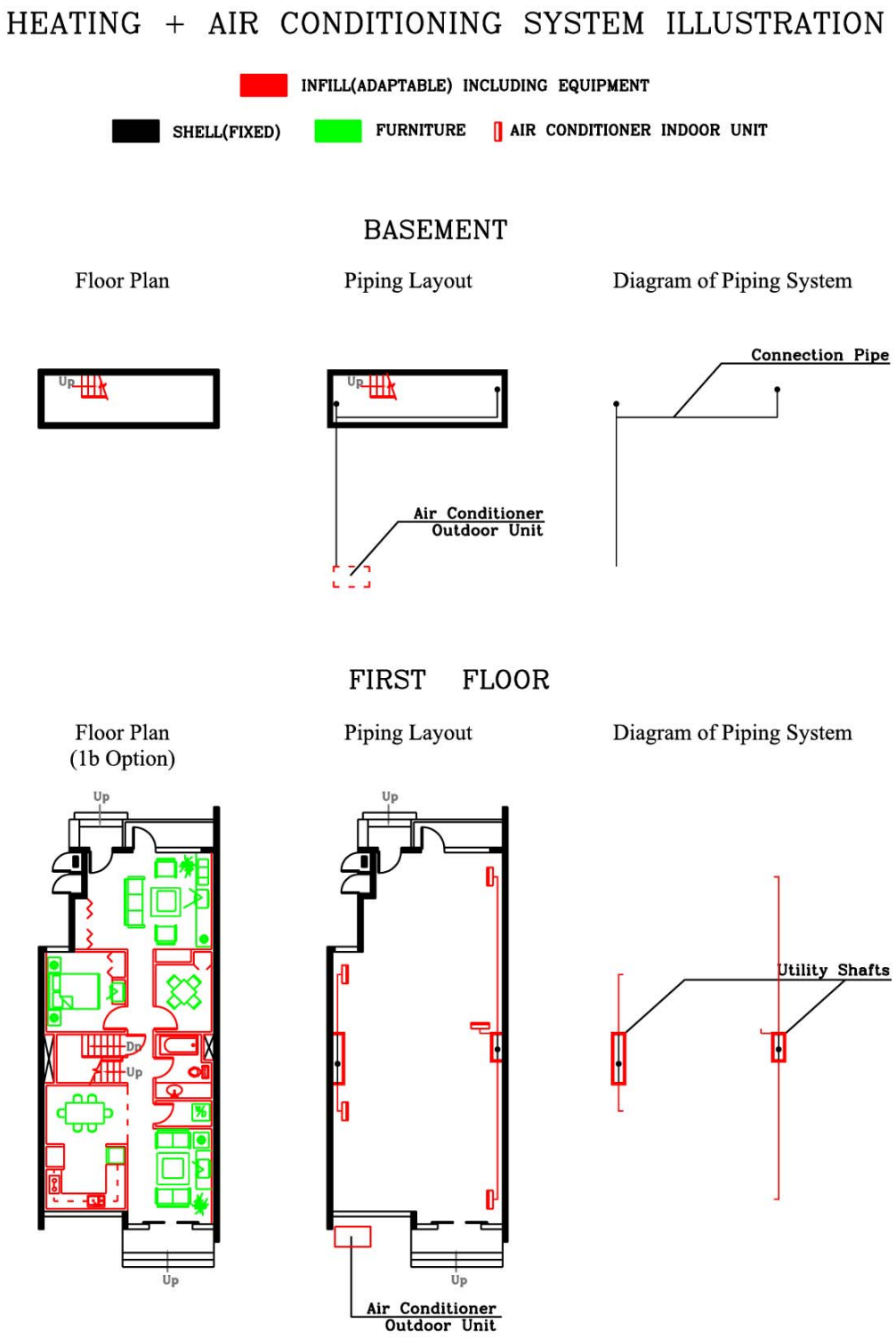

HEATING + AIR CONDITIONING SYSTEM ILLUSTRATION
INFILL(ADAPTABLE) INCLUDING EQUIPMENT
SHELL(FIXED)
FURNITURE
AIR CONDITIONER INDOOR UNIT
BASEMENT
Floor Plan
Piping Layout
Diagram of Piping System
Up
Connection Pipe
Air Conditioner
Outdoor Unit
FIRST FLOOR
Floor Plan
(1b Option)
Piping Layout
Diagram of Piping System
Dn
Utility Shafts
Air Conditioner
Outdoor Unit

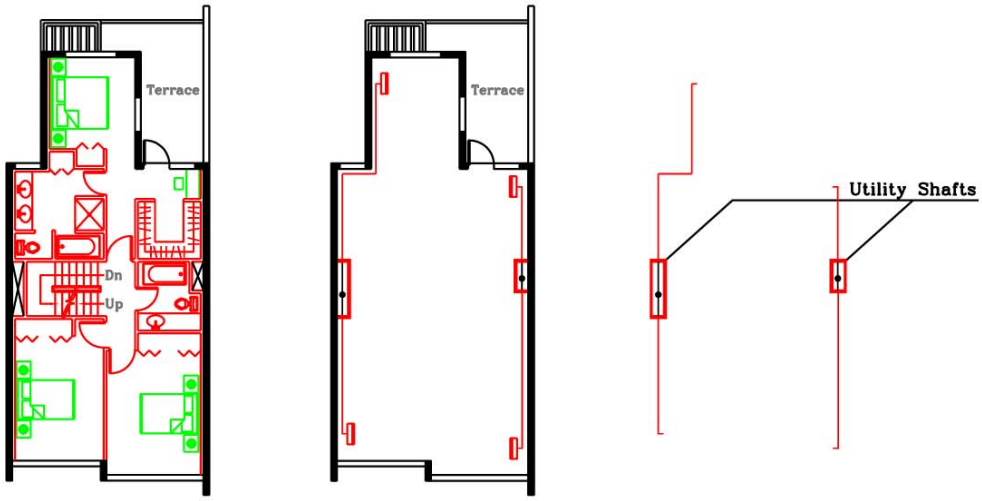
Figure IV-22

SECOND FLOOR

Floor Plan
(2b Option)

Piping Layout

Diagram of Piping System



THIRD FLOOR

Floor Plan
(3b Option)

Piping Layout

Diagram of Piping System

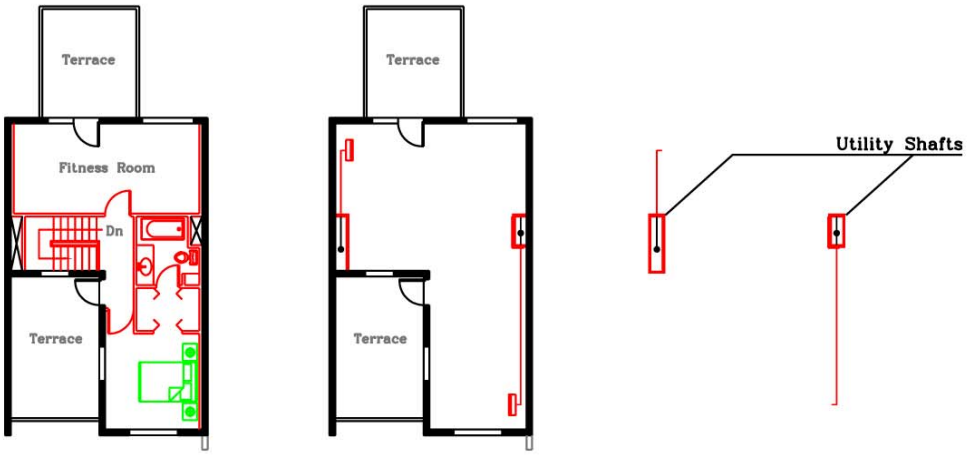


Figure IV-23

2.1.3 Gas piping system

The diagrams in **Figure IV-25** and **Figure IV-26** on the next two pages show gas piping in a single unit. Assume the gas here is only used in the kitchen for cooking. The unit gas pipe is connected to the group gas supply pipe by a unit gas meter, and then connected to the city gas supply pipe by a group gas meter.

(Source: http://www.ykqxwj.com/cpxl1.htm)

(Source: http://detail.china.alibaba.com/buyer/offerdetail/15-1032731-23267895.html)

Figure IV-24 Kitchen Gas Range and Pipes

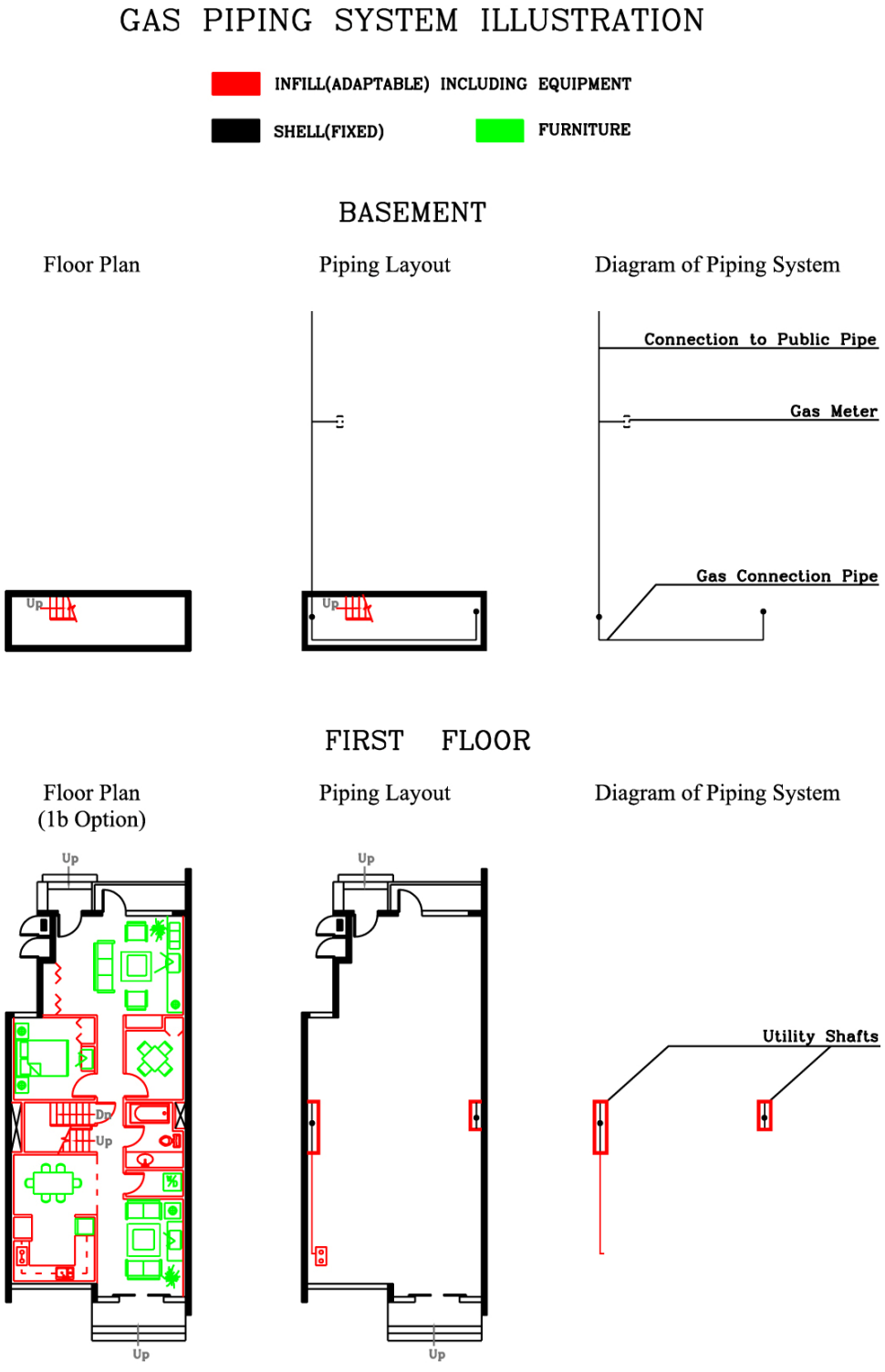
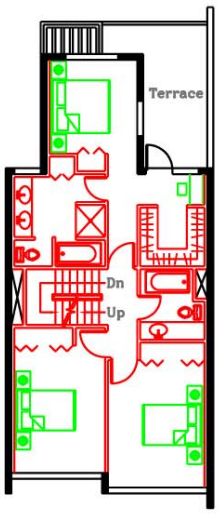

GAS PIPING SYSTEM ILLUSTRATION
INFILL(ADAPTABLE) INCLUDING EQUIPMENT
SHELL(FIXED)
FURNITURE
BASEMENT
Floor Plan
Piping Layout
Diagram of Piping System
Connection to Public Pipe
Gas Meter
Gas Connection Pipe
Up
FIRST FLOOR
Floor Plan
(1b Option)
Piping Layout
Diagram of Piping System
Utility Shafts
Up
Dn

Figure IV-25

SECOND FLOOR

Floor Plan
(2b Option)



Piping Layout

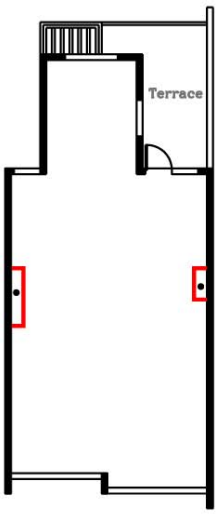
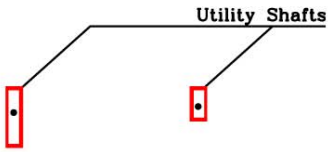
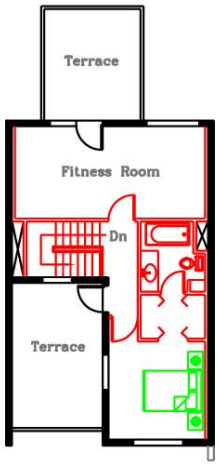


Diagram of Piping System



THIRD FLOOR

Floor Plan
(3b Option)



Piping Layout

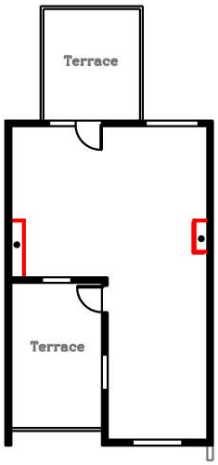


Diagram of Piping System

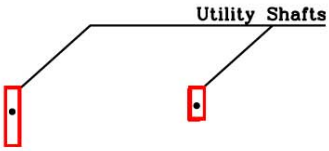
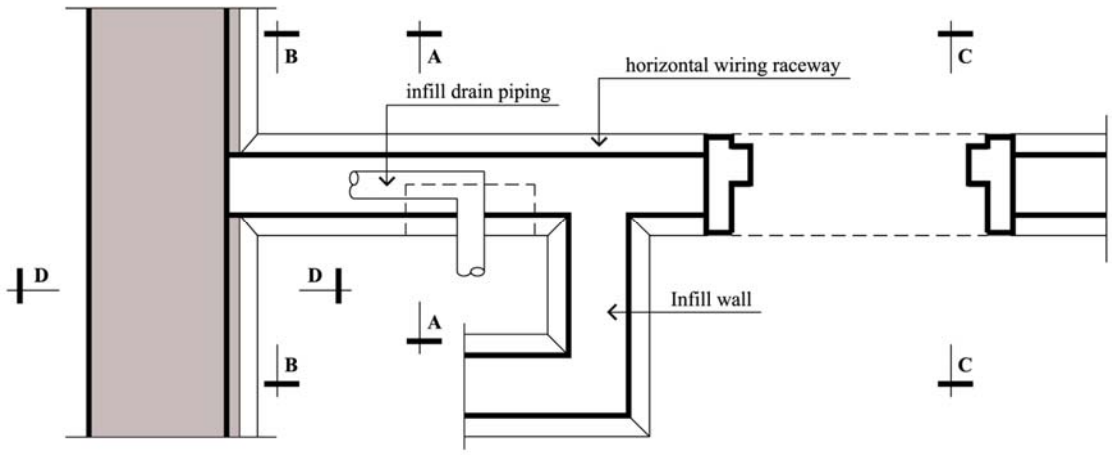


Figure IV-26

2.2 Cabling systems

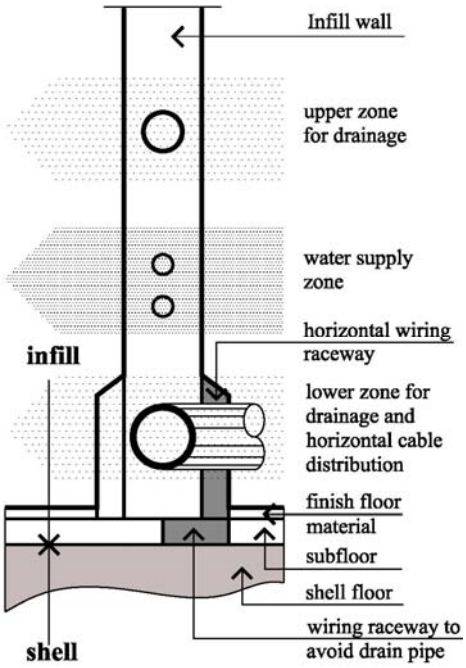
The cabling systems include electricity cabling system and data cabling system. Assume “Plugmold” manufactured by WIREMOLD is adopted in this townhouse to house horizontal cabling. A metal channel with cover is used under the doorway and where drainage pipes must be avoided. 1” thick Homosote covers the whole floor as a sub-floor above the structural concrete floor. Above the Homosote is the finish floor. All these details are shown in reference diagrams in **Figure IV-27**. The perspective diagram of the Shell part of the cabling system is shown in **Figure IV-28** on page 68. The Infill part of the cabling system is developed according to the idea on this Shell diagram.



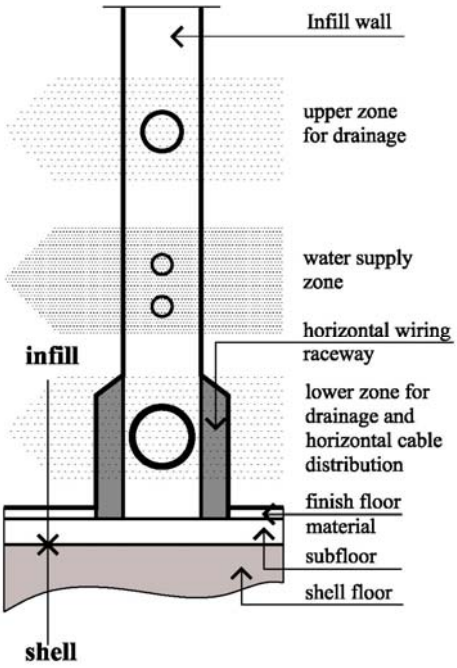
Partial Plan

Figure IV-27 Raceway Illustration (Source: Kendall, 2006)

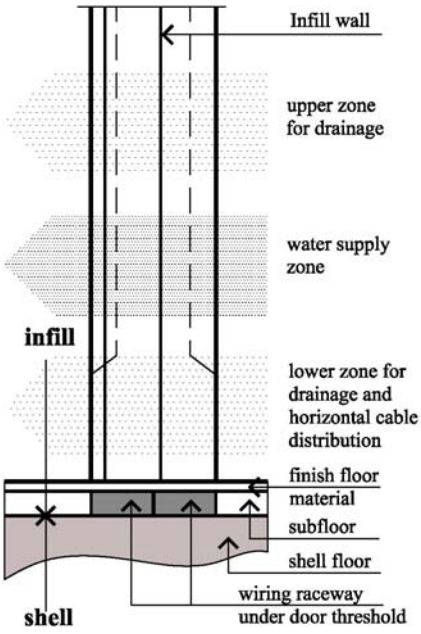
(Sections on the next page)



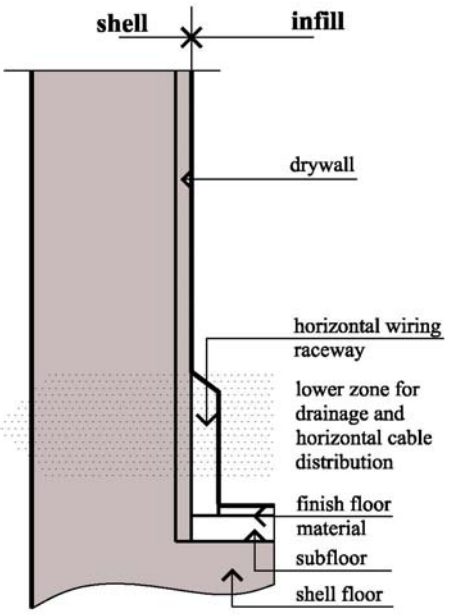
A-A Section lower drainage emerges from the wall



B-B Section the Infill wall



C-C Section the doorway



D-D Section the Shell wall

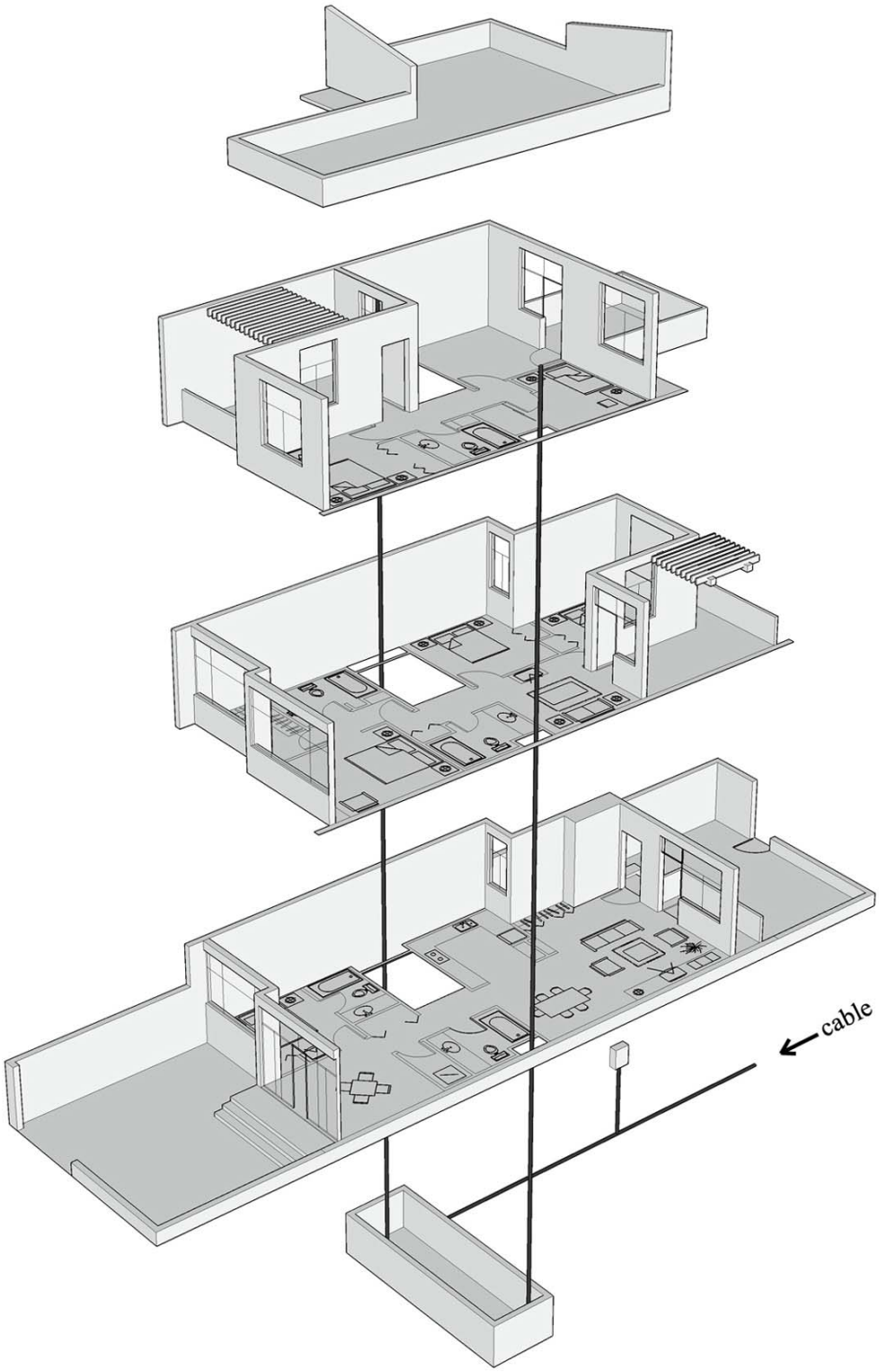


Figure IV-28 Shell Part of the Cabling Systems in Single Unit

2.2.1 Electricity cabling system

The electricity cabling system (diagrams shown in **Figure IV-31** and **Figure IV-32** on the next two pages) includes electricity cables, outlets, and switches. The unit electricity cable is connected to the group electricity supply cable by a unit electricity meter, and then connected to the city electricity supply cable by a group electricity meter.

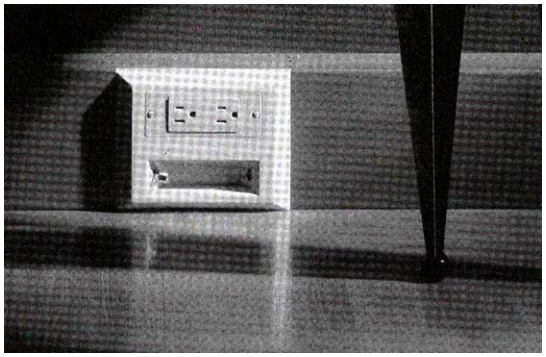


Figure IV-29 Baseboard Raceway

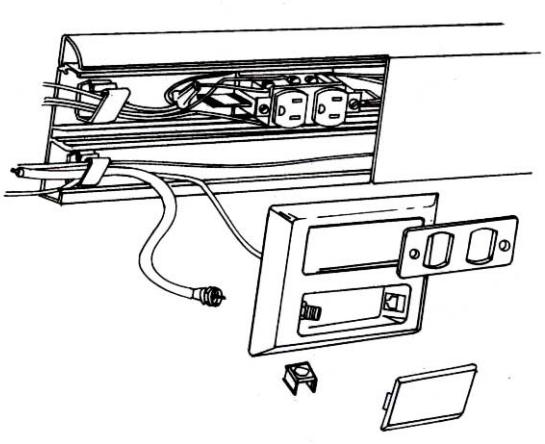


Figure IV-30 Details of a Jack

(Source of the above two: Friedman, 2002: P172)

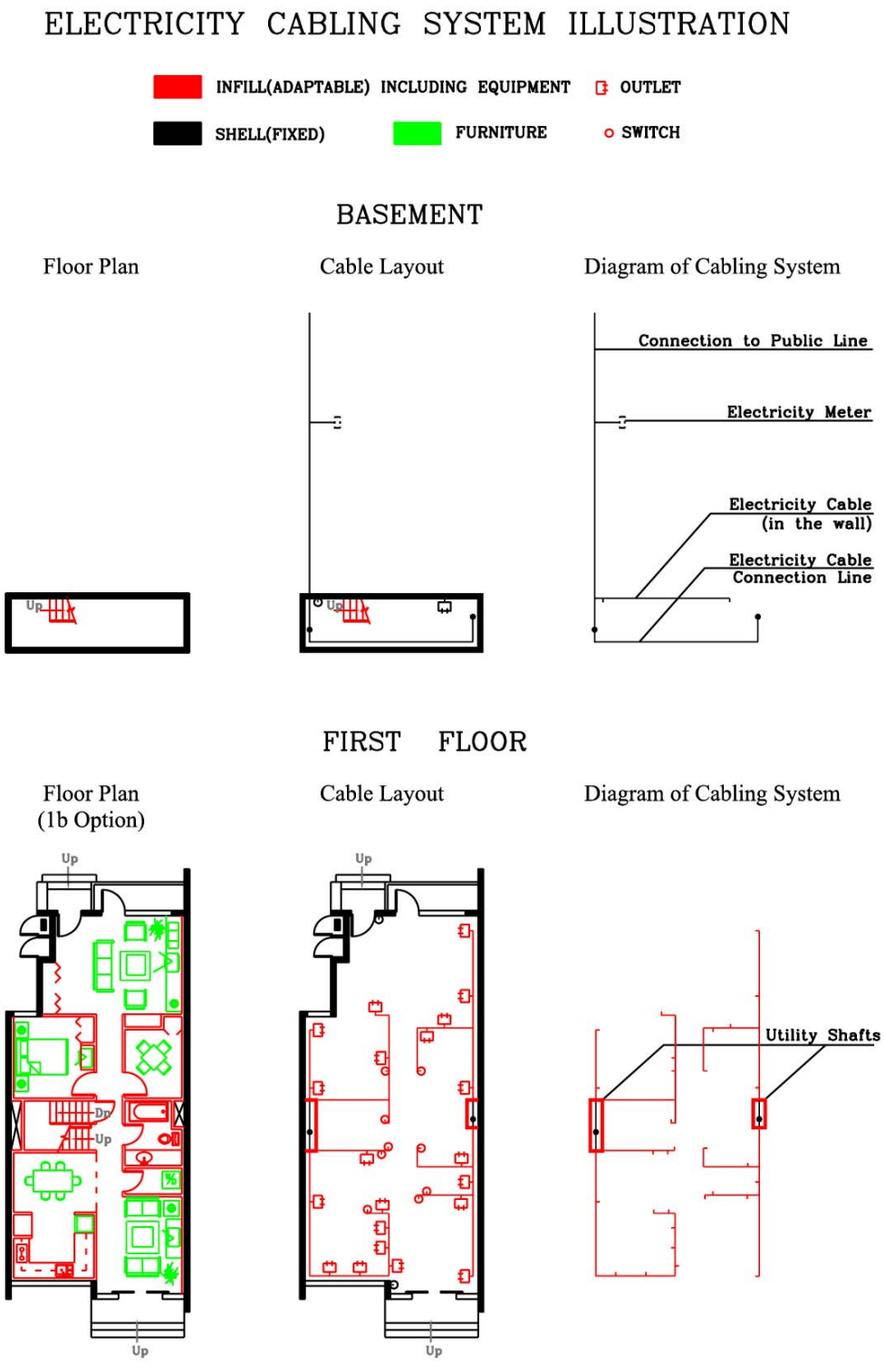
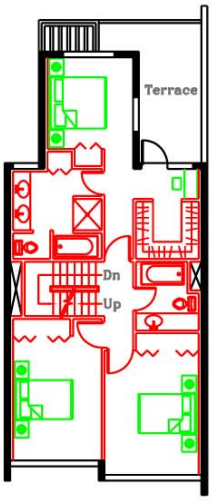

ELECTRICITY CABLING SYSTEM ILLUSTRATION
INFILL(ADAPTABLE) INCLUDING EQUIPMENT
OUTLET
SHELL(FIXED)
FURNITURE
SWITCH
BASEMENT
Floor Plan
Cable Layout
Diagram of Cabling System
Connection to Public Line
Electricity Meter
Electricity Cable (in the wall)
Electricity Cable Connection Line
Up
FIRST FLOOR
Floor Plan (1b Option)
Cable Layout
Diagram of Cabling System
Utility Shafts
Up
Dn

Figure IV-31

SECOND FLOOR

Floor Plan
(2b Option)



Cable Layout

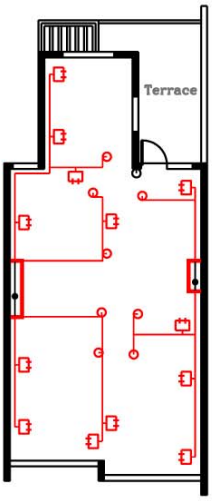
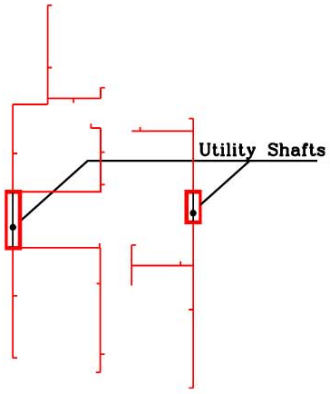
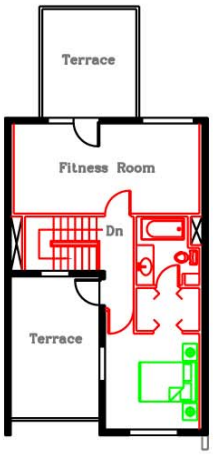


Diagram of Cabling System



THIRD FLOOR

Floor Plan
(3b Option)



Cable Layout

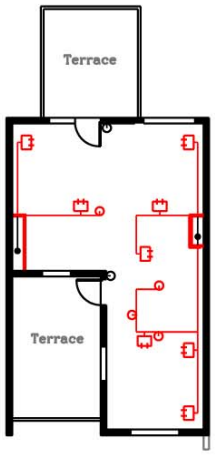


Diagram of Cabling System

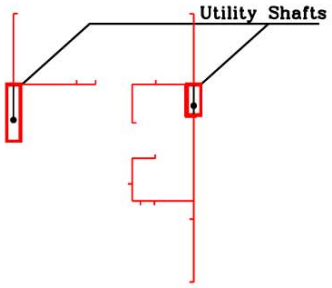


Figure IV-32

2.2.2 Data cabling system

The data cabling system (diagrams shown in **Figure IV-34** and **Figure IV-35** on the next two pages) includes internet cable, TV cable, telephone cable, and their hookups. The unit internet cable is connected to the group internet supply cable by a unit internet distribution box, and then connected to the city internet supply cable by a group internet distribution box. TV cable and telephone cable have the same distribution way with the internet cable.

Figure IV-33

(Source: www.levitonvoicedata.com)

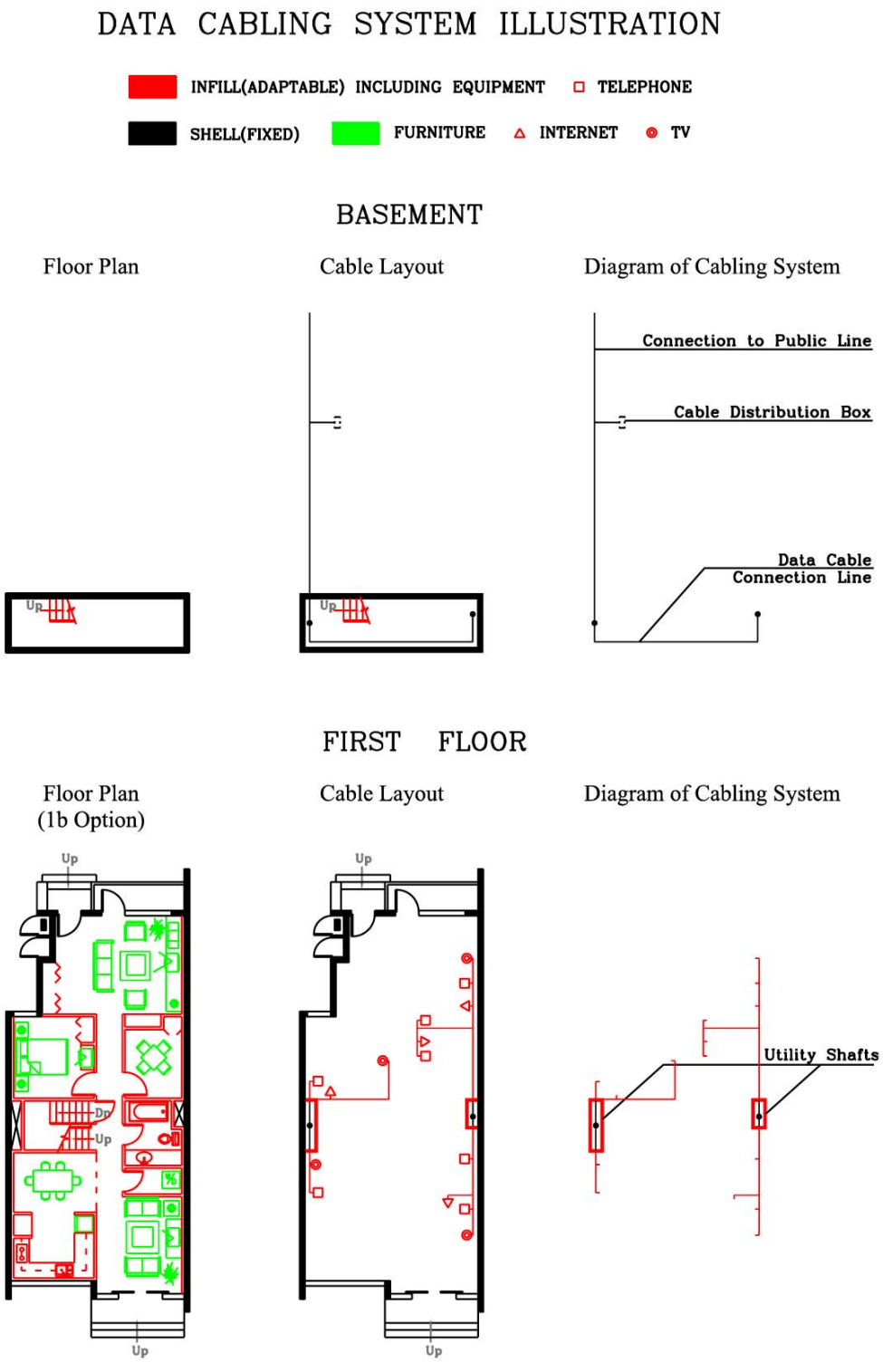

DATA CABLING SYSTEM ILLUSTRATION
INFILL(ADAPTABLE) INCLUDING EQUIPMENT
TELEPHONE
SHELL(FIXED)
FURNITURE
INTERNET
TV
BASEMENT
Floor Plan
Cable Layout
Diagram of Cabling System
Connection to Public Line
Cable Distribution Box
Data Cable
Connection Line
Up
FIRST FLOOR
Floor Plan
(1b Option)
Cable Layout
Diagram of Cabling System
Utility Shafts
Dn
Up

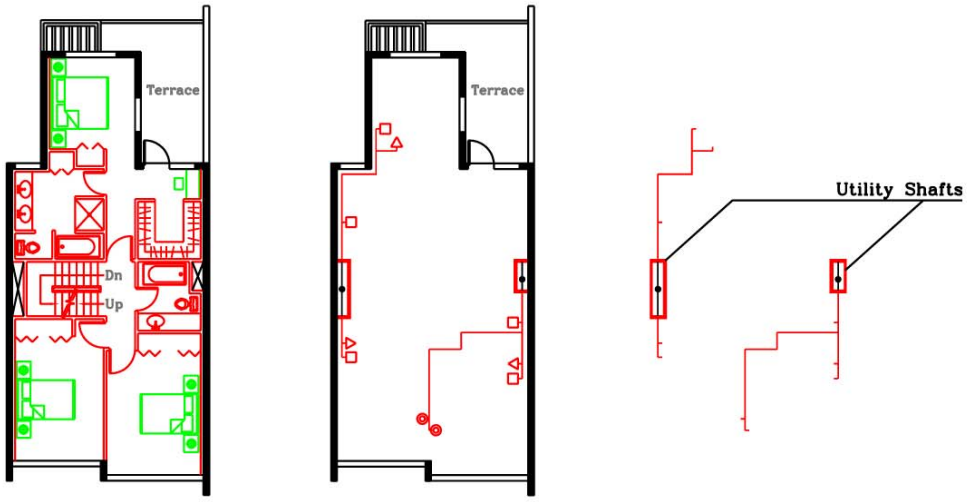
Figure IV-34

SECOND FLOOR

Floor Plan
(2b Option)

Cable Layout

Diagram of Cabling System



THIRD FLOOR

Floor Plan
(3b Option)

Cable Layout

Diagram of Cabling System

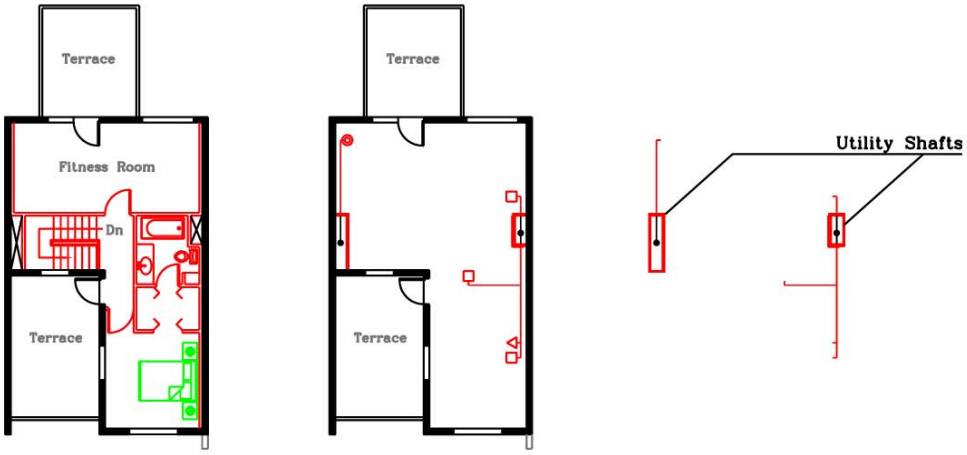
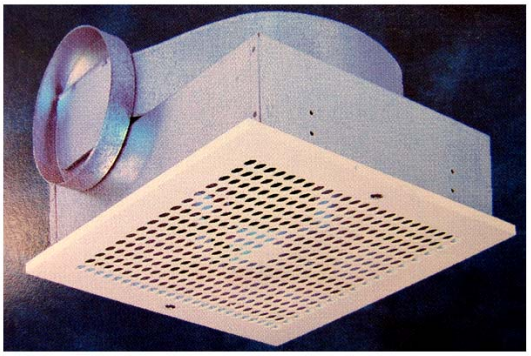


Figure IV-35

2.3 Ventilation system

The ventilation system includes exhaust fans and the related ducts. It also includes the duct connected to the dryer machine in the laundry. The air-conditioning system in this townhouse does not need ducts because it uses refrigerant instead of water or air as cooling medium. The perspective diagram of the Shell part of the ventilation system, and the detailed system diagrams are shown in **Figure IV-37**, **Figure IV-38,** and **Figure IV-39** on the next three pages. The Infill part of the ventilation system is developed according to the idea on this diagram. The duct in the Shell part goes above the top roof.



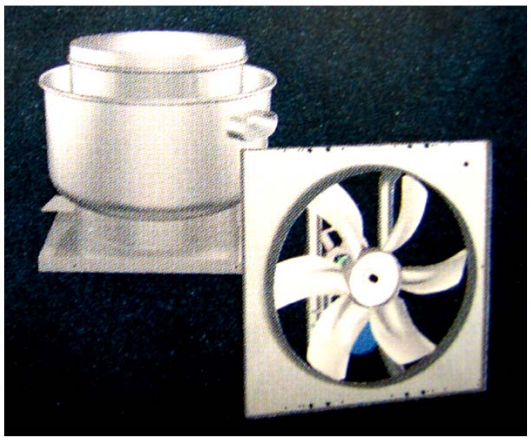


Figure IV-36

(Source: Greenheck Production Brochure, Jan. 2000)

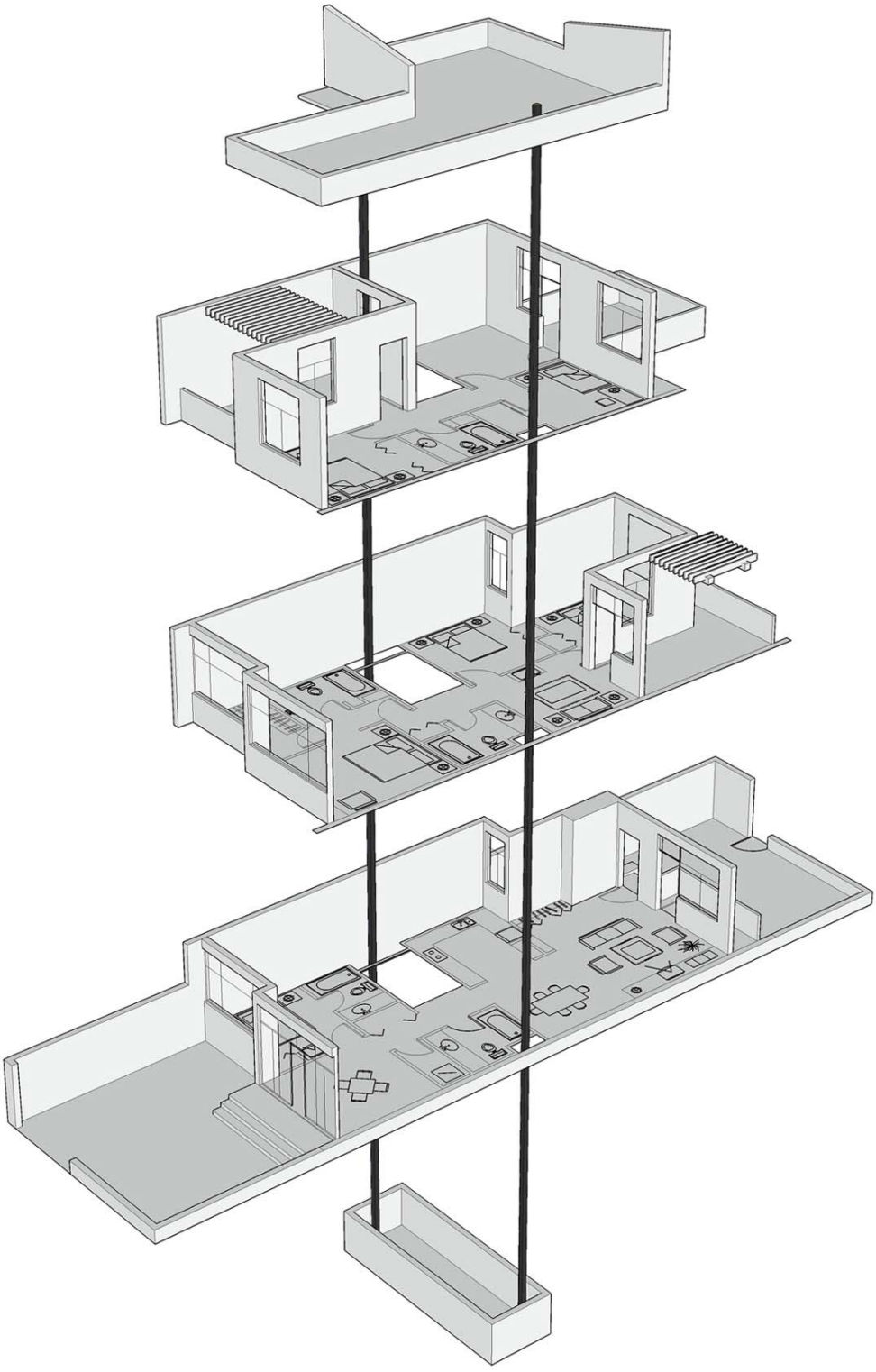


Figure IV-37 Shell Part of the Ventilation System in Single Unit

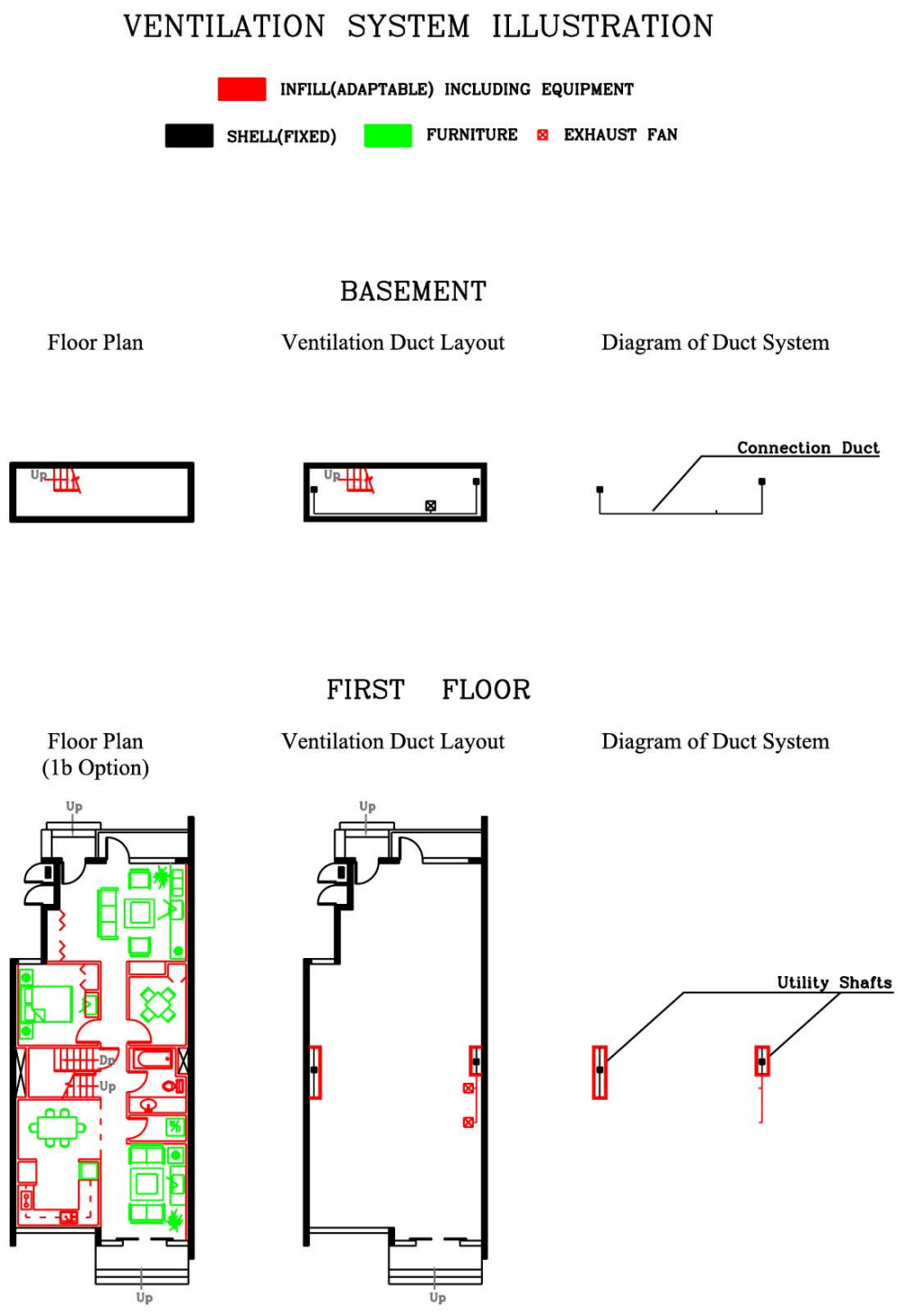

VENTILATION SYSTEM ILLUSTRATION
INFILL(ADAPTABLE) INCLUDING EQUIPMENT
SHELL(FIXED)
FURNITURE
EXHAUST FAN
BASEMENT
Floor Plan
Ventilation Duct Layout
Diagram of Duct System
Up
Up
Connection Duct
FIRST FLOOR
Floor Plan
(1b Option)
Ventilation Duct Layout
Diagram of Duct System
Up
Up
Up
Up
Up
Up
Utility Shafts

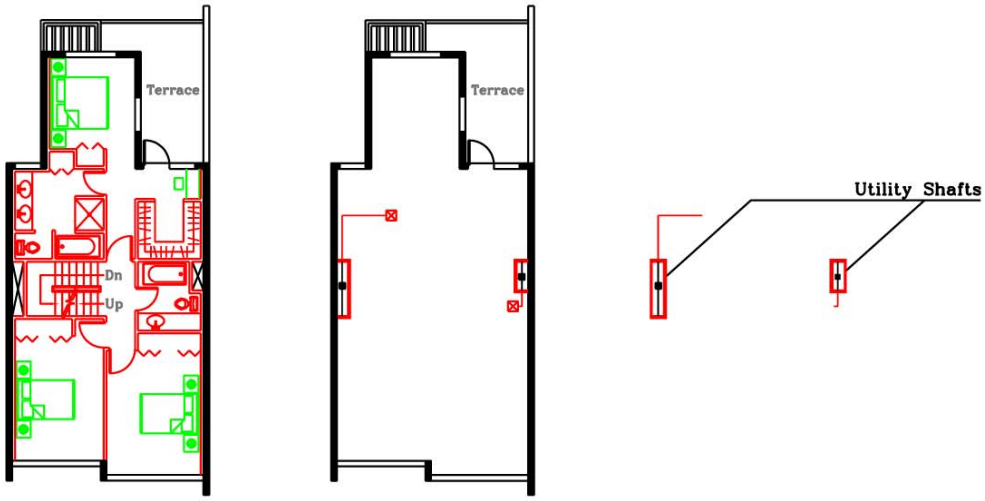
Figure IV-38

SECOND FLOOR

Floor Plan
(2b Option)

Ventilation Duct Layout

Diagram of Duct System



THIRD FLOOR

Floor Plan
(3b Option)

Ventilation Duct Layout

Diagram of Duct System

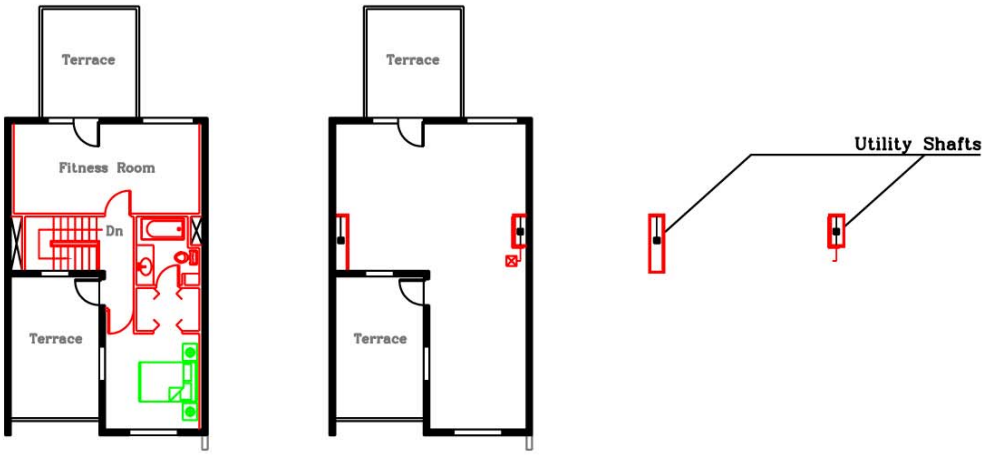


Figure IV-39

IV – 3: Management of complexities

As new technology develops and people's living styles change, many requirements from housing developers and housing occupants emerge during the housing production process, and many methods have been developed to meet these requirements. Open building has already been applied in many pioneer housing projects in different countries (examples shown in Appendix I). These experiences show that it is one of the most efficient methods for introducing new products for housing. In order to let occupants have their ideas become reality to a certain extent in final housing products, and help developers to reduce their investment risks, architects need to help them to manage the whole building process. Four scenarios for allocating the home buyer's controls are developed and shown in the diagrams in **Figure IV-40** to **Figure IV-43** on page 80 to page 83. These diagrams also show a range of developer's controls.

The traditional building method (Scenario D) considers building as a whole unit, and the developer decides everything without the housing occupants' participation. The housing occupants only need to bring their own furniture to move in when the house is ready. Scenario D indicates this process. It was the typical way in China before the urban housing reform took place. In order to meet diverse requirements, today's new housing process tends to divide the whole process into several independent parts.

In this thesis, a housing unit is divided into five parts: 1. façade element and fixed MEP system parts; 2. stair; 3. Infill walls; 4. kitchen and bathroom equipment with specific MEP lines where equipment is attached; and 5. furniture. The developer decides who controls which part. The first part --- façade element and fixed MEP system parts --- is assumed as a Shell part and controlled by the developer. The other parts are regarded

as Infill parts. Detailed descriptions of these four scenarios are shown in the following.

Scenario A: Housing occupants control all Infill parts. They can choose their preferred stair type in the fixed spatial position, choose the interior spatial layout from the "menu" provided by the developer, and choose all the necessary equipment and furniture. They have maximum freedom during their house building process and later as well.

Scenario B: Housing occupants control all Infill parts except the stair. But housing developers only define the stair spatial position and orientation, the housing occupants still can choose their favorite riser type, railing type, and material type of the stair. Besides this, the housing occupants can choose the interior spatial layout from the "menu" provided by the developers, and choose all the necessary equipment and furniture. They have certain restrictions during their house building process.

Scenario C: Housing occupants control all Infill parts except the stair and the Infill walls. They can choose their desirable equipment and the MEP lines attached to them in kitchen and bathrooms. They also have freedom to choose their furniture in their house. They have more restrictions during their house building process.

Scenario D: Housing occupants only have freedom to choose their furniture in their house. They have the least amount of freedom during their house building process.

The following part will discuss how housing consumers choose their houses facing these varieties.

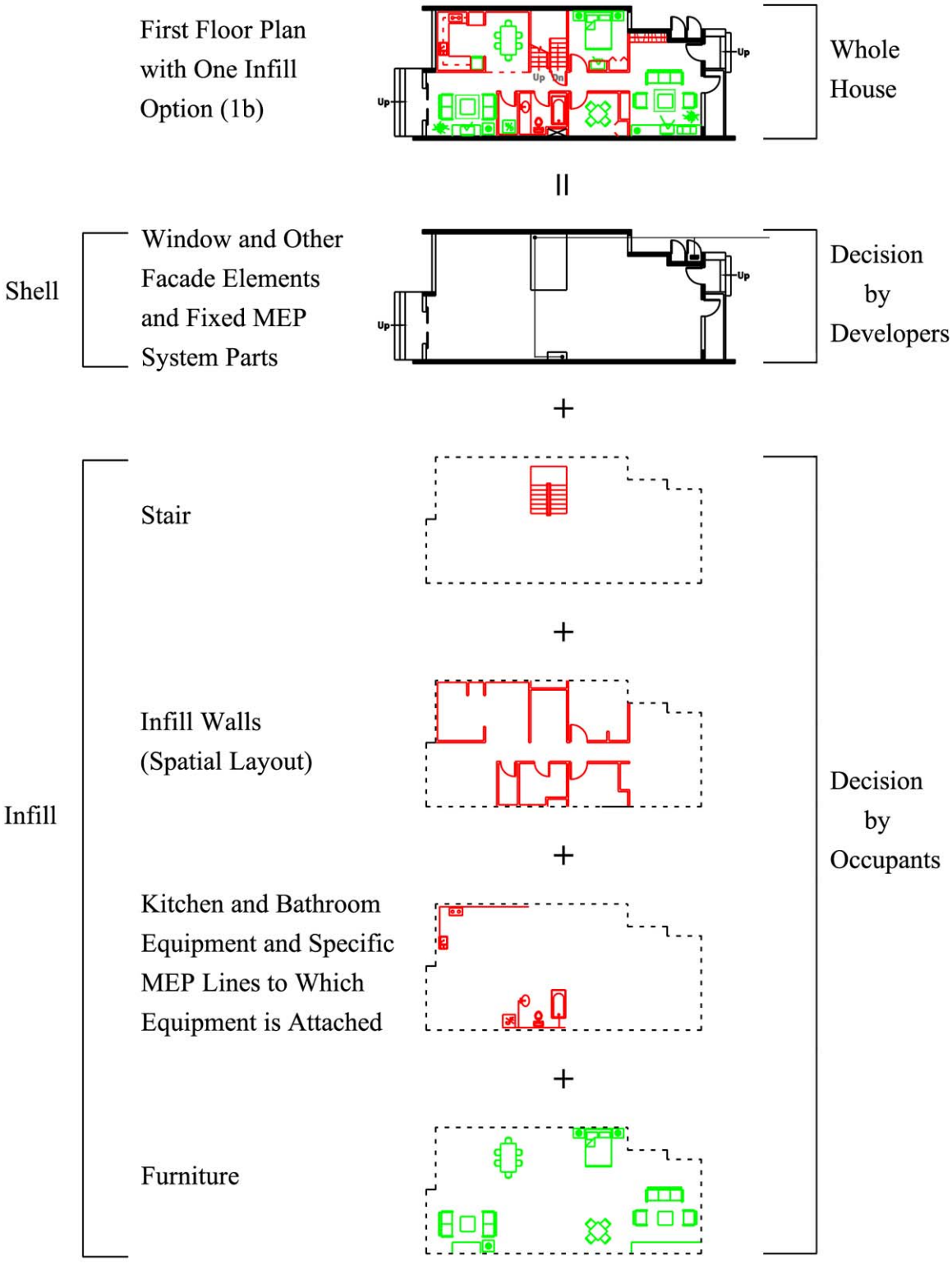


Figure IV-40 Scenario A

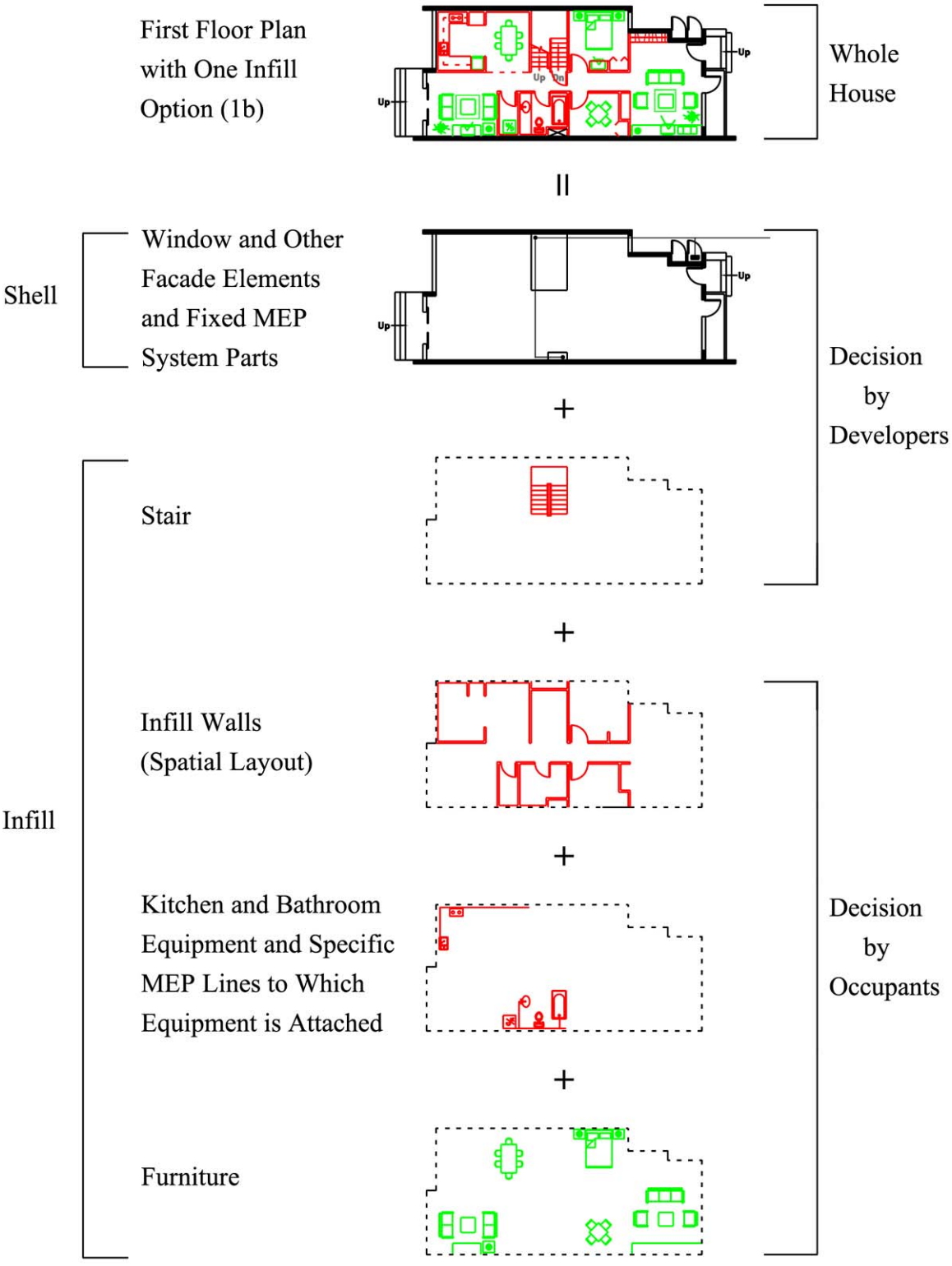


Figure IV-41 Scenario B

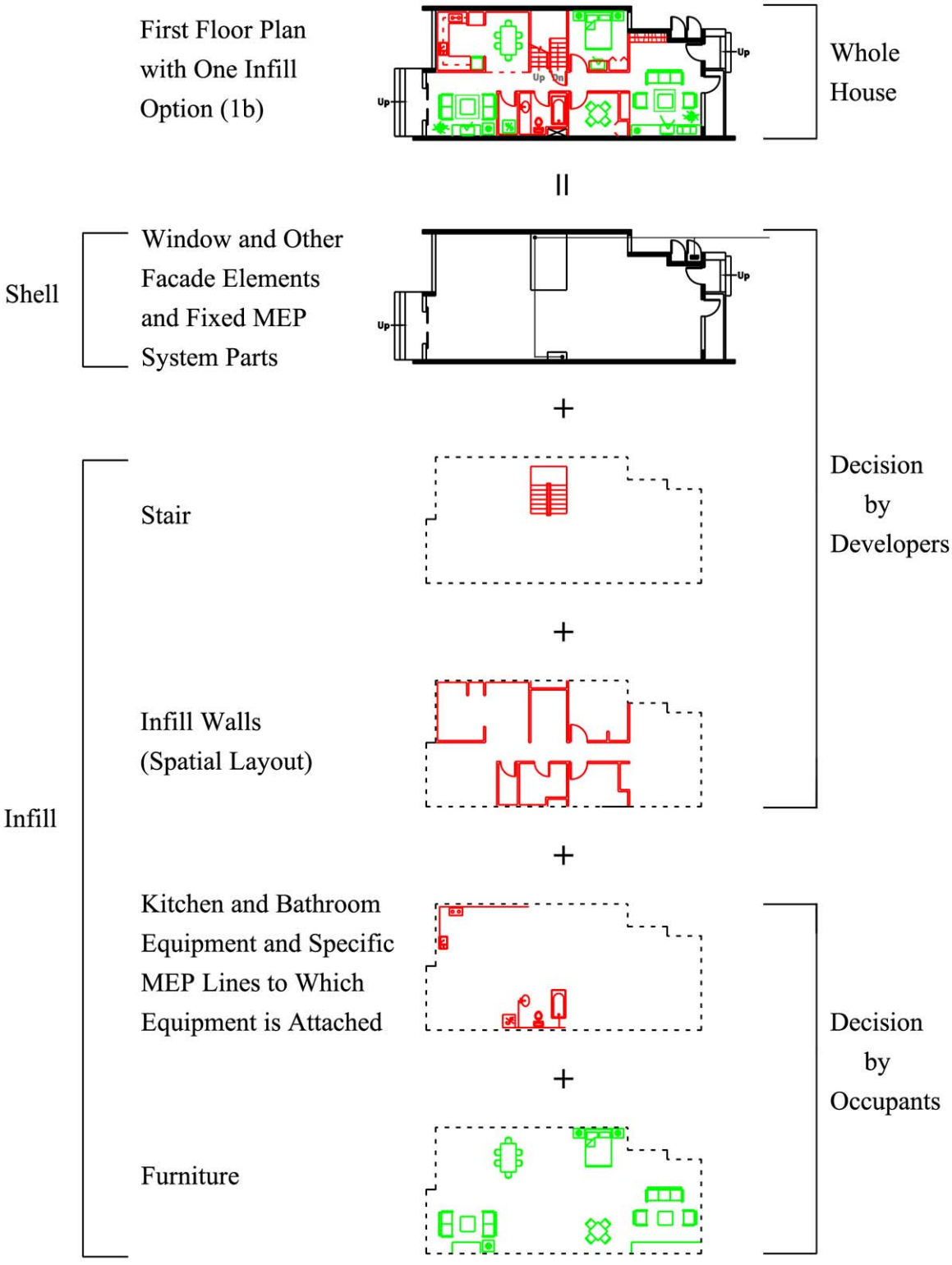


Figure IV-42 Scenario C

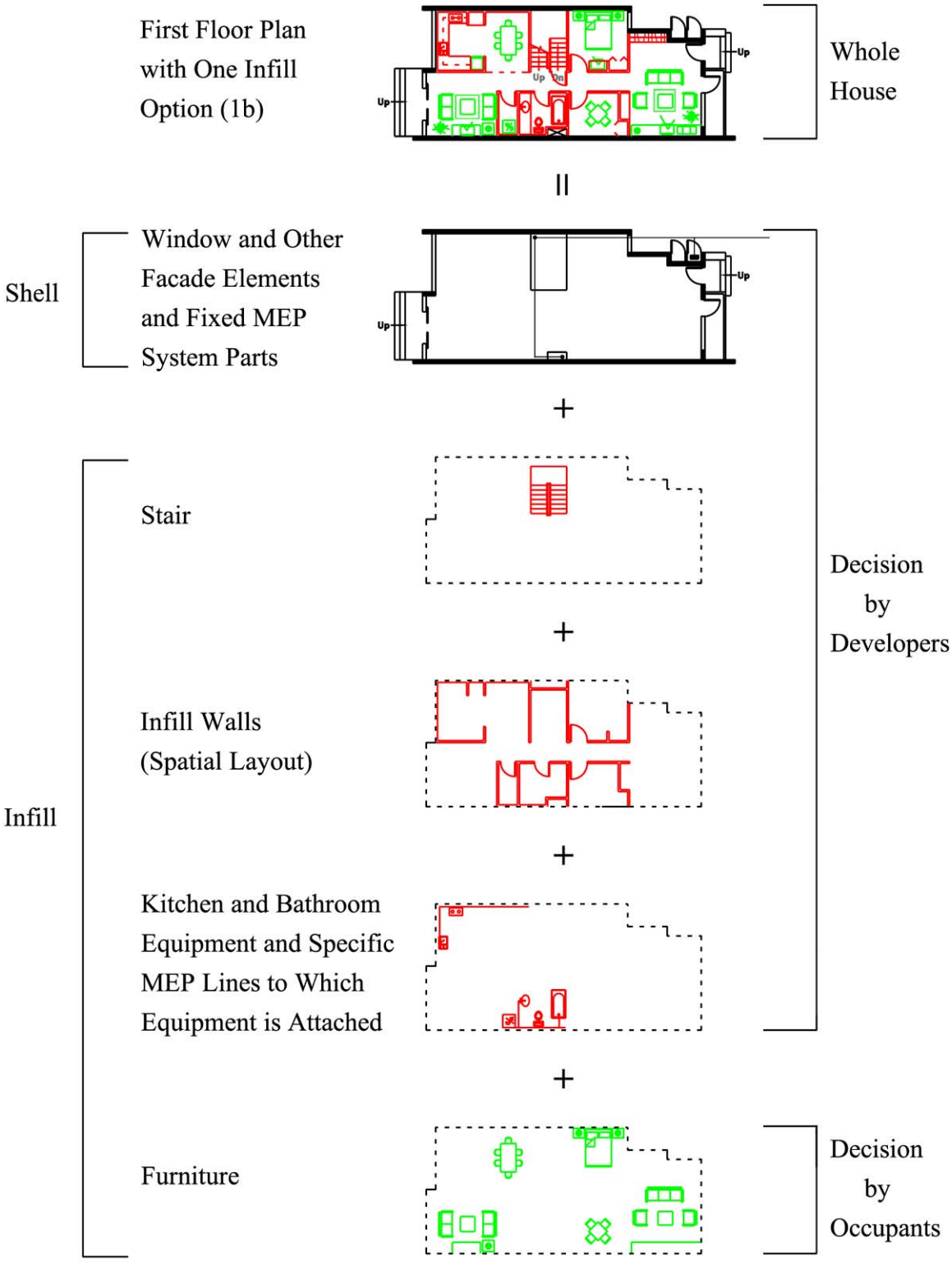


Figure IV-43 Scenario D

IV – 4: Consumer decision process

The diagrams in **Figure IV-44** and **Figure IV-45** on the next two pages show some options that can be provided for housing consumers. It includes unit options for single family and double family.

The unit options for single family have two types including four categories: 1. no bedroom on the first floor (it has one category), 2. One bedroom on the first floor for senior people to live in (it has three categories). Each category is divided into more details according to the location of the living room on the first floor, the location of the family room on the second floor, and on which floor the master bedroom is located. More choices can be provided if the category is further developed.

The unit options for double family are a supplement of the unit options for single family. They are categorized by the location of the master bedroom. Housing consumers in the open building process can have more choices than what can be found in today's housing market in China.

Both diagrams not only include floor plan combinations but also point out how many people can live in the specific housing unit. The option that has a bedroom on the first floor is also shown in the diagram. In addition, the diagram for single family includes other features of each combination. The floor plan combinations provide various room options for housing consumers. The other features can be selected according to housing occupants' specific interests. For example, the unit having a large fitness room is more appropriate for the occupants who like work-out. If the occupants like reading or working at home, the unit with a study space will be a suitable choice for them. This diagram is very important for housing consumers who do not have much knowledge on

the building design.

Unit Options for Single Family

LR: Living Room FR: Family Room
BR: Bedroom MBR: Master Bedroom
B: Back F: Front

1st Floor Options	2nd Floor Options	3rd Floor Options	Housing Occupants	BR on 1st Floor	Other Features
1d (B. LR)	**2a** (B. MBR)	**3a**	couple + (1-2) young children + middle-aged parents + guest	No	small Fitness Room
	2b (F. MBR)	**3b**	couple + (1-2) old children + guest or parents		large Fitness Room
1d (B. LR)	**2c** (B. FR)	**3d** (B. MBR)			Study Room
	2d (F. FR)	**3c** (F. MBR)			
1a (F. LR)	**2b** (F. MBR)	**3a**	couple + (1-2) children + parents + guest	Yes (Facing Back)	small Fitness Room
	2a (B. MBR)	**3b**			large Fitness Room
1a (F. LR)	**2d** (F. FR)	**3c** (F. MBR)			Study Room
	2c (B. FR)	**3d** (B. MBR)			
1b (F. LR & B. LR)	**2b** (F. MBR)	**3b**	couple + (1-2) children + parents + guest	Yes (Facing Front)	large Fitness Room
	2a (B. MBR)	**3a**			small Fitness Room
1b (F. LR & B. LR)	**2c** (B. FR)	**3d** (B. MBR)			Study Room
	2d (F. FR)	**3c** (F. MBR)			

To be continued on the next page

Figure IV-44

Continued on the front page

1st Floor Options	2nd Floor Options	3rd Floor Options	Housing Occupants	BR on 1st Floor	Other Features
1c (B. LR)	**2a** (B. MBR)	**3b**	couple + (1-2) children + parents + guest	Yes (Facing Front)	large Fitness Room
	2b (F. MBR)	**3a**			small Fitness Room
1c (B. LR)	**2d** (F. FR)	**3c** (F. MBR)			Study Room
	2c (B. FR)	**3d** (B. MBR)			

Unit Options for Double Family

LR: Living Room FR: Family Room
BR: Bedroom MBR: Master Bedroom
B: Back F: Front

1st Floor Options	2nd Floor Options	3rd Floor Options	Housing Occupants	BR on 1st Floor
1a, or **1b,** or **1c,** or **1d.**	**2b** (F. MBR)	**3c** (F. MBR)	couple + 1 child + guest or parents + couple (unrelated) or couple + 1 child + guest + couple (related) --- parents of the above couple	Yes or No
		3d (B. MBR)		
	2a (B. MBR)	**3c** (F. MBR)		
		3d (B. MBR)		

Figure IV-45

The following will discuss how housing consumers choose their housing unit from the various options shown in **Figure IV-44** and **Figure IV-45** on the front two pages. The decision tree diagram is shown in **Figure IV-46.**

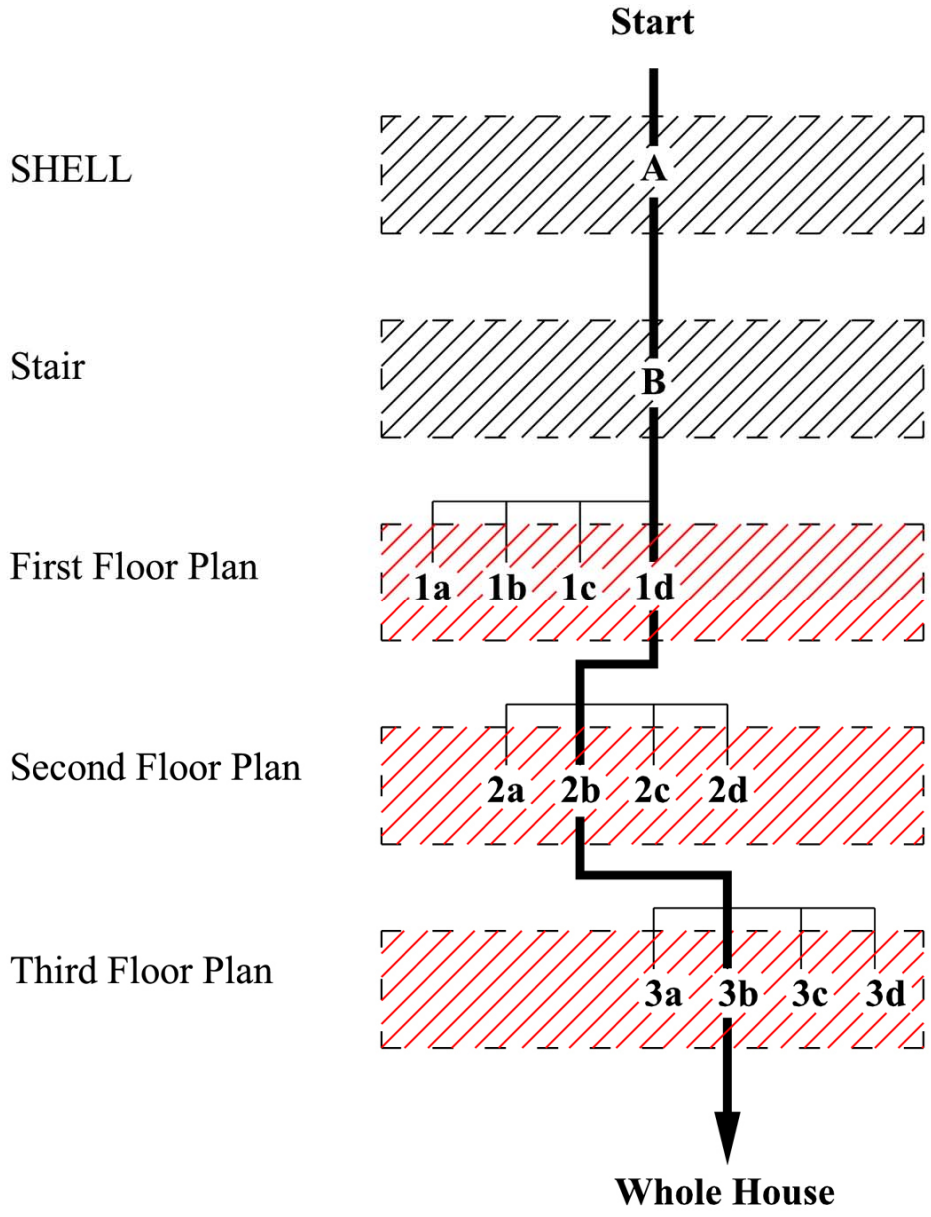


Figure IV-46 Decision Tree

The Shell is decided by housing developers. For the study example in this thesis, even the stair spatial position and orientation are also fixed as part of the Shell; housing consumers still can have some other choices on the stair. For example, they can have open or closed riser type (examples are shown in **Figure IV-47**), different materials of handrails such as wood, metal, or aluminum (examples are shown in **Figure IV-48** on the next page), or different graphic patterns on handrails (examples are shown in **Figure IV-49** on the next page). Based on the finish material on the floor and the staircase, the height of riser will be minor difference. The consumer even can have different kinds of stair platforms (examples are shown in **Figure IV-50** on page 91). All these details will be further discussed later.

Figure IV-47 Open or Closed Stair Riser

Source: (Left) http://www.fullermedical.co.uk/images/is01%20th.jpg

(Right) http://www.robertsengineering.f2s.com/glass%20balustrade.htm

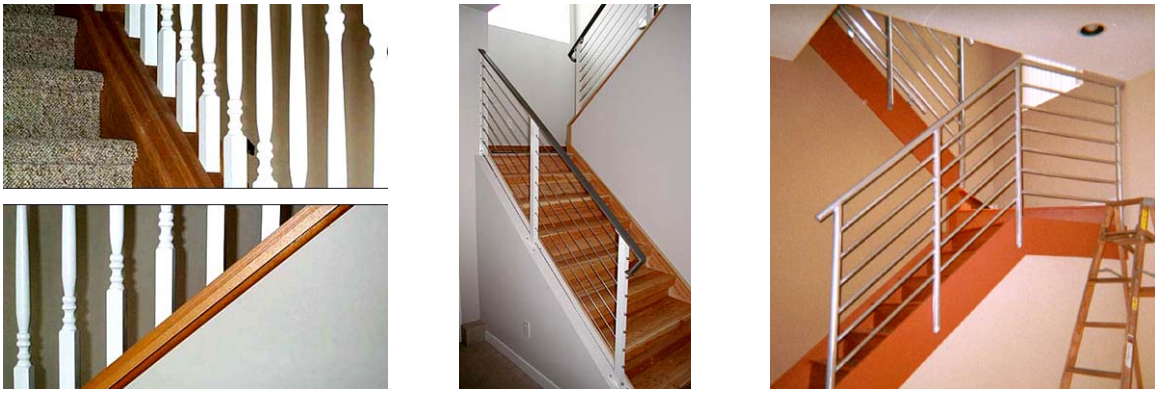


Figure IV-48 Different Handrail Material

Source: (Left) http://www.royalhomes.com/options/interior/45553.html
(Middle) http://www.yokomori.co.jp/english/products/d-step.htm
(Right) http://www.mataluminumproducts.com/images/Interior%20pipe%20stair%20rail%20-%20full.jpg

Figure IV-49 Different Handrail Pattern

Source: (Left) http://www.elgamalgroup.com/elgamalgroup/housing_development/housing_full.htm
(Right) http://www.brooksmarinefab.com/architecturalfab.html

Figure IV-50 Different Pattern of Platform

Source: (Left) http://www.brooksmarinefab.com/architecturalfab.html
(Right) http://www.yokomori.co.jp/english/products/d-step.htm

After the home buyer chooses the Shell and stair, they go further down the decision tree to choose the first floor plan, then the second and the third floor plans. All these floor plans, together with the fixed basement floor plan and the roof plan, will make a new townhouse meeting their specific requirements and preferences, and it has great adaptability for now and future changing.

IV – 5: Floor plan combinations

It is much easier for home buyers to accept the design by providing them visualized graphical floor plan combinations instead of showing them abstract diagrams or telling them how many possibilities are available by scientific calculations. Ten floor plan combinations are developed in this thesis and each combination can meet specific requirements for each family. All these diagrams are shown in **Figure IV-51** to **Figure IV-70** on the following pages. These combinations provide more choices for home buyers, thus making this townhouse more valuable for housing developers and housing consumers.

Floor Plan Combination

Choice - 1

First Floor: **1d**

Second Floor: **2a**

Third Floor: **3a**

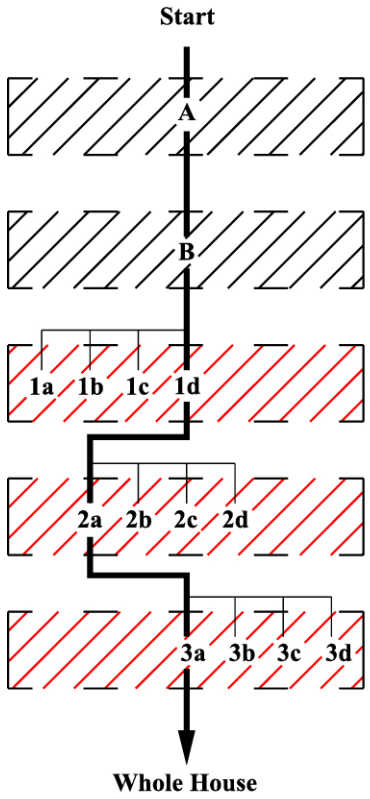


Figure IV-51

This townhouse has a living room facing the back yard, a big dining room facing the front yard, and a kitchen and a small dining room in the middle part of the first floor. A family room facing the front terrace and a master bedroom facing the back yard are on the second floor. A fitness room facing the front terrace is on the third floor. This unit can house a couple, 1-2 young children, and the couple's middle-aged parents. The spare room can be for guest use.


1d:
1200
500
5200
Entry
Front Yard
Up
Dn
Up
Up
Back Yard
5700
1800
2100
3300
2000
5100
6600
1200
3900
2200
1100
2000
5600
3300
3600
2a:
1200
3300
2400
Terrace
Dn
Up
3900
3300
2000
3000
2100
600
1200
3900
3300
3100
4500
3300
3600
3a:
1200
3300
2400
Terrace
Fitness Room
Dn
Terrace
3900
3300
2000
5100
600
3900
3300
1100
2400
4100
3300
3600
1d + 2a + 3a

Figure IV-52

Floor Plan Combination

Choice - 2

First Floor: **1d**

Second Floor: **2d**

Third Floor: **3c**

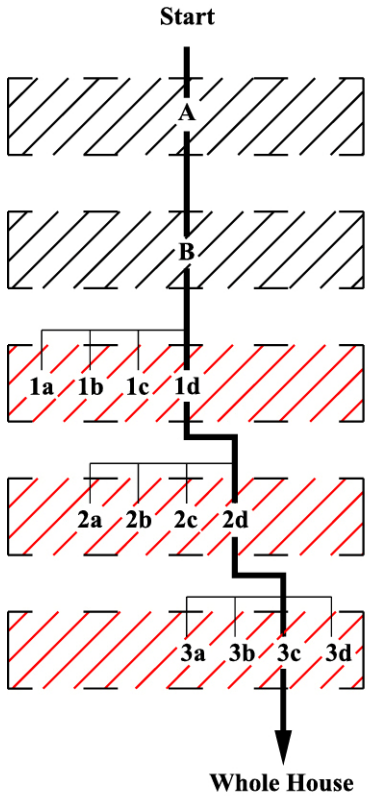


Figure IV-53

This townhouse has a living room facing the back yard, a big dining room facing the front yard, and a kitchen and a small dining room in the middle part of the first floor. A family room facing the front terrace is on the second floor. A master bedroom facing the front terrace and a study room facing the back yard are on the third floor. This unit can house a couple and 1-2 old children. The spare room can be for guest or parents use.

1d + 2d + 3c

Figure IV-54

Floor Plan Combination

Choice - 3

First Floor: **1a**

Second Floor: **2b**

Third Floor: **3a**

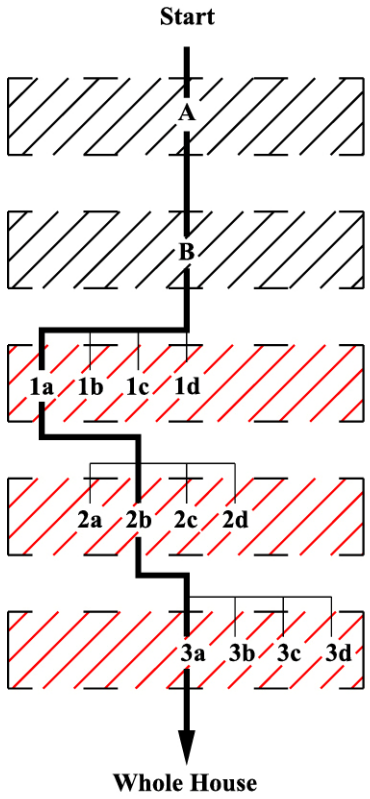


Figure IV-55

This townhouse has a living room facing the front yard, a bedroom (with its own bathroom) facing the back yard, and a kitchen and a dining room in the middle part of the first floor. A master bedroom facing the front terrace is on the second floor. A fitness room facing the front terrace is on the third floor. This unit can house a couple, 1-2 children, and their parents. The spare room can be for guest use.

1a + 2b + 3a

Figure IV-56

Floor Plan Combination

Choice – 4

First Floor: **1a**

Second Floor: **2d**

Third Floor: **3d**

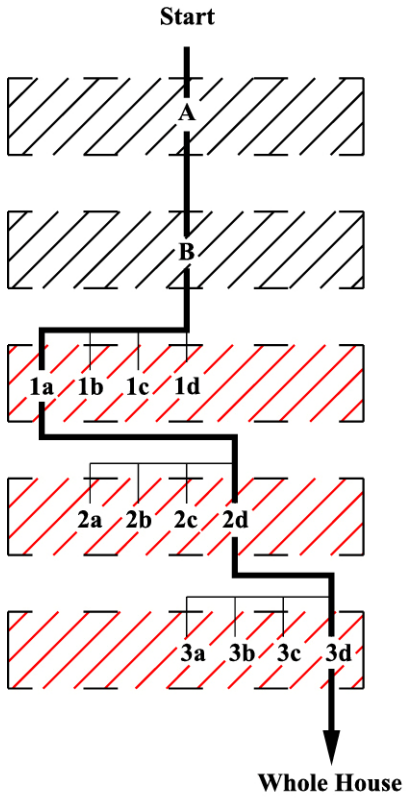


Figure IV-57

This townhouse has a living room facing the front yard, a bedroom (with its own bathroom) facing the back yard, and a kitchen and a dining room in the middle part of the first floor. A family room facing the front terrace is on the second floor. A master bedroom facing the back yard and a study room facing the front terrace are on the third floor. This unit can house a couple, 1-2 children, and their parents. The spare room can be for guest use.

1a + 2d + 3d

Figure IV-58

Floor Plan Combination

Choice – 5

First Floor: **1b**

Second Floor: **2a**

Third Floor: **3b**

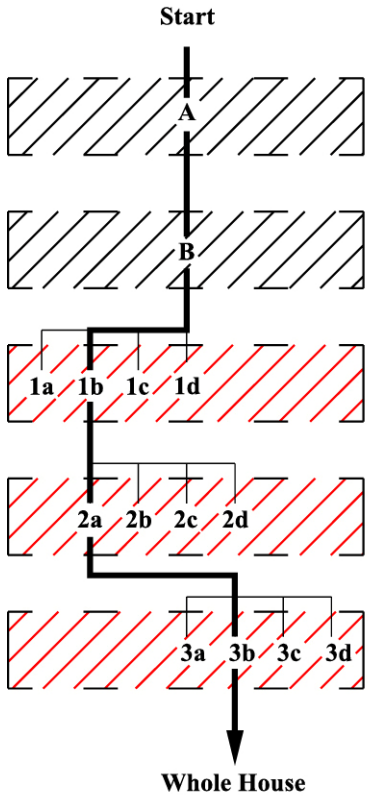


Figure IV-59

This townhouse has a living room facing the front yard, a family room and a kitchen facing the back yard, and a bedroom and a card room in the middle part of the first floor. A master bedroom facing the back yard and another family room facing the front terrace are on the second floor. A fitness room facing the front terrace is on the third floor. This unit can house a couple, 1-2 children, and their parents. The spare room can be for guest use.


1b:
1200
500
5200
Entry
Front Yard
Up
Dn
Up
Up
Back Yard
5700
1800
2100
3300
2000
2400
2700
6600
1200
3900
3300
2600
1100
3900
3300
3600
2a:
1200
3300
2400
Terrace
Dn
Up
3900
3300
2000
3000
2100
600
1200
3900
3300
3100
4500
3300
3600
3b:
1200
3300
2400
Terrace
Fitness
Room
Dn
Terrace
3900
3300
2000
5100
600
3900
3300
2500
1600
3500
3300
3600
1b + 2a + 3b

Figure IV-60

Floor Plan Combination

Choice – 6

First Floor: **1b**

Second Floor: **2c**

Third Floor: **3c**

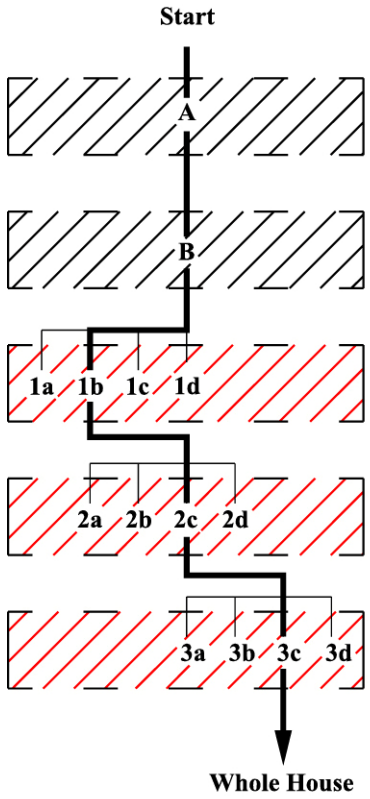


Figure IV-61

This townhouse has a living room facing the front yard, a family room and a kitchen facing the back yard, and a bedroom and a card room in the middle part of the first floor. Another family room facing the back yard is on the second floor. A master bedroom facing the front terrace and a study room facing the back yard are on the third floor. This unit can house a couple, 1-2 children, and their parents. The spare room can be for guest use.


1b:
1200
500
5200
Entry
Front Yard
Up
Dn
Up
Up
Back Yard
5700
1800
2100
3300
2000
2400
2700
6600
1200
3900
3300
2600
1100
3900
3300
3600
2c:
1200
3300
2400
Terrace
Dn
Up
3900
3300
2000
5100
600
1200
3900
3300
2500
600
4500
3300
3600
3c:
1200
3300
2400
Terrace
Dn
Terrace
3900
3300
2000
5100
600
3900
3300
1600
2200
3800
3300
3600
1b + 2c + 3c

Figure IV-62

Floor Plan Combination

Choice – 7

First Floor: **1c**

Second Floor: **2b**

Third Floor: **3b**

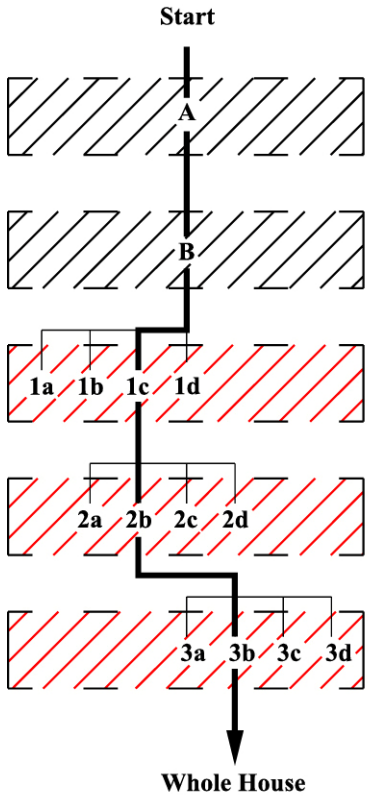


Figure IV-63

This townhouse has a living room facing the back yard, a kitchen facing the front yard, and a bedroom and a dining room in the middle part of the first floor. A master bedroom facing the front terrace is on the second floor. A fitness room facing the front terrace is on the third floor. This unit can house a couple, 1-2 children, and their parents. The spare room can be for guest use.

1c + 2b + 3b

Figure IV-64

Floor Plan Combination

Choice – 8

First Floor: **1c**

Second Floor: **2c**

Third Floor: **3d**

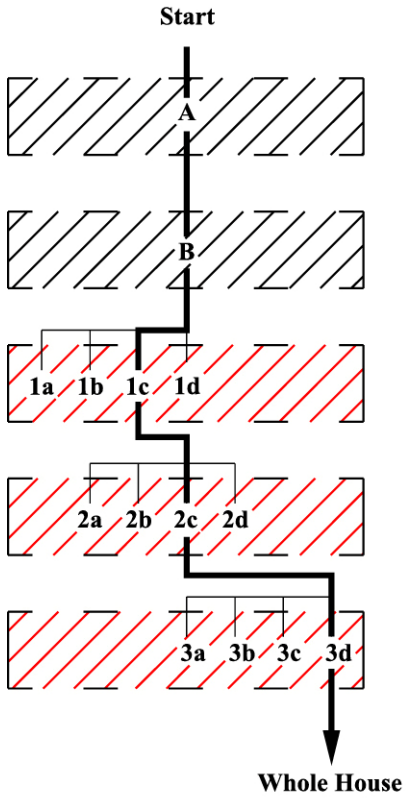


Figure IV-65

This townhouse has a living room facing the back yard, a kitchen facing the front yard, and a bedroom and a dining room in the middle part of the first floor. A family room facing the back yard is on the second floor. A master bedroom facing the back yard and a study room facing the front terrace are on the third floor. This unit can house a couple, 1-2 children, and their parents. The spare room can be for guest use.

1c + 2c + 3d

Figure IV-66

Floor Plan Combination

Choice – 9

First Floor: **1d**

Second Floor: **2b**

Third Floor: **3d**

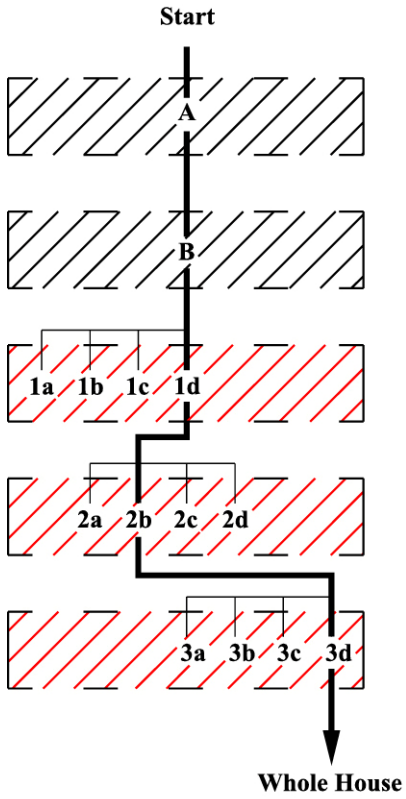


Figure IV-67

This townhouse has a living room facing the back yard, a big dining room facing the front yard, and a kitchen and a small dining room in the middle part of the first floor. One master bedroom facing the front terrace is on the second floor. Another master bedroom facing the back yard and a study room facing the front terrace are on the third floor. This unit can house one couple, one child, and another couple (This couple can be related to this family such as the couple's parents or unrelated to this family). The spare room can be for guest or parents use.


1d:
1200
500
5200
Entry
Front Yard
Up
Dn
Up
Up
Back Yard
5700
1800
2100
3300
2000
5100
6600
1200
3900
2200
1100
2000
5600
3300
3600
2b:
1200
3300
2400
Terrace
Dn
Up
3900
3300
2000
5100
600
1200
3900
3300
2500
600
4500
3300
3600
3d:
1200
3300
2400
Terrace
Dn
Terrace
3900
3300
2000
5100
600
3900
1700
1600
1100
2200
4300
3300
3600
1d + 2b + 3d

Figure IV-68

Floor Plan Combination

Choice – 10

First Floor: **1b**

Second Floor: **2a**

Third Floor: **3d**

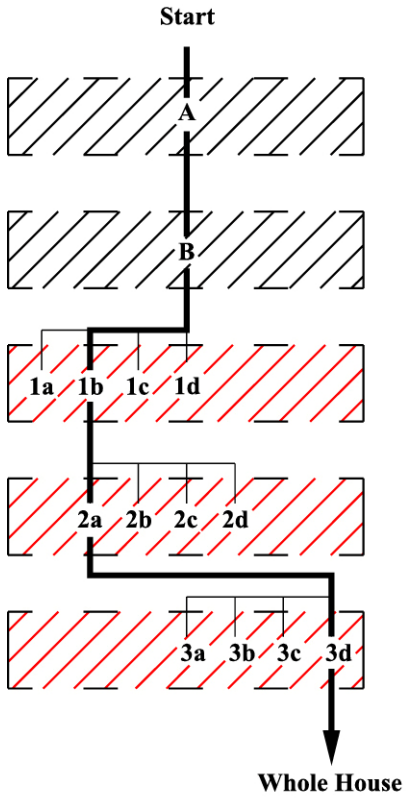


Figure IV-69

This townhouse has a living room facing the front yard, a family room and a kitchen facing the back yard, and a bedroom and a card room in the middle part of the first floor. One master bedroom facing the back yard is on the second floor. Another master bedroom facing the back yard and a study room facing the front terrace are on the third floor. This unit can house one couple, one child, and another couple (This couple can be related to this family such as the couple's parents or unrelated to this family). The spare room can be for guest or parents use.

1b + 2a + 3d

Figure IV-70

IV – 6: Summary

In this chapter, the open building process is demonstrated through a proposed townhouse which is based on an existing townhouse already built in China. Several aspects have been studied so far: first, fifty original townhouse floor plans were studied and one of them was selected as the study example. Second, the interior spatial layouts and the MEP systems in this proposed townhouse were studied, based on the Shell and Infill distinction. Third, the question of how to manage the resulting complexities and demonstrate consumer choices was studied. Fourth, the home buyers' decision process was studied. And finally, some floor plan combinations were made in order to let home buyers easier to choose. Furthermore, a single unit perspective diagram shown in **Figure IV-71** on the next page gives a complete visual presentation. The red part in that diagram constitutes the Infill walls that can be in various positions based on different floor plan choices. The other part is the Shell and cannot be changed by consumers even though they have different floor plan choices.

All the discussions so far are connected with the design process. The next chapter will discuss the housing production process according to the current housing market in China.

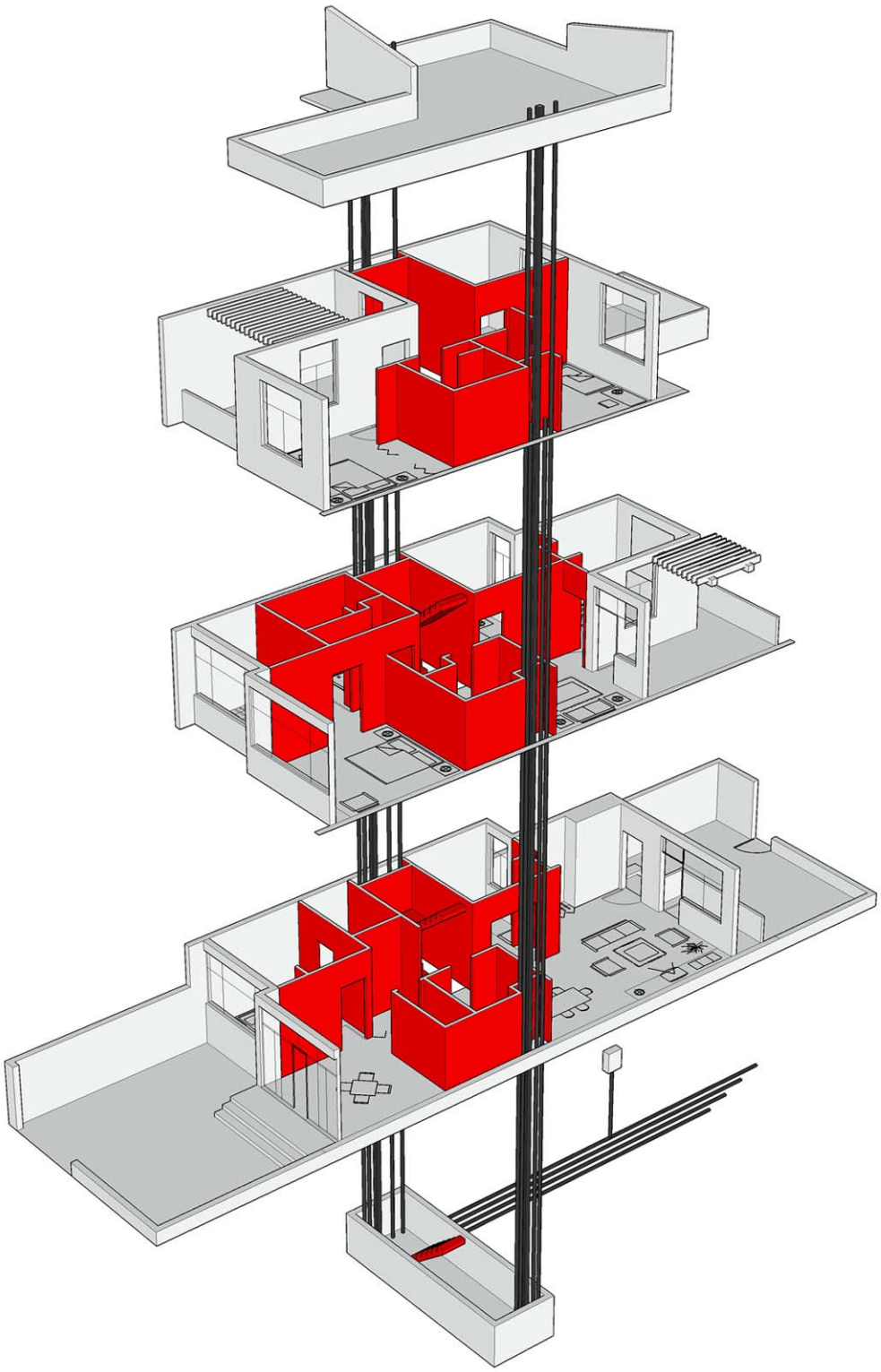


Figure IV-71 Single Unit Perspective Diagram

Chapter V

Market Analysis

V – 1: Case study: Shandong First Construction and Decoration Co. Ltd.

(Source: http://www.firstdec.com/english/about-us.asp)

a. Company introduction:

Figure V-1 Company Site View

Shandong First Construction & Decoration Company was founded in Jinan, China in 1994. In China's current housing industry, this company is the only large scale decoration company that adopts high technology in its factory production process and makes every wood decoration part produced in the factory to be assembled on the site. In addition to the administration department, the company includes a design institute, a

construction and installation department, a wood factory, and a hotel equipment supply company (diagram shown in **Figure V-2**). This company mainly engages in large- and medium-scale interior decoration projects such as hotels, residential buildings, office buildings, shopping centers, and hospitals. In 2004, it finished over 60 design projects and more than 80 decoration and construction projects as a main contractor. Besides the domestic projects, the company also has some overseas projects, such as the Chinese Embassy in Sudan. This company has 3,000 employees and more than $6 million in fixed assets.

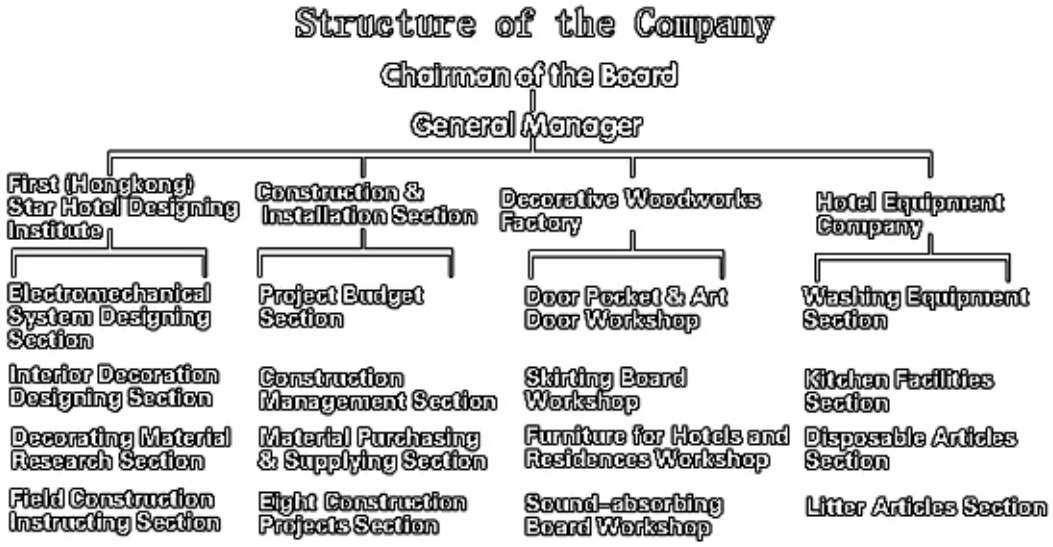


Figure V-2 Company Organizational Chart

The design institute, headquartered in Hong Kong, has four branches in Shanghai, Beijing, Shenzhen, and Jinan respectively, with 168 professionals in total. The wood factory has 38,600m^2 building area and over 300 employees of which 2/3 are college graduates. More than 100 pieces of equipment were imported from Germany and Italy. Strict product management and quality control systems are adopted in this factory.

b. How does the company operate during the entire production process?

On-site checking ----- parts produced in factory ----- assembled on site

Figure V-3 Woodwork Production Process Model

In order to meet clients' requirements for high quality, low cost, and short construction time, Shandong First Construction & Decoration Company invested a huge amount of money on decoration production lines imported from Germany and Italy, in addition to numerous investigations and research work. The company professionals were successful in overcoming three technical problems:

1. The controversy between non-standardized on-site construction dimensions and the accurate production dimensions;
2. How to integrate diversified decoration characteristics into mass production;
3. The complications of production in one place and assembly in another place, which usually caused many mistakes.

They finally moved into a new factory-production area in the housing decoration field. Their woodwork production process model diagram is shown in **Figure V-3**. The traditional procedures used by other decoration companies inevitably result in products of lower quality and less durability, and negative impacts such as chemicals, noise, and garbage in the living environment during the decoration period and even a short period after that. Shandong First Construction & Decoration Company integrates customers' specific decoration requirements into the mass production process by using sophisticated techniques, and increases qualities by eliminating unnecessary nail holes, cracks, color

differences, and deformations which easily happened in the traditional process. Their method also shortens construction time and protects the living environment by reducing the pollutants on the work site.

Their products include standard woodwork and non-standard woodwork. Standard woodwork includes doors and doorframes, baseboards, wardrobes, partitions, fixed furniture, wood decorations, sound-absorbing boards, and decorative boards. All of them are painted before they are sent to the construction site. Non-standard woodwork is designed by factory designers according to the construction drawings provided by decoration designers. For those products not produced in this factory, the company buys them in the market or asks sub-contractors to buy them.

In order to meet housing consumers' different requirements, the company also provides three decoration choices for them to choose. Each choice covers different items, and the details are shown in the diagram in **Figure V-4** on the next page**.**

		Choice–1	Choice–2	Choice–3
Door and Doorframe				
Latex paint for wall and ceiling *				
Bathroom	Wall tiles and Floor tiles *			
	Toilet, Bathtub, Sink *			
Kitchen	Wall tiles and Floor tiles *			
	Sink *			
Decorative Floor				
Wall Baseboard				
Cabinet				
Closet				
Drop Ceiling in Dinning Room and Living Room				
Special Function Wall				
Partition				
Fixed Furniture				
Lighting Fixture				
Movable Furniture and Electronics *				

*: These items are not included in the two groups shown above.

Figure V-4 Decoration Choices

The company current production process diagram is shown in **Figure V-5** on the next page. In addition to the information provided by this company web site, this diagram also references to the telephone interview (details shown in Appendix IV) of a professional who is working at the Home Division in this company. The interview was conducted from 1:00pm to 1:30pm at local time on Oct. 13, 2005.

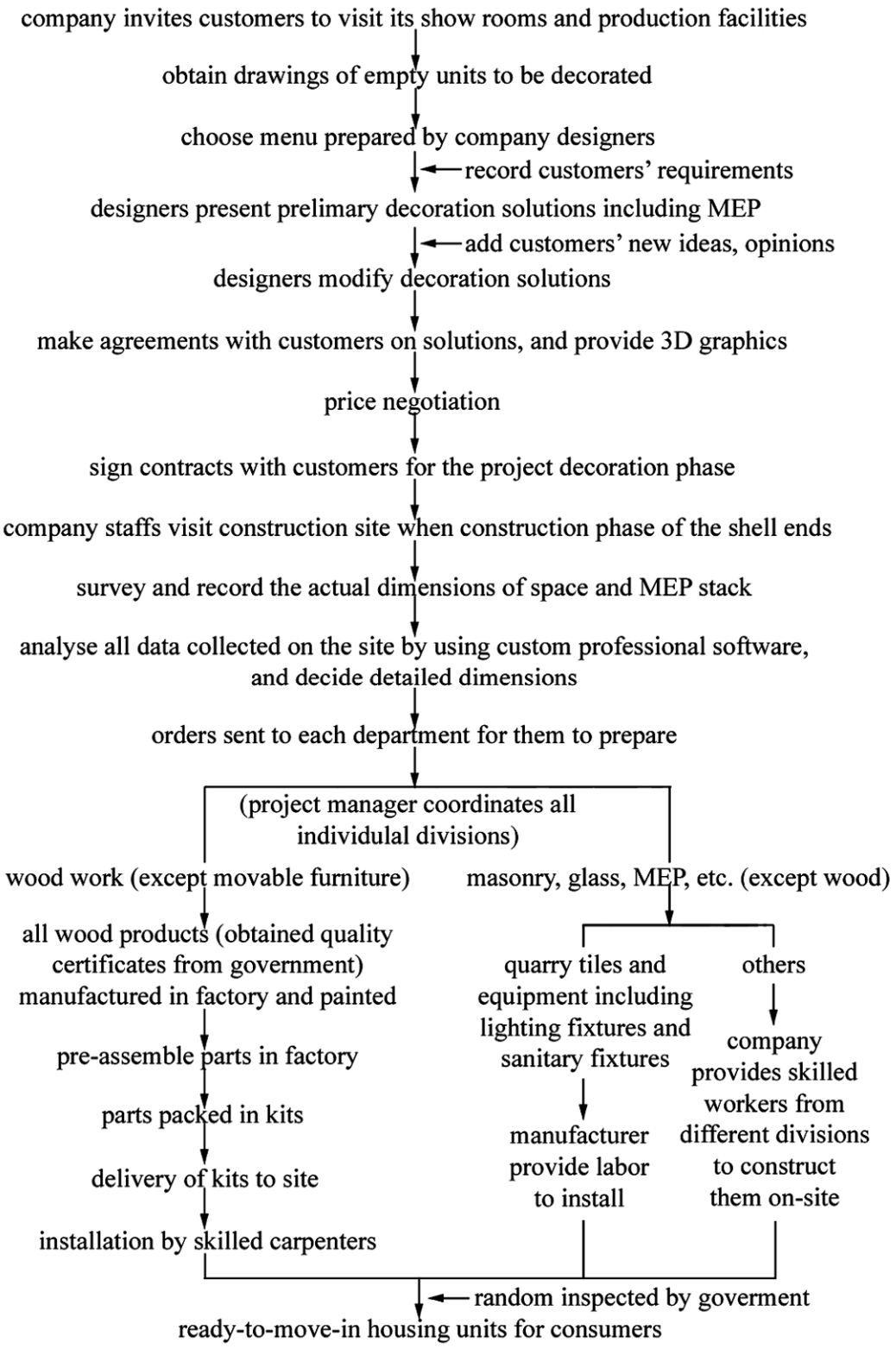


Figure V-5 Company Current Production Process

c. Why can the company succeed with the existing process?

With the help of the advanced technology and unique decoration method, the company can finish a large scale project within a much shorter time period compared to other companies, and has thus gained a very good reputation within the domestic decoration field. The project with 8,000m^2 renovation area including 229 suites and 10 elevator hallways in Hong Xiang Building, which was owned by the Ministry of Industrial Information, would need more than 100 working days if it was done by other company using traditional methods. This company only took 38 days to complete it, thus bringing the company many large-scale decoration projects afterwards. Furthermore, with the publication of *Detail Requirements for Decorated Commercial Housing* in May 2002, the government's support also helped the company to expand its services nation-wide.

Compared to the traditional decoration process, the method adopted in this company has several advantages:

1. Provides a product library to meet different housing consumers' specific requirements. The book *Standardized Wood Products Manufactured in Factory* includes almost all kinds of wood products which are related to housing decoration such as doors, baseboards, corner guards, moldings, partitions, cabinets, and suspended ceilings. It also provides 48 kinds of standard colors for consumers to choose.
2. Ensure the products with high quality and long durability. Computer controlled machines can have products accurate to 0.01 mm in dimension. Wood products with special process can guarantee no warps, cracks, or distortions within 30 years, and the paint quality can compete with high-end

furniture.

3. Reduce pollutions to a minimum and protect the living environment.
4. Dramatically promote the installation efficiency and shorten the decoration period about 60% compared to the traditional method.
5. Extend guarantee period from the normal 1-2 years to more than 5 years, thus creating a sense of safety for housing developers, housing management companies, and housing consumers.

Compared to the waste during the traditional decoration period and the saving during the construction period, in addition to the above five advantages, the reasonable high sale price caused by the factory-produced decoration products will directly make housing developers more profitable. For example, in 1999, Shandong Wei Hai Big House Real Estate Company invited this company to decorate the newly built housing units. The additional cost for each square meter was less than 400 yuan, but the final housing market price increased 500 yuan per square meter. The developing company not only gained 100 yuan per square meter but also turned the construction cost of some items into their net profit. (Those items were usually destroyed and replaced by the products chosen by the housing owner, if the real estate company sold the housing unit without decoration.) For housing consumers, it is hard to get the same high quality products even if they spend the same amount of money or more, on their housing units and decorate them by themselves, let alone the time and energy they spent during the decoration process. After all, this is beneficial to all parts involved in this process.

d. What problems need to be solved to move forward to implementing the open building process in the Chinese townhouse market?

Even though the factory-production method adopted by this company was regarded as “the third revolution towards Chinese Infill industry”, compared to the open building principles, Shandong First Construction & Decoration Company still has many problems needing to be solved on the way to a fully open building process, such as:

1. All the housing projects done so far are limited to large-scale newly-built residential projects. It is not financially accepted if the products are used in small-scale projects or individual units, because the production and installation costs will be too high to be accepted by housing owners.
2. The company has paid more attention to the decoration characteristics than to adaptability. For example, the production and installation methods using demountable lightweight partitions and changeable pipes have not been considered. That is to say, if the occupants want to change the interior layout of their unit, the housing unit decorated by this company makes such adaptation no less difficult than “traditional” methods of Infill.
3. The company has not attempted to expand its “Infill” package to include all of the parts necessary to “fill-in” an empty Shell as defined in this study.

Actually, the existing problems may not cause any barriers for this company to expand its business because currently no other companies can compete with it in this area. But, from the standpoint of company long-term development and the entire housing industry, if they can solve those problems, it will lead to another big revolution.

V – 2: Open building as a way to balance supply and demand, and some unique features in China now and in the future

After 1999, as the central government started to pay cash to urban residents and let them choose their housing, all newly-built housing was pushed into the housing market. From then on, the balance between supply and demand came to show its important role in housing production processes. Because of the availability of abundant cheap labor with low construction skills, intensive use of labor on construction sites, and the lack of factory-produced building components are still the main stream in today's China's housing industry.

The uneven social and economic conditions of different regions in China provide an opportunity for open building to be applied in the housing industry selectively --- in certain regions for certain people. Those cities with strong economies and higher consumer incomes may become the avant-garde in popularizing this new building process even though the significance of open building is still not recognized by most people in China, especially the governors and regulators. For example, the housing price in several residential districts in Guanzhou in 1998 reached to 9,000 *yuan* per square meter of the building area, which was much higher than the housing price in other cities. Those housing units were built with much higher standards either in the community facilities or the surrounding environments. Yet, the housing capacity for initial choice or future changing had not been taken into account. This "weakness" did not cause any problem at that time because those housing units were designed for the rich people including those white-collar foreigners who came to that city for business or short-term work and some residents from Hong Kong who bought houses either for investment or

for their vacation lodging.

In the current China's housing market, many housing consumers have gradually switched their housing emphasis from "need a space to shelter" to "choose a house to live". The publication of *Detail Requirements for Decorated Commercial Housing* in May 2002 and the pioneer behavior of Shandong First Construction and Decoration Company in housing decoration field show that the "ready-to-move-in" house will be a trend in the future China's housing market. The woodwork produced in this company was, in a certain way, similar with the Infill system of the open building process, and urban residents came to accept it. As we demonstrate advantages of a "full" open building process, housing consumers will be happier to accept it if the technical problems can be solved. Of course, it needs more energy from different aspects such as policy supports, business and technical innovations including developing competitive and complete Infill systems which are fit for China's social and economical situation, and labor trainings to explore this field. Some Infill systems invented and used in other countries are shown in Appendix III.

V – 3: The challenges for the open building approach in current social conditions in China

As a multi-disciplinary building approach, the open building process employs a set of unique design, construction, logistics, long-term management, and finance processes. Even though housing investment has increased rapidly and thousands of millions of square meters of new housing space are constructed each year, it is still difficult for housing developers to carry out their projects designed in this new process.

The structure of the entire housing industry changes slowly and many constraints resulting from the old housing system still prevent it from progressing forward smoothly. Due to its technical and organizational complexities and the related political difficulties, the open building process is not easy to carry out in the current, immature housing market in China. There are several main barriers that need to be overcome.

1. Lack of strong support from the government

Thinking of how the open building process was carried out and developed in Japan and some European countries with the strong early help of the governments, we especially need the support from the government in research funding and changes in regulations and policies. The policy carries heavy weight in building industry. No new process or strategy can be disseminated efficiently without government incentives, let alone pioneer projects in the housing industry.

2. Disorder in the supply channels and in the labor market.

The market-based labor market expands gradually while government-owned enterprises shrink. Currently, there are some important factors in the supply channels and labor markets that need to be studied:

1) Inadequate services: supply companies do not provide satisfactory guarantees of service and there is no effective supervision system, resulting in many arguments and conflicts which waste time and money from the company and consumers, and increase the price of the product indirectly.
2) Fragmented logistics systems: the result of which is that material and other

building components cannot be circulated at sufficiently low prices.

3) Extensive local protections: the investor is usually asked in a certain way by some governors to appoint their local construction companies as contractors to build the housing projects including using the local materials, no matter if they are qualified or not. Some local construction material providers even provide unqualified products to the construction company to make more profits under this special protection.
4) Complicated and excessive regulatory restrictions: the result of which reduce the choice for the company operation and make them have to develop redundant structures, assets, operations, and contractual relationships.

3. Low skills of construction workers

Most construction workers come from rural areas where a large amount of surplus labor exists. They usually don't know how to coordinate with other workers from different disciplines. Their low education level prevents them from learning labor skills that are required on today's construction site. Lack of necessary construction knowledge has been a barrier for a worker to work on the new construction sites. This is especially the case for the open building process; on the other hand, workers can be trained for the specific work of Infill installation using integrated teams. Yet, investors usually don't like to pay money to train those workers because of the higher mobility in this field.

4. Low management skills

Those managers on the construction site usually are not trained professionally.

They keep on using the old management skills adopted in the earlier planning years and often experience difficulties when they meet new situations. The management training, if they have it, is usually superficial and not effective. Lack of efficient management often brings more conflicts and troubles during the construction period, thus indirectly raising the production cost.

After all, cultivating the investment and management market to meet the specific requirements in finance and long-term management is key important for the successful dissemination of the open building process in China.

Chapter VI

Conclusion

Since the “open building” concept resulted in the first projects in Europe in the 1970’s and in Japan in the 1980’s, it is increasingly recognized as an alternative to the conventional approach in the housing sector, and many projects have been built in other countries. Facing China’s current social environment with urban residents’ diverse housing requirements and a huge urban housing market, can the open building approach also be implemented in China’s housing sector? This thesis has studied China’s urban housing development history and the current housing market. It has proposed a new way of delivering townhouses, based on an existing townhouse in the market. The thesis has also used an existing decoration company with successful experience in residential projects as a possible model for the new housing process discussed in the thesis.

By demonstrating a new way to conceive, design, and deliver townhouses, the thesis has attempted to show that the open building approach is a possible way to solve some problems in China’s urban housing sector and that, with further development, this approach can be implemented in China.

From the view of the history, social conditions, and design and technical

possibilities, the implementation of the open building approach can become a reality if certain key problems can be solved. Some of them have been pointed out in the thesis, which include: 1) lack of strong support from the government; 2) disorder in the supply channels and in the labor market; 3) low skills of construction workers; and 4) low management skills. Also, certain aspects of this new approach that have not been studied in this thesis require further study, such as market finance and product innovations.

From the standpoint of the development history of the open building approach in other countries, it is evident that many experiments had been done before this new approach went into the market. During this process, many related factors were considered at a certain point to adjust, improve, invent, or enact new rules and regulations. These experiences indicate that substantial government support is needed at the beginning. The same situation will happen in China. Adopting this new approach in the housing industry is a big investment and a high risk for any single company acting alone. No one is willing to do that before it can be proved profitable and feasible or at least that this approach has a high possibility of succeeding. Obviously, the barriers pointed out in this thesis are not easy to be overcome in a short time, just as with other new technology or processes that are not easy to be implemented at the beginning if they need large investments to overcome many barriers.

Nevertheless, the open building approach has shown its potential in the housing industry. I have tried to show that it can not only benefit housing developers and housing consumers but also promote the development of sustainability in the urban housing sector. The future of this approach implemented in China is bright, but it needs time on the way to that.

APPENDIX

AP – I: Built housing examples by the open building approach

AP – I – 1: Walk-up apartment

a. **Project:** Pelgromhof , Zevenaar, Netherlands, 1998

Designer: Frans van der Werf

(Source: Proceedings of the 10th Annual Conference of the CIB W104 Open Building Implementation. Paris, France Sept. 2004)

Funded by the Zevenaar Residential Construction Foundation and the Pelgrom Foundation, the Pelgromhof project was built in 1998 and contains 215 dwellings for the elderly – aged 50 and over. It combines principles of open building, ecological / sustainable design and organic architecture inspired in part by Rudolf Steiner's work. It incorporates 169 apartments for independent living, a nucleus of 46 rooms for assisted or intermural care living, and parking for 86 cars. It also has a reception room, a social center with kitchen, a restaurant, theater shop and library. The project was awarded experimental status by the Dutch government and was also selected as a National Model of Sustainable and Energy efficient Construction by the Ministry of Housing. It meets the

criteria of the Dutch National Sustainable Construction Measures for Residential Building, but goes further by using natural paints and heat pumps.

This project embodies many basic principles of open building:

1. Open construction: Each resident has a hand in creating a place that corresponds to his or her own way of life. Occupants lay out their own dwellings using a full scale model.
2. Life-time guaranteed dwelling: The project offers living space for households in different later stages of life, popularly known as “go-go’s, slow-go’s or no-go’s”. It answers senior needs for accessibility, safety and adaptability.
3. Social cohesion: Full social integration of older people who will require some assistance. The Pelgromhof provides tailored care and a safe, tranquil yet vital environment located close to the city center.
4. Organic architecture: The project’s shapes and colors and landscaping, in keeping with the owners’ philosophy, are intended to house residents in communication with nature. The site features abundant plantings in planting beds and on external walls and roofs, in addition to air purification, specimen trees, flowing water and a diversity of flora and fauna.
5. Digital superhighway: Telemetering as an aid to safety, communications and energy management are integrated into the project.
6. Sustainable construction: Among many green architecture features of the building are: bio-ecological paints and other materials, new high efficiency floor heating, reduced use of concrete, heating with solar energy, application of individual and collective heat pumps for energy savings in climate control,

and optimization of window and roof insulation under “green” roofs.

The project was recently awarded the prestigious Dutch Building Award.

Figure API-1 Building in the Neighborhood

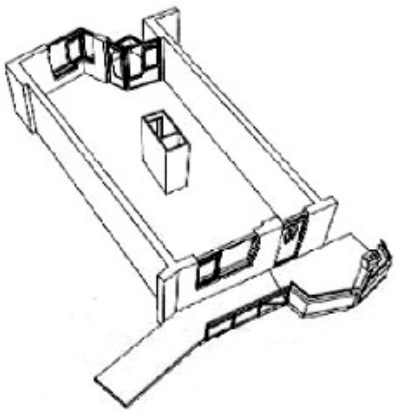


Figure API-2 Base Building of Unit
(Source: http://www.habraken.com)

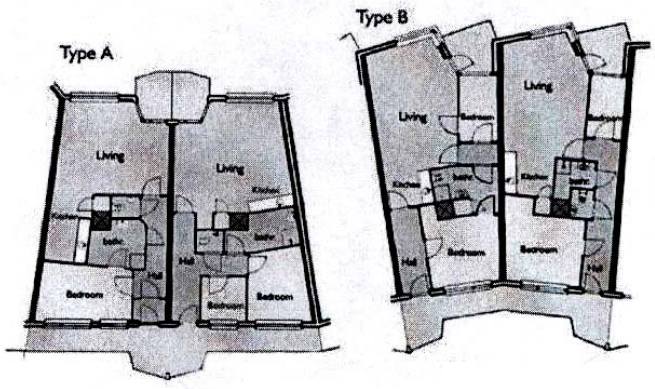


Figure API-3 Infill Options
(Source: Frans van der Werf, 2005)

Figure API-4 View of the Closed Yard

Figure API-5 View of the Restaurant Roof and the Yard

b. **Project:** Technology competition winning project 2000, R&D project 2001-02, Helsinki, 2004

Designer: Kahri & Co Architects

Investor: SATO-company

Cost, data & internet consultant: ToCoMan Group

(Source: Proceedings of the 10th Annual Conference of the CIB W104 Open Building Implementation. Paris, France Sept. 2004)

PlusHome Ltd. was founded in 2000 based on business concept, industrialized construction and advanced information technology. It provides many choices to people including large various floor plans and detailed choices with current prices. The housing solution is for Nordic circumstances while information service is world wide. The pilot projects are 2 blocks including 78 flats in total.

Open building design solutions:

1. Structure for blocks of flats allows different sizes of flats and floor plans one on top of the other. Also available are alternative designs for the same size flats. After reservation there is a large variety of material and equipment choices for occupants.
2. Design with two basic type blocks of flats is based on ArchiCAD- application, which is connected to data-consults quantity and cost services, selling, and occupant services. Design is based on the use of advanced modeling, where all client-choices are built in separately.
3. Industrialized building method is used with two alternative framework-

systems: steel (pilot)/concrete (next project). Installation and piping freedom with zoning principle and flexible electric distribution system in all partition walls.

4. Building structures are in principle well sustainable for future changes- the pilot remarkably, the other solution with some limits, both with well sustainable light partition wall-system.

Figure API-6 Pilot Project

Figure API-7 Site Plan

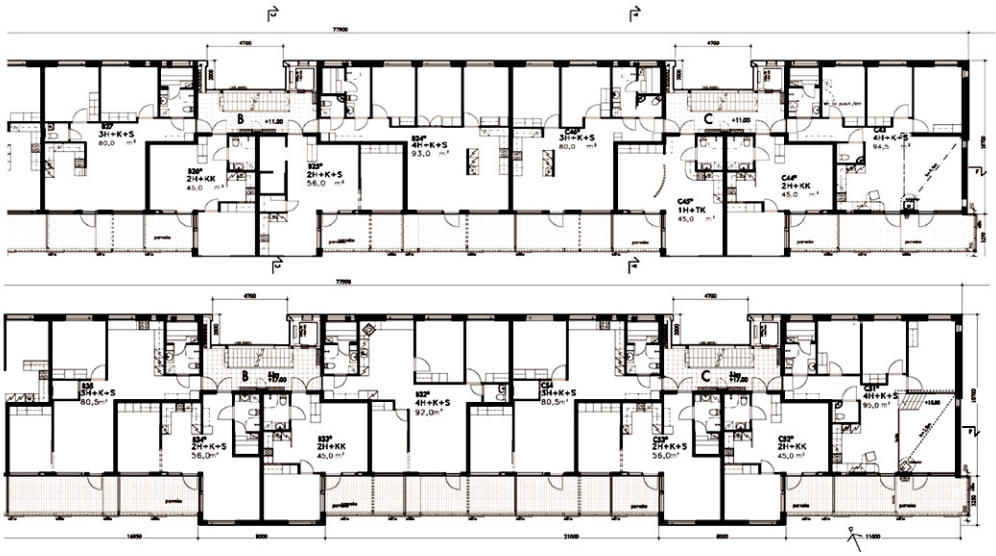


Figure API-8 Occupant Choices on the Different Floors

Figure API-9 Different Choice on the Same Floor

Figure API-10 Alternative Two-room Flats

Figure API-11 Alternative Family Flats

c. **Project:** Hui-Feng New Village, Wuxi, China, 1985

Designer: Bao Jiasheng and Professionals in Wuxi Housing Bureau

This is the first experimental project using open building process in China. It brought in occupants' decisions in the housing process and created a new way to make housing to accommodate future changing needs, as Jiasheng Bao said (1987) "We seek a new way of mass housing to let household join in the housing process and to seek a new channel leading to flexibility and variable housing design. At the same time, we look for new principles and methods concerning the pattern of urban areas and to find out the ways of how to combine traditional values with modern residential construction." This community is composed of nine low-rise set-back courtyard type buildings and two villa type houses with the average dwelling unit floor area of 55.76 m^2 and 214 units in total.

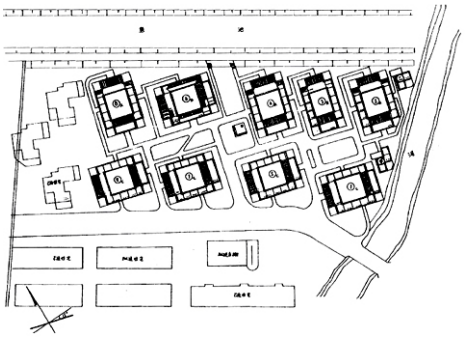
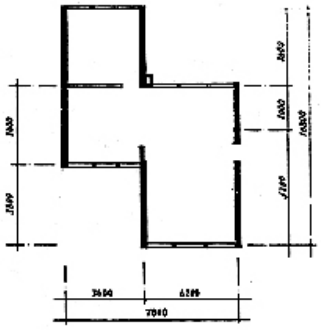


Figure API-12 Exterior View

Figure API-13 Site Plan

(Source of the above two: Kendall & Teicher, 2000: P107-108)



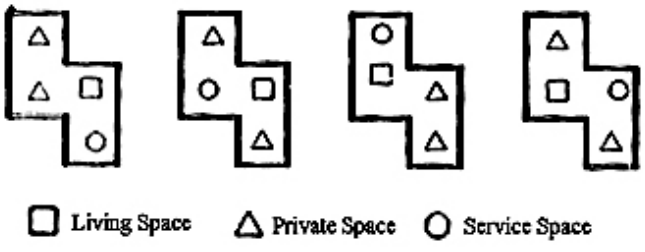


Figure API-14 Unit Support

Figure API-15 Space Variations

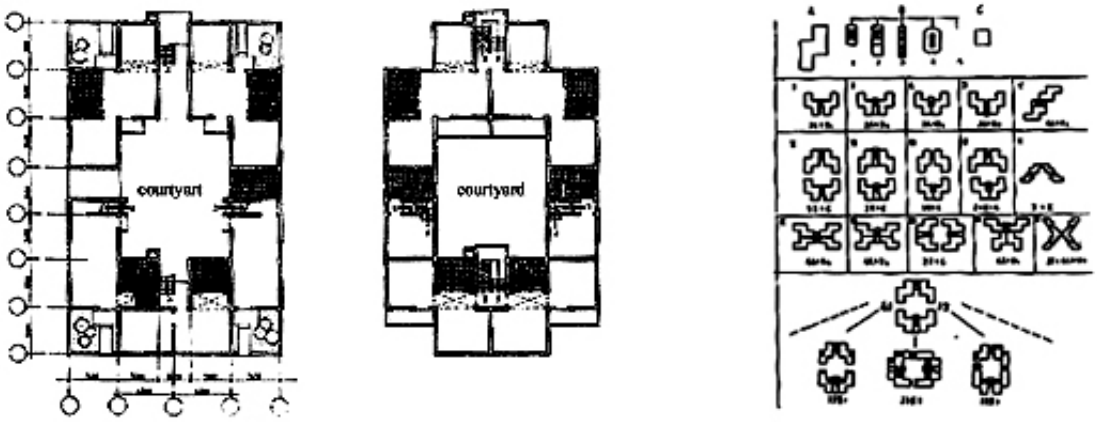


Figure API-16 Composite Support and its Variations

(Source of the above three: Open House International, 1987: Vol.12, No.1, P7-16)

d. NEXT 21 in Osaka, Japan

Architect: Yositika Utida, Mitsuo Takada, Seiichi Fukao, Osaka Gas Corporation, Next21 planning team

Owner: Osaka Gas Corporation

> In this project, building elements are classified into two groups: long-life elements with a high degree of communal utility such as columns, beams and floors, and short-life elements in private areas such as partition walls, building facilities and equipment. The major advantage of this grouping is that the needs of the inhabitant can be reflected while maintaining social worth as a cityscape and as a building.
>
> - Yositika Utida,

Next21 is an experimental 18-unit housing project conceived by Osaka Gas Corporation in collaboration with the Next21 planning team. The main object of the project is to make a more comfortable life possible without increasing energy consumption, by creating houses symbiotic with nature and balancing the public predetermination and the individual occupants' preference.

F4-10. Next21 (left: rendering, Source: Osaka Gas Co., Ltd.; right: real view, source: Next 21 Project team, P1-142, 1-143)

(Source: Liu, 2001: P78)

AP – I – 2: High-rise apartment

a.

AS OY LAUTTASAAREN MERITÄHTI

Helsinki, Lauttasaari
Vattuniemenkatu

Completed 1997
Three tower blocks, 10 storeys and terraced housing
96 free market owner-occupied apartment units
Gross floor area 11 780 m²

Client:

Julius Tallberg - kiinteistöt Oy

General contractor:

Skanska Oy

Architect:

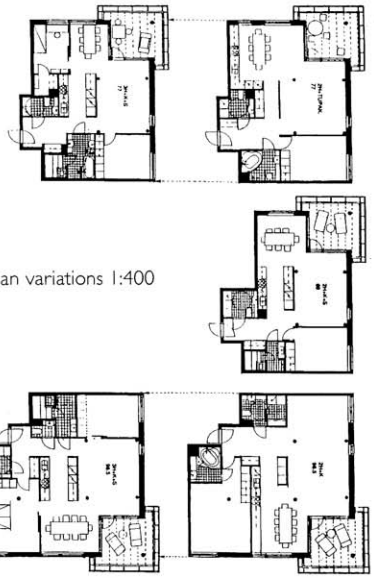
Arkkitehdit Gullichsen Vormala Ky

Building Systems:

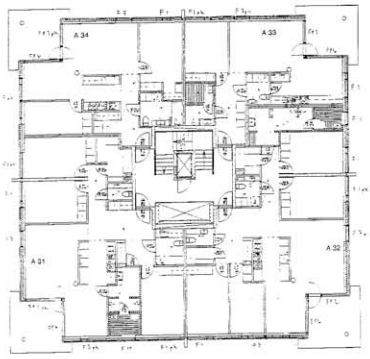
– In situ reinforced concrete frame with optional placing (in the construction phase) for load-bearing walls between apartments; sandwich element facades with windows placed according to floor plans chosen by first resident, pipes inside the slab according to chosen floor plan

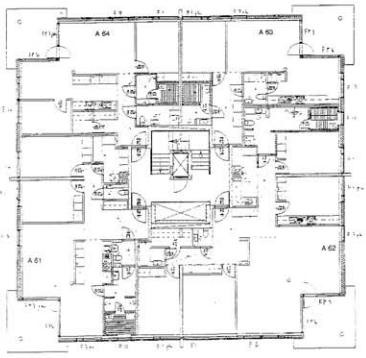
Process:

– Size of apartment chosen by buyer who could also influence the floor plan



Plan variations 1:400





Plans 1:400

(Source: Tiuri, 1998: P44-45)

b.

1993 Green Village Utsugidai
Hachioji, Japan

Fig. 4.72 Photograph courtesy of HUDc.

ARCHITECT: HUDc and Han Architects (base building)
OWNER: Green Village Utsugidai Condominium Association
DWELLINGS: 76 condominium units
SUPPORT CONSTRUCTION: Reinforced concrete; piping trench within the slab
INFILL PROVISION: Haseko Corporation

This coop project was built to accommodate varied unit sizes and layouts. It has 76 units ranging in size from 97–173m^2. Design was organized among three teams of professionals, two of which worked with three-generation households, and the other with general household types. The three-generation-household dwellings were among the first contemporary ones of their kind in Japan.

(Source: Kendall & Teicher, 2000: P119)

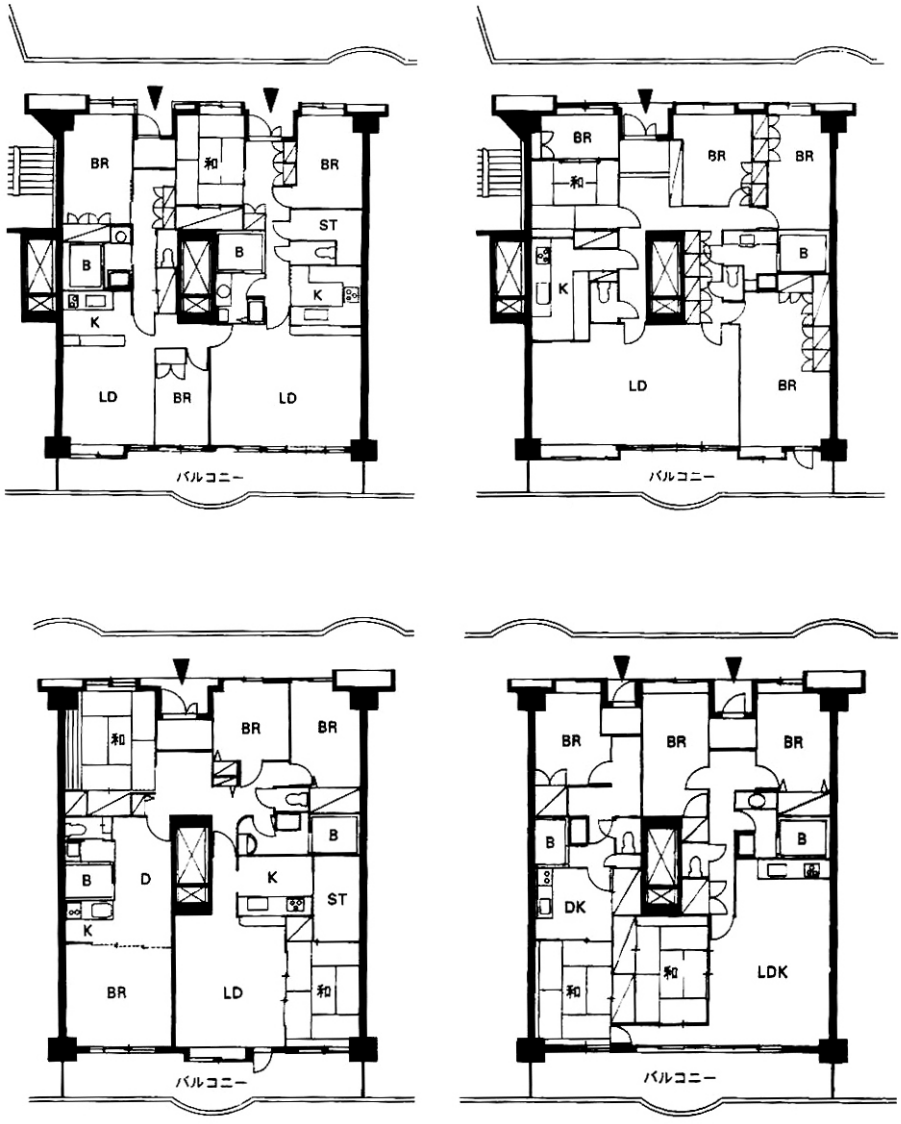


Fig. 4.76 Four different dwelling units.
Drawings courtesy of HUDc.

(Source: Kendall & Teicher, 2000: P121)

AP – I – 3: Townhouse

Wenswonen

38 homes with flexible layouts Zaltbommel - De Waluwe

Flexibility and Architecture

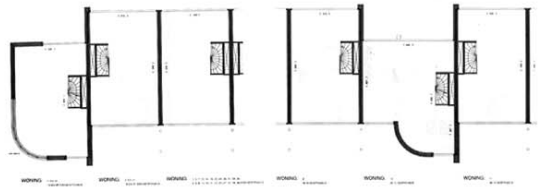
Willems van den Brink, an architectural firm in Eindhoven, the Netherlands, specializes in new living concepts. They have designed thirty-eight flexible homes like a kind of backbone in the De Waluwe (the latest expansion plan in Zaltbommel) plan: Waalveste. These are linked in two rows of 19 houses opposite each other with a residential park in between. Through their different exterior finishes, the four terrace houses at the ends of the blocks and the two gatehouses in the centre ensure a flowing transition to the surrounding buildings and the park-like surrounds. The houses have a basic layout over two or three floors; while the specific floor plans, façades and extensions can be designed by the future residents themselves, using the flexible Wenswonen® (Desirable Living) concept from HIVG.

An Open Architecture

This project uses a systematic design and construction process, with a combination of factory production and site construction. The goal is to provide accommodation capacity in several respects. To assist home-buyers, a simple user interface software was developed

For each townhouse, users can choose a small dwelling, or can extend it with the addition of a third floor or a rear extension (see diagrams). Once this decision is made, interior floor plans can be designed. Because the base building electrical, plumbing and ventilation systems have been carefully designed with multiple points of attachment, buyers can select a variety of positions for bathrooms and kitchens. Following these decisions, further choices are available for style of cabinets, finishes and other details.

The Base Building



Examples of initial Fit-out designs

Finished Facade of Waalveste

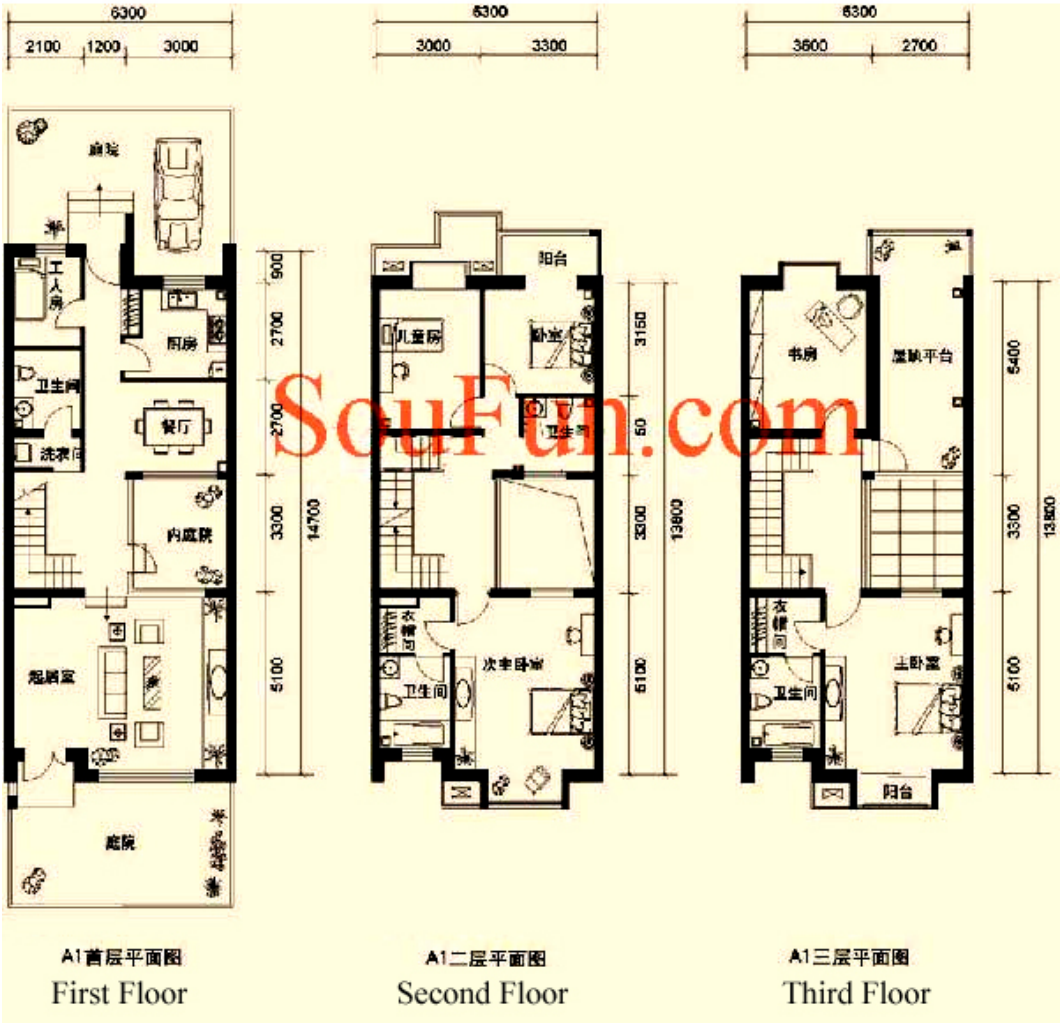
Installation of the facade module

(Source: http://www.bsu.edu/bfi)

AP – II: Built townhouses in China

莫奈花园 位于温榆河中段，空港城范围内，地处十多年前便已成熟的 CVD 中央别墅区内，东距京顺路 3 公里，西距京承高速 3 公里，交通便利。

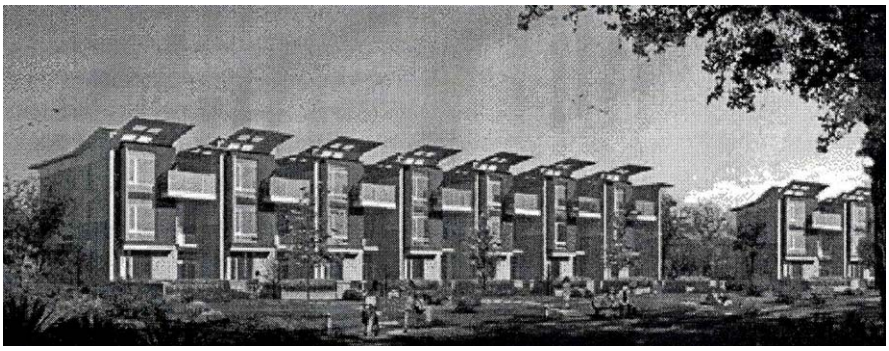
温榆河、罗马湖、龙腾世纪文化公园、西侧专属公园，将莫奈花园包裹在一个优美的大环境中，同时，莫奈花园近邻中央美术学院建筑设计分院，国家高等艺术学府的浓郁人文气息与氤氲湖水送来的鲜湿空气赋予莫奈花园特有的文化底蕴，远离都市浮躁喧嚣，近享湖畔优雅氛围。



(Source: http://newhouse.soufun.com/house/1010071571.htm)

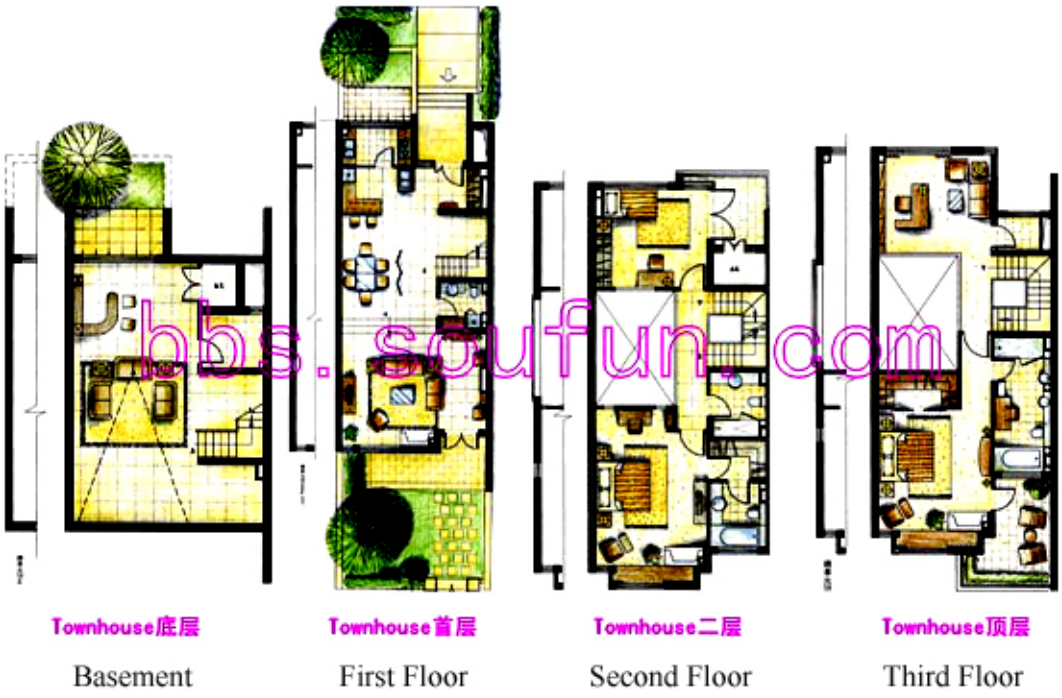
境界 属于二代Ｔｏｗｎｈｏｕｓｅ产品，在设计上保留此类产品“有天有地”的特点，并在规划上引入了一些国外已经相对成熟、严谨的居住理论和模式。

境界反对现代规划理论提出的功能上的肢解即把居住区、工作区、商业区肢离的做法。在小区



中尽量引入在很多欧洲城市所具有的优点，就是人们在一个五分钟（５００～６００米）的步行距离之内，能够满足他的商业、社交、文化、居住这样的一种复合功能，即混合功能区。基于此，水晶城在沿街的立面首层做了一些文化性的商业，包括书店、健身、文化、休闲等商业设施。

由组团空间到中心的十字交叉的林荫大道的开敞空间，到半私密的玄关空间，再到私密的户内空间，多元的空间层次塑造了小区丰富的空间感。入口的两个塔式建筑，南北轴线上的绿轴，以及会所形成了社区的标志。



(Source: http://newhouse.soufun.com/house/1010038833.htm)

靠山居艺墅 位于丰台区京石高速卢沟桥边永定河畔，距离三环路仅 15 分钟路程。项目总用地 35,040 平方米，规划建筑面积 8 万多平方米，整个园区绿化率高达 30％以上，是京西稀有的低层低密度的台地 TOWNHOUSE 社区。

出自大师手笔的现代简约风格为落脚点。斜屋顶，大面积的石材装饰，配合浅灰色砖体表现其沉稳、明快的超前感，尽显欧洲大陆的山地风情特征。

整个园区的园林设计有德国 WSP 精心打造，灵感来自意大利如画般的台地园林风格，结合了德式园林的简约手法，重点表现园林与建筑的逻辑关系，增大人群视野的宽度和广度，营造舒适怡人的居住环境。利用自然台地的走势，设计了瀑布、叠水等景观，五条潺潺流水，宛如立体的五线谱自然流淌，每栋房屋如音乐大师手中跳动的音符，在晨曦中苏醒……在晚霞中休憩……

(Source: http://newhouse.soufun.com/house/1010074152.htm)

美树假日 亚运村正北十公里，毗邻国家森林公园，紧靠小汤山“北部风景旅游区” 。五环路全程免费通行、京承高速的续建、安立路北延、汤立路拓宽、机场北路兴建、地铁五号线等工程的全面开工，使地段更多瞩目、更多发展潜力。

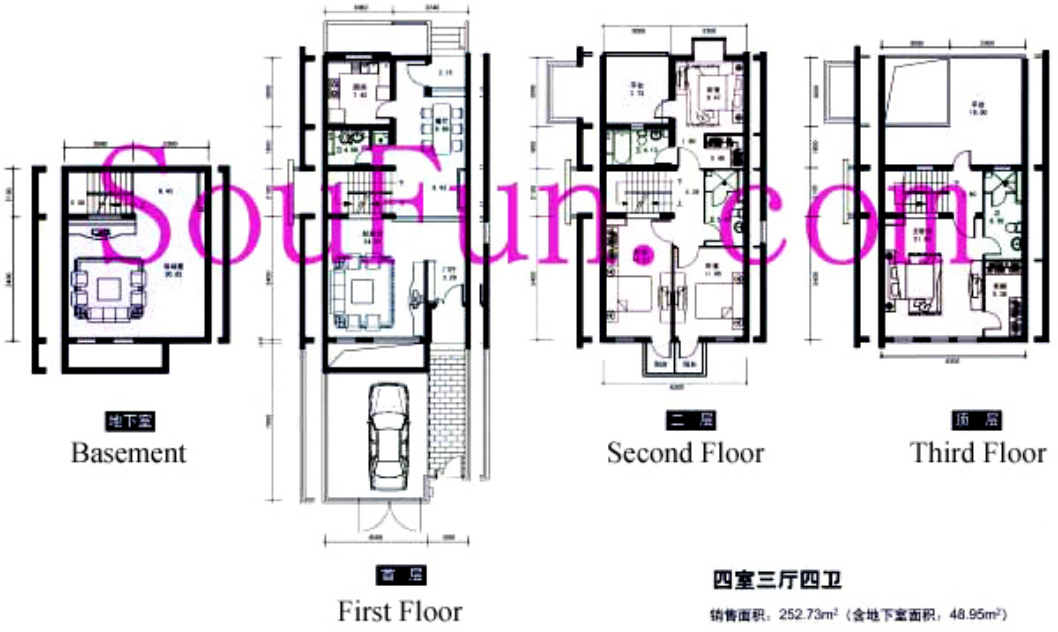
美树假日是以德国风情的联排、叠拼别墅为主的低层、低密度舒适型别墅住宅区，配以适量公寓。建筑采用 “短肢剪力墙”结构，坚固结实。面北通透的室内空间，具有良好的通风采光效果，并使视野更加开阔。门廊、观景露台、私家阳台层叠错落，进退有序。建筑线条优美流畅，色彩搭配和谐优雅，远眺青山、蓝天，建筑与自然融为一体。

(Source: http://newhouse.soufun.com/yahoo/house/1010039055.htm)

流星花园 总建筑面积约为 50 万平方米，位于京北成熟居住区回龙观的核心位置，北邻宽达 500 米的京北城市绿化带，南面为回龙观地区规模最大的公园集中绿地。花园包括时尚公寓、联排、独栋别墅等，独具德式风格特色。

国内顶尖园林景观公司“土人景观”为小城提出“绿核、绿廊、绿巷”三大主题思想，形成类似于生命循环系统的有机生态格局。整个 TOWNHOUSE 区的景观以河边绿色生态核为主，利用景观长廊贯穿整个小区，并在建筑前后形成更次一级的绿色通道，使景观从该生态核渗透到中轴绿廊，再由绿廊渗透到建筑周边，形成一个类似于生命循环系统的有机格局，在这里，建筑就如同细胞一样点缀在绿色背景之下，并不断从中汲取营养。

流星花园先期开工的 B 区 Townhouse 联排别墅，建筑面积约为 9 万平方米，含 318 套联排、独栋别墅，并建有会所、幼儿园、学校等社区配套设施。小区既保持了 Townhouse 有天有地的建筑风格，又满足了部分城市白领花不多的钱享受花园洋房的生活意趣。



(Source: http://newhouse.soufun.com/house/1010034113.htm)

AP – III: Infill systems invented and used in foreign countries

These Infill systems include a new solution recently developed in Japan for old condominium renovations, which is a supplement to Shandong company because they only work for newly built housing units. These systems may become a solution for a certain part of China's urban housing industry and be used by contracts with the inventors, or act as a useful reference for the Chinese professionals to develop a new method to fit their housing conditions.

a.

***Matura** Infill System*

The development of the Matura infill system was begun by John Habraken and Age van Randen in 1989. After a long development period it entered the market in 1995. The system can be used both in newly built housing and in apartment renovation. It is a comprehensive infill system, which means that the system supplier provides all parts and components required for an individual unit. Other major concepts are that every apartment can be treated as an individual assignment and that the system enables the application of modern means of industrial production.

The Matura system components are:

- Modular polystyrene matrix tiles as the main "installation carrier" floor system
- I-profile in the lower parts of walls as wiring installation space (secondary "installation carrier")
- Wiring system with quick connectors and under-door components
- No-slope drainage system for gray water.

Other essential components and parts are:

- Surface materials, interior partition walls and doors
- Storage furniture, kitchen and bathroom equipment.

Figure APIII-1 Description of Matura Infill Systems in Netherlands (Source: Tarpio & Tiuri, 2001: P17)

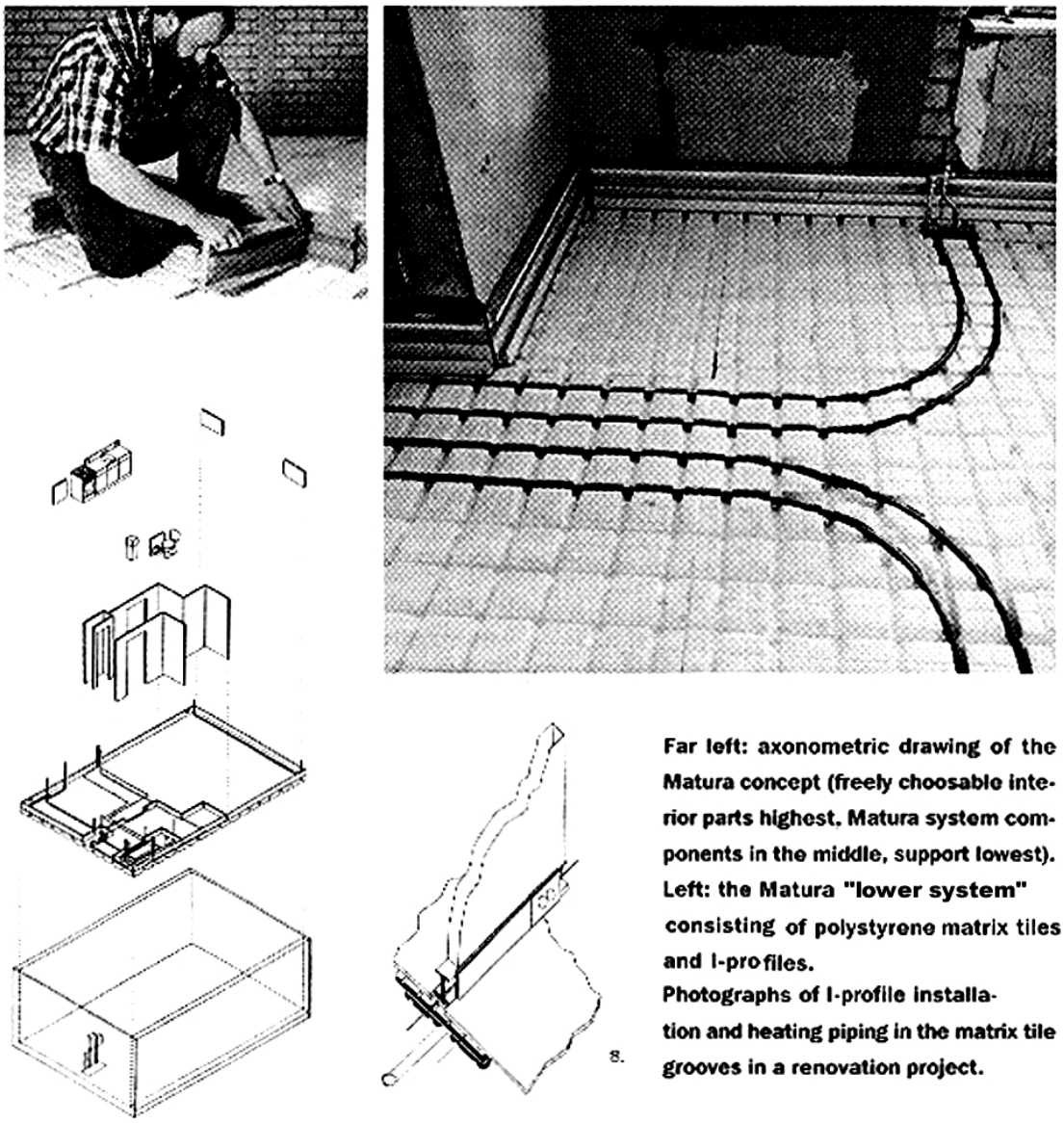
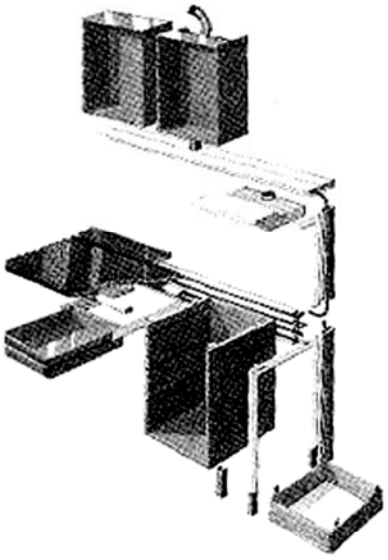


Figure APIII-2 Illustration of Matura Infill Systems in Netherlands
(Source: Tarpio & Tiuri, 2001: P17)

b.

Esprit system



The basic idea of the Esprit system is opposite to Matura´s: visible components are especially designed, whereas any systems available on the market may be used for hidden installations. Like Matura, the Esprit concept relies greatly on using the abilities of modern prefabrication. The design demands for Esprit products were customer orientation, prefabrication, replaceable components, reusability and the possibility of "plug and play" joints.

The aim has been to create a comprehensive system that consists of furniture-like objects. The system offers solutions for electricity, communication and security needs and has some individuality in it. It is supposed to consist of various interior products and of heating, air conditioning and other comfort equipment. Esprit products would include, for example, sanitary and kitchen equipment, wall systems and heating elements.

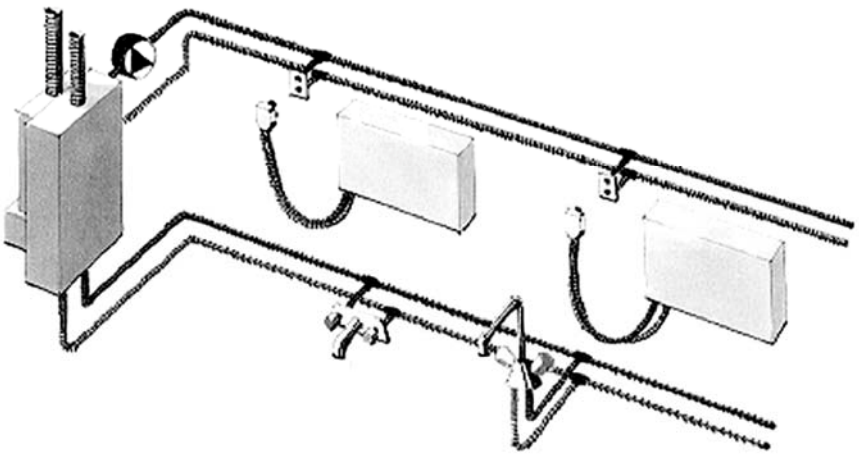
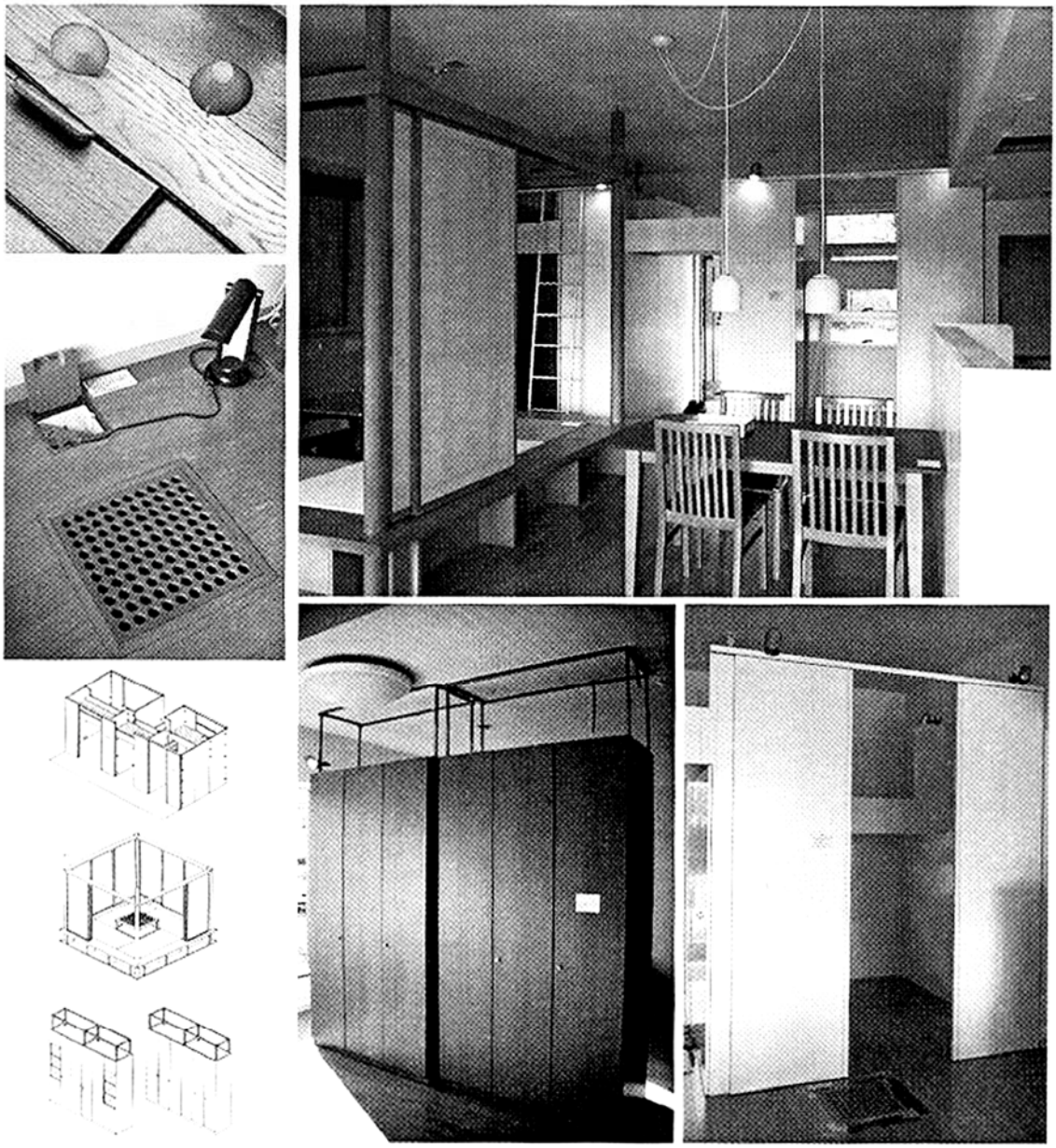


Figure APIII-3 Esprit Infill Systems in Netherlands

(Source: Tarpio & Tiuri, 2001: P18)

c.

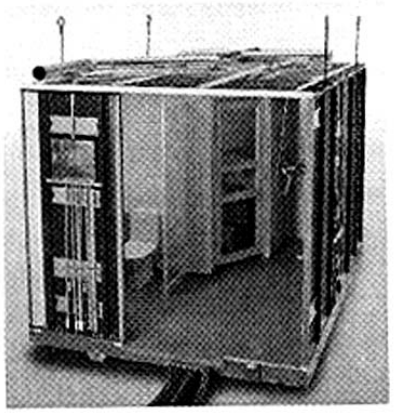


In the Shin Toshi Infill System the living spaces are converted into a series of rooms by spatial boxes, a stage unit and movable furniture. Photos at right: living spaces with Japanese style room unit, movable storage units as space dividers, and minimal room unit as a children´s room. Left: a special wood-rubber compound material that can be removed by a suction pad, and air-heating grating and electricity/information plug integrated into the floor. Axonometrics of minimal spatial boxes, Japanese style room unit and movable furniture.

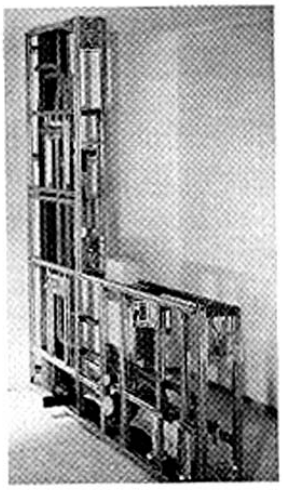
Figure APIII-4 Shin Toshi Infill System in Japan
(Source: Tarpio & Tiuri, 2001: P35)

d.

Bathroom units



Structural parts for wet spaces



Easily movable kitchen based on independent modular units

HVAC distribution box for individual apartment

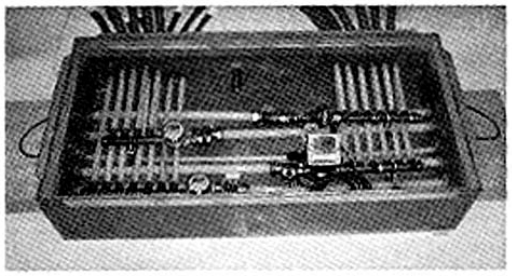


Figure APIII-5 Infill in Finland
(Source: Tarpio & Tiuri, 2001: P58-59)

e. NEXT-Infill

(Source: Proceedings of the 11th Annual Conference of the CIB W104 Open Building Implementation. Tokyo, Japan Sept. 2005)

Facing the increasing stock of condominiums, based on the open building concept, Sekisui Chemical Company developed an infill package model “NEXT-Infill” for eco-friendly skeleton remodeling of these existing buildings without affecting the building structure. The “base infill” in this model addresses the basic building service such as insulation, acoustics, and ventilation. The “lifestyle infill” in this model addresses social requirements such as facility renewal and plan change. This Infill package model may be adopted in the construction of condominiums with Shell and Infill separate.

1. Concept of the Infill System

We would like to introduce the industrialized infill package model, the "NEXT-Infill System", which was developed by Sekisui Chemical Co., Ltd., to provide sustainable housing. This system consists of two layers: a base infill system to support basic building service (insulation, acoustics, and ventilation) and a lifestyle infill to support social requirements(facility renewal and flexible plans).

Structural members are planned so that used materials can be shipped back to our company's factory for either reuse or recycling when the building is remodeled in future. By fully utilizing the technical know-how of each layer that we have accumulated as a provider of prefabricated housing, we have standardized the building materials, the unit construction method, and the convertibility of buildings. As a result, we can satisfy the cost performance of housing construction and construct a house in 2 weeks.

The following figure shows the abovementioned concept and the composition of, and system used in, each layer.

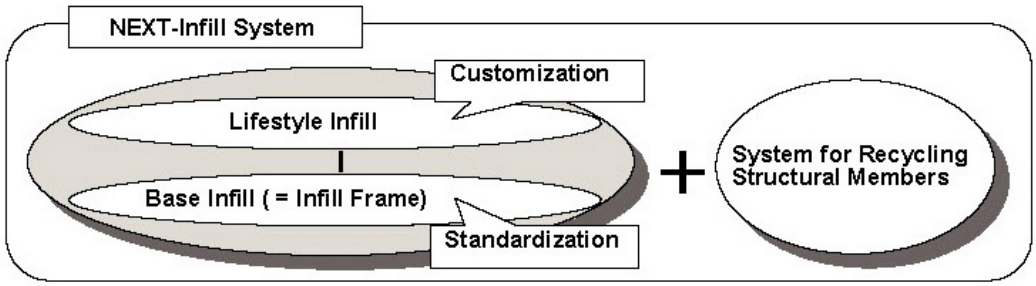


Figure 1 Concept of the "NEXT-Infill System".

2. Technology to construct a living space in a twisted skeleton

2.1 Development of the six-phased frame in a skeleton

We build an infill unit within an existing building that has secular deformation and create living spaces that are practically the same as modern housing units. We also improve the building's basic performance for living with insulated walls and acoustic floors. This infill unit is designed on the basis of the concept of industrializing the units used for finishing the building. The floors, walls, and recessed and projecting ceiling corners of the infill unit are built with self-supporting members. By connecting these members, a cubicle-shaped infill unit is formed within the skeleton. The infill unit is completed by installing new panel members onto the frame. A base infill is built by assembling a few infill units (see Fig. 2). By using this unit construction method, the construction period and construction costs are reduced to half those of ordinary construction methods.

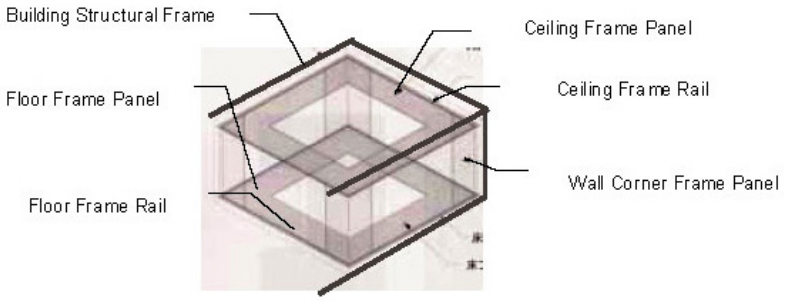


Figure 2 6 Hexahedral Infill Frame Model.

2.2 Joining by the Dry Construction Method

Using dry-joining by screwing and insertion of panels.
As the wall units are made in panels, it is easy to change the floor arrangement and it is possible to reuse the panels. Few mixed waste materials are produced when the house is demolished.

2.3 Developing Resources for Recirculating Building Materials

More than 60% of building materials can be reused during the next building remodeling period by using the structural panels and placing-type floor materials that we have developed from waste wood and plastic pieces as recycled resources. This system can be set up by installing partition walls, placing-type floor materials, and water supply and drainage piping systems using completely dry construction methods.

We have developed structural panels and placing-type floor panels using waste wood and plastic pieces and have been using these

Development of Recycled Floor Material

Placing-type floor material with waffle-shaped back.
The supports can be installed in any place

Development of Recycled Wall Material

Strong wall material made of wood chips arranged toward one direction.
Strong enough to keep screws and nails.

Photo 1 Recirculating Building Materials

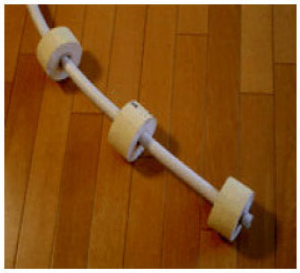
3. Technology to establish interface between infrastructure of skeleton and a living space to be constructed

3.1 Development of Technologies for Variability

The floor pre-construction method is used to maximize the freedom of the design in response to planning that involves resident participation. As a result, a simple, variable infill unit is realized. It has the following features:

1) Variability of the floor plan, for example in the locations of partition walls, and pre-molding of wiring at the building edges
2) Variability of water supply and drainage facilities, such as pressurized draining unit (20-mm-diameter pipe)
3) A simple pipe installation method that uses steel-reinforced polyethylene pipe and elastic pipe supports without the need for fixtures.

(resilient pipe supports)



(metal-reinforced polyethylene pipe)

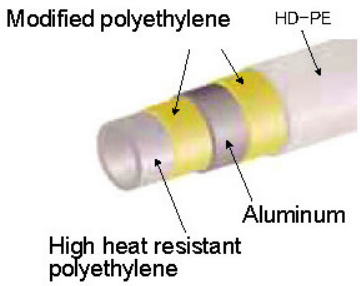


Photo 2 placing-type piping systems

Table 1 Comparison of Polyethylene pipe

	Bridged polyethylene pipe	Metal-reinforced polyethylene pipe	Remarks
Oil resistance	No worry about oil resistance because no plasticizer		PE pipes were shipped to sewage treatments
Chemical resistance	Polyethylene is generally considered excellent		
Working temperature	95 ℃	95 ℃	
Working pressure	0.65 MP a	0.8 MP a	
Liner expansion coefficient	23 * 10-5	5 * 10-5	
Minimum bending diameter	300mm (20A)	100mm (20A)	
Function to maintain shape	No	Yes	

3.2 Pressure drainage system of small diameter

We have developed a highly efficient and low noise pressure drainage system. Unlike the conventional system that drains water using power after it is pooled in a reservoir, the newly-developed system drains water each time water-related equipment is used. It improved design freedom of a housing unit considerably because it does not need a vent pipe.
The newly developed drainage system can be placed under a low floor because it done not need a slope not to mention that the drainage pipe has a small diameter, which makes it possible not to obstruct constructing a space in a stock building.

Photo 3 pressurized small-diameter drainage piping system placing-type piping systems

Table 2 Developped Pump Specifications

Item	Specifications
Motor	Direct current brushless motor
Outlet diameter	25mm
Revolving speed	2500rpm
Specified outflow amount	45L/min
Maximum power consumption	180W
Maximum output	145W
Outer dimension (pump)	L220 * W100 * H150mm
Mass	6.5kgf

5. Pursuit of Variability in the Lifestyle Infill from the Resident's Viewpoint

Residents' housing preferences are diverse, so well-coordinated proposals are always required. A lifestyle infill must be flexible enough to satisfy the preference of each resident. As one solution to satisfying residents' preferences, we have adopted the interior-styling system developed by our firm. (See Fig. 3)

Figure 6 SEKISUI Interior Style System

AP – IV: The air-conditioning data from MITSUBISHI HEAVY-Haier.

The following air-conditioning data came from professionals in technical department in the company --- MITSUBISHI HEAVY-Haier. These calculations were based on the floor plan choice-1 sent to them earlier.

a. A letter came from a technician in the company (answers are characters in bold size)

The unit photos in part c and built examples in part d are in the attachment of this letter.

早上好！

施工图纸请见附件。请对下列疑问作回复或确认：

1) 能否仅用一台外机，外面空间可能不够大放两台？

可以，用 KX4,最大一台 24 匹，但价格稍贵。

2) 每个房间和外机的功率各为几匹？每只管子尺寸估计为多少大？

一楼： 餐厅：22 平方，RFK36KX,1.5 匹，一台；RFK22KX,0.8 匹，一台；（壁挂式）气管：12.7mm,液管：6.35mm,排水：DN20.

客厅：37 平方，RF71KX,3 匹，一台；（立柜式）气管：15.88mm,液管：9.52mm,排水：DN20.

二楼： 卧室 1：11 平方，RFK22KX,0.8 匹，一台；（壁挂式）气管：12.7mm,液管：6.35mm,排水：DN20.

起居室：12 平方，RFK22KX,0.8 匹，一台；(壁挂式)气管：12.7mm,液管：6.35mm,排水：DN20.

卧室 2：16.2 平方，RFK28KX,1 匹，一台；（壁挂式）气管：12.7mm,液管：6.35mm,排水：DN20.

更衣室：7 平方，RFK22KX,0.8 匹，一台；（壁挂式）气管：12.7mm,液管：6.35mm,排水：DN20.

三楼： 健身房：11 平方，RFK28KX,1 匹，一台；（壁挂式）气管：12.7mm,液管：6.35mm,排水：DN20.

起居室：12 平方，RFK22KX,0.8 匹，一台；（壁挂式）气管：12.7mm,液管：6.35mm,排水：DN20.

卧室 2：16.2 平方，RFK28KX,1 匹，一台；（壁挂式）气管：12.7mm,液管：6.35mm,排水：DN20.

室内机合计：30.1kw,11.5 匹；
室外机匹配：28kw ，10 匹

以上方案供参考，可以现场考察后优化配置！

3) 制热、制冷功率为几匹？
暂考虑为 10 匹

请注意： 1) 因维修和外机较重考虑，空调外机不能置于二楼或三楼阳台和屋顶，只能放在后花园里；可以！
2) 所有室内机，除客厅可用柜式外，其它均悬挂于墙上。可以
3) 垂直方向的管子置于间井中，水平方向的管子置于墙内。

基于上述，价格为多少？

全部用变频多联机，

报价为:
报价有效期限:30 天

序号	名称	型号	数量	单位	单价	合计	备注
(一).VRV 主要设备							
1	变频室外机	RFC280KX	1	套	35700	35700	三菱重工海尔
4	柜式室内机	RF71KX	1	台	5516	5516	三菱重工海尔
5	壁挂式室内机	RFK22KX	5	台	3906	19530	三菱重工海尔
6	壁挂式室内机	RFK28KX	3	台	4256	12768	三菱重工海尔
7	壁挂式室内机	RFK36KX	1	台	4606	4606	三菱重工海尔
11	小计					78120	

设备费用: 78120
安装费用: 21000
工程总价: 99120

b. Drawings (sent back from the company)

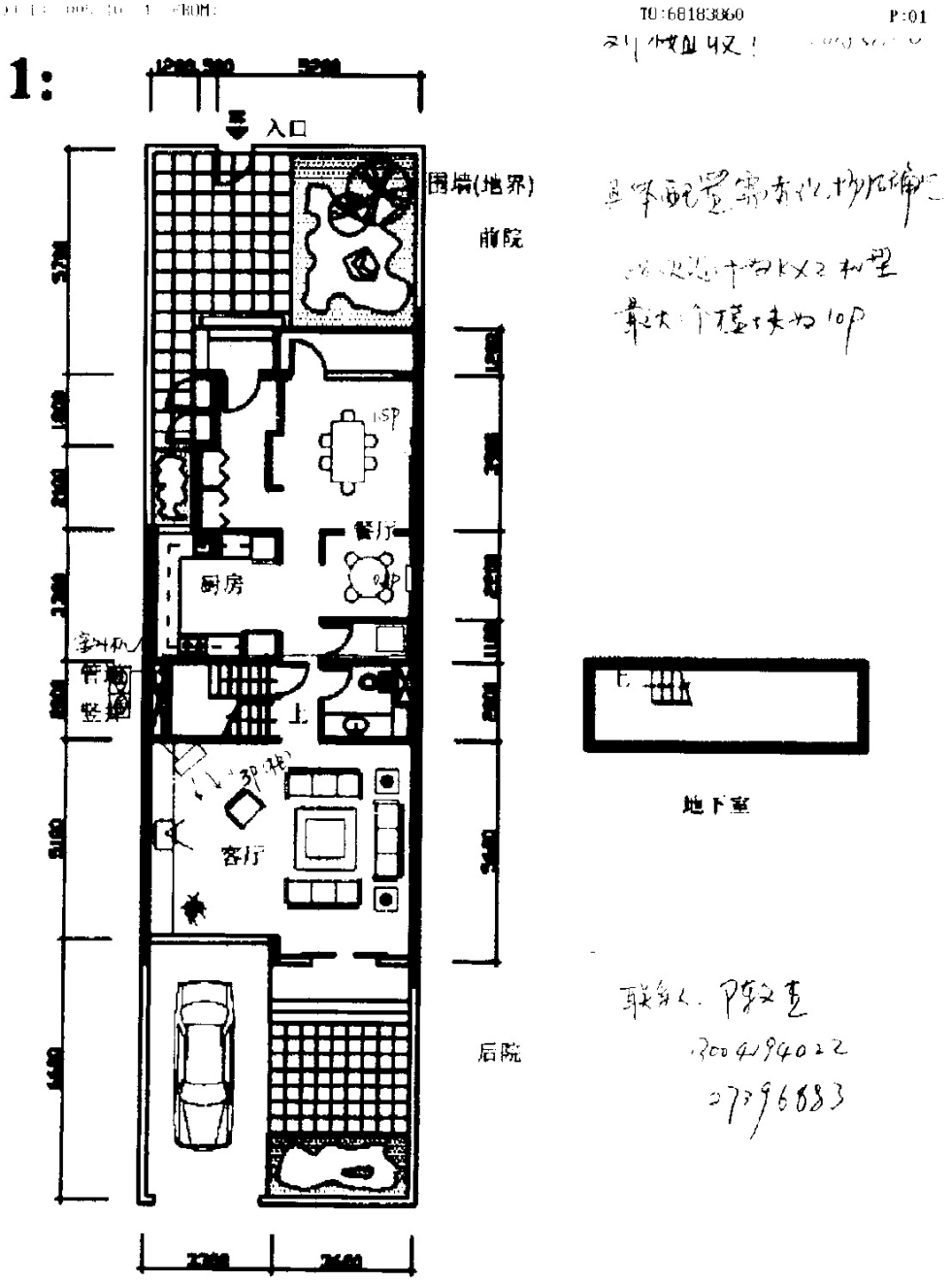


Figure APIV-1 Basement and First Floor Plans

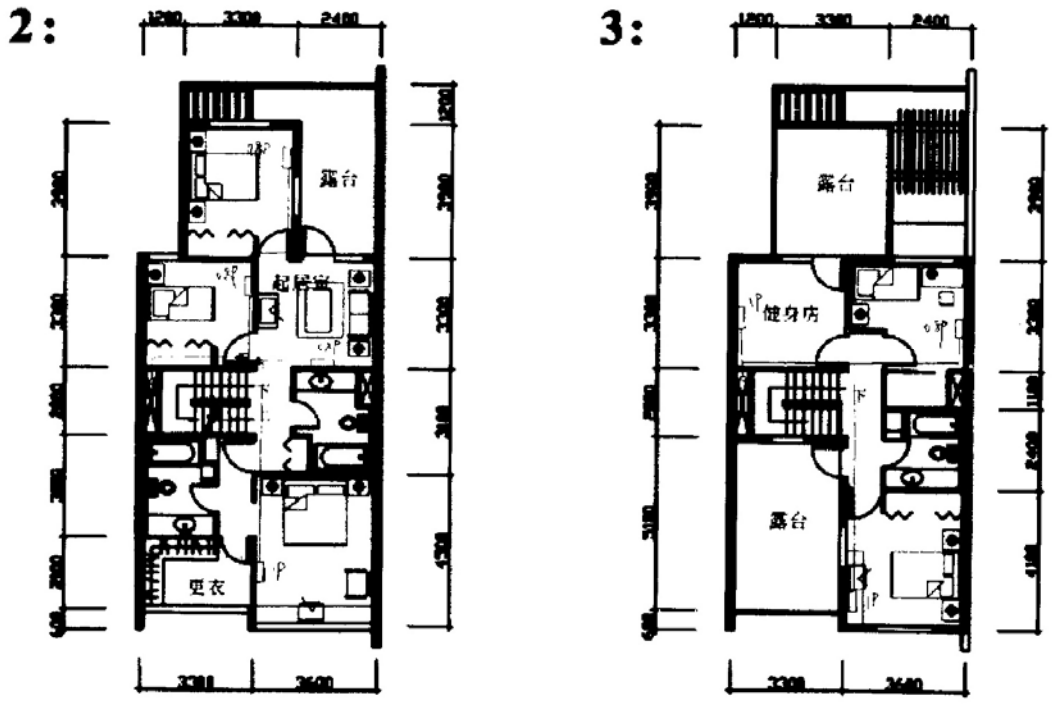


Figure APIV-2 Second and Third Floor Plans

c. Unit Photos (outdoor unit and indoor unit types chosen in this solution**)**

Figure APIV-3 Outdoor Unit

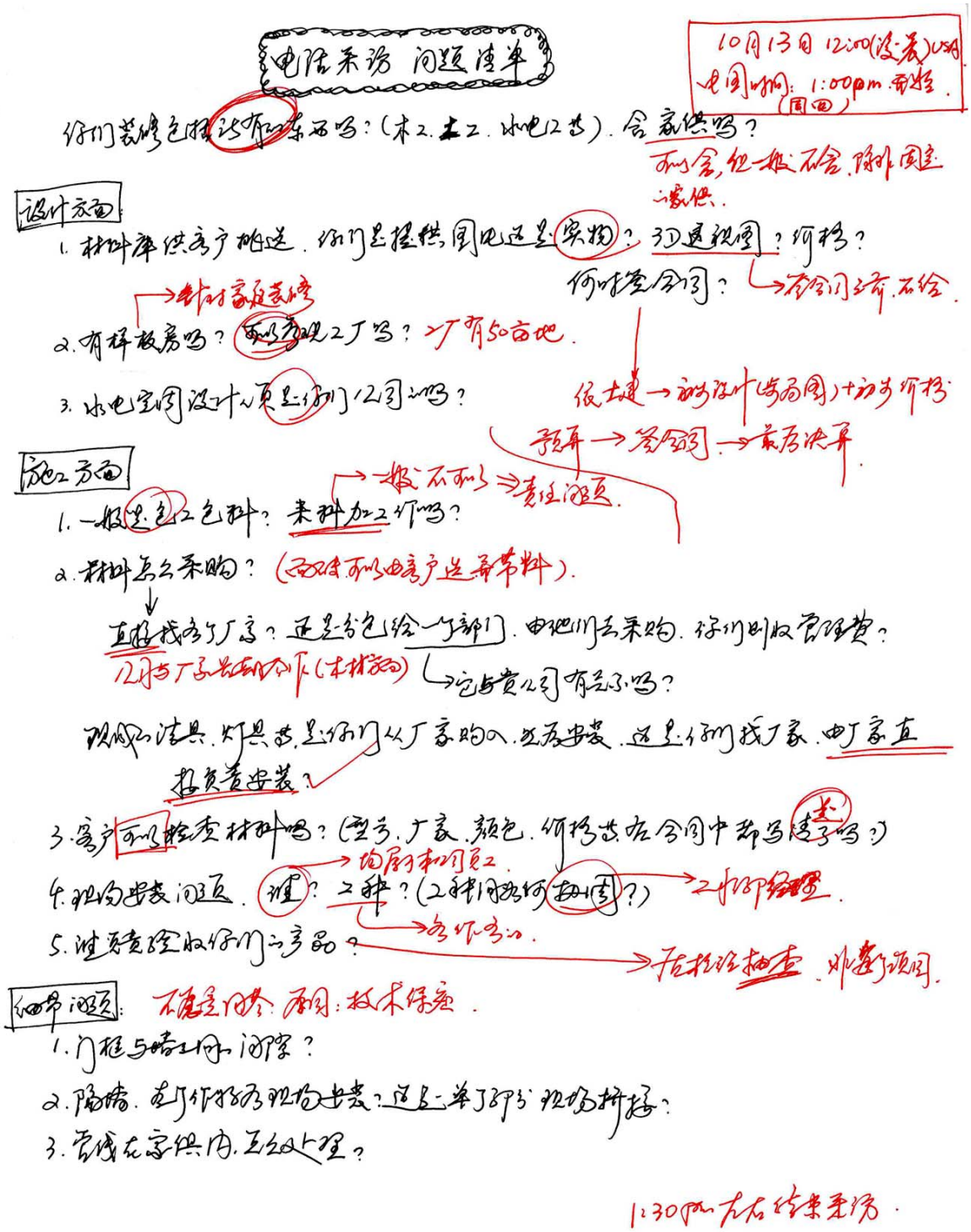
Figure APIV-4 Indoor Unit

Figure APIV-5 Indoor Unit

d. Built Examples:

Figure APIV-6 Built Examples Using this System

e. Telephone interview questions translated according to the questionnaire shown in the following page.



Questionnaire

1. Do you have an example housing unit (sales model unit) for customers to visit?
a .yes b. no
2. Do you have a material library for customers to use?
a .yes b. no
3. What kind of project do you decorate?
a .new housing units b. old housing units c. both
4. How many design schemes of the spatial layouts do you provide for customers?
a. 1 b. 2 c. 3 or more
5. How do you demonstrate the design scheme?
a. floor plans b. perspective renderings c. 3D "virtual" models
6. Do you include the cost estimation in each scheme?
a .yes b. no
7. Do you cover ALL the decoration items in the project?
a .yes b. no
8. Can customers provide some items and ask you to install?
a .yes b. no
9. Can customers request to install some items later by themselves?
a .yes b. no
10. Do you cover the furniture?
a .yes b. no
11. Do you prepare all items in an off-site fabrication or prefabrication facility?
a .yes b. no
12. How do you buy the materials?
a. buy directly from material supply companies
b. ask sub-contractors (which is not affiliated with your company) to buy all the material, the company collect the managing fee
c. buy some items directly from market and others from sub-contractors
14. Do you let your customers to check material before they are used in the project?
a .yes b. no
15. Do you let customers to visit your company production or prefabrication facility?
a .yes b. no
16. Who installs on the site?
a. crew who are trained and know how to install all the material
b. crew from different disciplines such as carpenters, plumbers, electricians and each install their products
c. both a and b according to different project
If your answer is c. then: What is the criterion?
a. single housing unit b. many housing units (large quantities on one site)
17. How long is the guarantee period after the housing unit is ready to move in?
a. 1 year b. 1-3 years c. 3 years or more
18. Do you cover all the cost during the guarantee period?
a .yes b. no

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