CARBON IMPACT OF SHARED SPACES IN URBAN HIGH DENSITY RESIDENTIAL PROJECTS: CHINA

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By

Duo Xu

DArch Committee:

Clark Llewellyn
Yiru Huang
Kath Williams
Andy Kaufman

Keywords: Residential building, Shared space, Carbon emission
Abstract

Reducing greenhouse gas emissions has become a controversial topic that needs to be researched thoroughly. When reducing the carbon emission of urban high density residential buildings, decreasing and carbon emission caused by residents’ behavior along with the carbon emission of construction material and building’s heating/cooling energy consumption is of the same importance, while the former has always been ignored. In the design phase, decisions regarding shared spaces will influence the building’s shape, thus anyway considerable negative effect on carbon emission both at construction stage and building heating and cooling energy consumption. Therefore, it is not welcome when it is related to low-energy buildings. However, shared space such as the opened first floor or balconies can provide amenity places for residence so that on the other hand decrease the frequency of transportation on motor vehicles. This study will analysis the extent to which changes in shared spaces affect the physical and social performance of carbon emission of urban high density residential projects, and thereby provide pre-design information for future reference for residential buildings with less carbon emission and less environmental pollution.

The dissertation proves that the value of shared spaces in residential projects lies not only in the humanity aspect, but also in the contribution to carbon emission reduction. This research displays a deeper and wider understanding in shared space, which provides new concepts on shared space for designers, policy makers, as well as normal residents, with which both the sustainability and living quality of the residential building could be enhanced.
Key Words: Residential building, Shared space, Carbon emission reduction
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Chapter 1 | Introduction

1.1 Research Background

The important decisions that affect energy consumption and carbon emissions are often made at the beginning of the design. For building energy conservation and emission reduction, the few efforts made in the initial stage can achieve the effect achieved at large costs in the final stage. Therefore, the designer should consider energy consumption and carbon emission in the beginning of the design. The consideration in this regard will affect the generation of form of the building.

![The definition of shared spaces](source: Author)

Figure 1.1 The definition of shared spaces

In general, public space of residential projects are at two different hierarchies, one category includes public roads, community centers, community centered gardens, greenbelts and other spaces; the other one category includes the enclosed semi-public spaces consisting of residence groups or extensions of residence groups, including small yards between residential buildings, roof garden, middle public platform as well as opened
ground floor spaces of buildings. The first public spaces belong to public spaces in the residential area; the second public spaces belong to shared spaces in the residence. (Figure 1.1)

Carbon dioxide, especially from transport and industrial production, is the most important greenhouse gas causing global warming and climate change. Due to human consumption of fossil fuels as well as carbon dioxide emission to the ocean, since the industrial era, the content of carbon dioxide in the atmosphere has risen by 35%.

Figure 1.2 shows the annual carbon dioxide emissions (2006) in each region of the world. In recent years, due to the rapid growth of the Asian population, rapid urbanization process and growing vehicle amount, the Asia has became the region with the highest carbon emission in the global, about 38%.

Shanghai is one of China’s largest international metropolises. In recent years, Shanghai has maintained a sustained economic growth. At the same time, from 2000 to 2007, the building energy consumption in Shanghai increased at an average annual rate of 10.2%, the total amount of CO2 increased from 19,522,500 tons to 38,575,100 tons, an average annual growth rate of 8.6%. Therefore, reducing carbon emissions and achieving
low-carbon economy and green growth is another requirement of China for Shanghai and other cities during the rapid urbanization. (Figure 1.3)

Figure 1.3 Carbon emissions per capita of Shanghai

Source: Theoretical approach and empirical analysis of low carbon cities in Shanghai

Residential buildings are most related to people’s daily life. Their basic function is to provide people with ideal residence and create the building space environment to meet people’s needs. The evolution of residential buildings is the reflection of social development. In the increasingly serious problem of global warming today, in addition to achieve the suitability and comfort for living, reducing carbon emission of residential buildings is the necessary requirement of achieving sustainable development and alleviating the climate issue.

1.2 Transition from Energy Consumption Perspective to Carbon Emission Perspective
Requirements for low-energy buildings are often layered with the carbon strategies. Sifting through these codes, definitions and concepts to develop a systematic approach for describing low carbon strategies is required to provide clear guidance for national policy and to ease communications difficulties.

In terms of shared spaces in urban high density residential buildings, there is no wonder that the building shape is one of the most important considerations in the conceptual stage of building design. Too often, however, decisions on the building shape are based on energy efficient only, which has the evident disadvantage of limiting the potential of performance improvement. The potential of shared space for saving energy and raw materials as well as the possibilities of limit transportation frequency are ignored here.

Although the energy consumption of cooling and heating accounts for a large proportion of the total energy use in residential buildings. We cannot draw to the conclusion that anything that will decrease the geometric efficiency is not sustainable, it is very common to find building performance assessment models that do not take into account these considerations and therefore have a limited capability and scope. This leads to inadequate aggregate indicators for the actual assessment of the sustainable performance of the building envelope for a sustainable energy efficient building.

The carbon concept provides a compelling vision of how to link energy needs to sustainable living habitat, and, as a consequence, it is an important paradigm for thinking about how to create and manage the built environment in a manner that parallels the behavior of residents. Transportation energy is coupled to the built environment in the sense that the relationship of building location to user needs and the public spaces in the community can significantly impact the scale of transportation energy. It has been proved that compact, denser urban environments have the benefit of reducing transportation.
energy, but they are unfortunately less suited for some emerging low-carbon strategies.

A collateral benefit of carbon vision is that, for practical reasons of economics and limited space availability, minimizing building energy consumption becomes a priority. For a variety of technical and cultural reasons, a wide variety of definitions of low carbon are currently being used. These differences are particularly evident upon examining EU and US policies regarding shifting buildings to sustainable energy practices over the next 40 years. The vision for both the EU and the US is a low carbon built environment within this time frame including both new and existing buildings. This is a compelling vision for the future that strongly and directly confronts the built environment contribution to climate change and suit itself into the context of carbon with many other industries. A final major benefit of the low carbon concept is that it is a very integrated vision which includes all stages of the life cycle of the building, making it more accurate to evaluate the shared spaces in urban high density residential projects.¹

1.3 Research Scope

The research scope is the shared space of urban residences. In order to increase the depth of this research, this dissertation will mainly select the open ground floor space as the typical example of shared space of residential, and focus the climate region on Shanghai in the Yangtze River Delta region, thus estimating carbon emission in a more specific way.

Due to many actual categories of carbon emission, in this research, three main problems most related to open ground floor of residences in the life cycle of buildings are discussed: (1) change of carbon emission caused by the open ground floor of residences to
the operation of building equipment system (Figure 1.5 left); (2) change of carbon emission caused by the open ground floor of residences to material production and transportation of external building envelope (Figure 1.5 right); (3) effect of the open ground floor of residences on emission reduction of resident’s travel (Figure 1.6).

Problems (1) and (2) can be summarized as the physical influence of open ground floor on the carbon emission of residential buildings, which will be studied in the Chapter 4 of this dissertation; problem (3) is the social influence of open ground floor on the carbon emission of residential buildings, which will be studied in the Chapter 6 of this dissertation. In addition, problem (1) reflects the influence of open ground floor on building energy consumption. These three problems are closely related to living quality, living environment and social interaction in the space created by open ground floor for residences. The relationship between overall change of carbon emission and above-mentioned three problems can be expressed as the formula 1.1:
\[ \Delta E = \Delta E_{\text{PHY}} + \Delta E_{\text{OPR}} + \Delta E_{\text{MAT}} + \Delta E_{\text{TRIP}} \]  

(1.1)

\( \Delta E \) is the change of carbon emission caused by open ground floor

\( \Delta E_{\text{PHY}} \) is the change of carbon emission caused by open ground floor to the operation of building equipment system (kgCO\(_2\)/m\(^2\))

\( \Delta E_{\text{OPR}} \) is the change of operation of building equipment system during building operation maintenance caused by open ground floor (kgCO\(_2\)/m\(^2\))

\( \Delta E_{\text{MAT}} \) is the change of carbon emission caused by open ground floor to relevant material production and transportation of external building envelope (kgCO\(_2\)/m\(^2\))

\( \Delta E_{\text{TRIP}} \) is the change of carbon emission caused by open ground floor to motorized travel of residents (kgCO\(_2\)/m\(^2\)).

In addition to studying above three problems with the qualitative analysis method, this dissertation will combine the quantitative calculation method to estimate the revenue.
and expenditure of energy consumption and carbon emission of residences after open ground floor is used, summarize the mechanism of open ground floor on above three factors as the conceptual relationship matrix, and finally make a summary and conclusion (Figure 1.7).

![Figure 1.7 The matrix of 3 factors](image)

Source: Author

### 1.4 Research Methodology

The research is about the shared space of urban residences. This dissertation will explore the influence of the shared space on emission reduction. The research methods include literature research, software simulation, data collection, case analysis, investigation, chart analysis, design suggestion and so on. Literature research is to understand the development history and current situation of the shared space of residences mainly through literature review; software simulation is to simulate the energy consumption of residences mainly through PKPM building energy simulation software, to establish the experimental model and analyze the influence of shared space of residences on building energy consumption and carbon emission; data collection is to collect
research-related carbon emission factor data in all kinds of specifications and documents in order to conduct quantitative calculation; case analysis is to mainly select the typical actual design case of residences’ shared space to analyze the expression of the case in meeting the personalized needs of shared space of residential areas in the daily life; investigation is to mainly observe residents’ daily motorize travel, find problems and needs from phenomena observed and accumulated, prepare questionnaires for most important contradictions in the phenomena, and collect data for analysis in order to determine the real preference demand orientation; chart analysis is to make the collected questionnaires into charts for data statistics and to obtain the information about residents’ travel as the basis for estimation of influence of residences’ shared space on emission reduction of residents’ travel; design suggestion is to give the tentative design suggestions on above basis and provide basis at the angle of emission reduction for design of residences’ shared space.
Chapter 2 | Theoretical Research and Literature Review

2.1 Open Ground Floor

It is not that the open ground floor as an architectural technique appears until modern times. As early as in ancient times, ethnic minorities living in southwest China had already begun to set up the open ground floor as one floor in the construction of residence. The dry-column house in Western Yunnan and Hunan, “half-floor building in Guizhou and “stilted building” in Chongqing are the typical examples. In usual, the ground floor layer set up is used to raise livestock or store things, and the above layer is used to live (Figure 2.1). This building can isolate moisture and prevent intrusion of insects, snakes and beasts. For example, the stilted building in Western Yunnan, with one side hung in the river, underside extending long “legs” deeply into the river, and another side built on the bank, naturally forms a two-floor building. The ground floor part is used to store things or as barn and firewood house, or to raise livestock; the above part is used to live. The front side is close to the street and the back side is close to the river, and the building looks very exquisite and beautiful.

Figure 2.1 Guizhou "half floor" (left), Xiangxi "stilts" (right)
Source: http://www.weather.org.cn/mtji/4055.jhtml
In 1926, Le Corbusier named the open ground floor as the top of “five points of new architecture”, which is also the architectural feature generated after modern buildings use frame structure and walls do not bear load in modern times (Figure 2.2). Villa Savoye is a famous masterpiece. The designer gives full play to the features of the frame structure, with one layer opened as a garage. In addition, Marseille Apartment, his another representative work of residential building, whose opened layer is supported by huge pillars for parking and ventilation, practices the theory.

![Figure 2.2 Le Corbusier’s elevated city](source)


In Japan’s traditional houses and temples, the “high bed culture”, namely open ground floor is also very common. For example, the Izumo Taisha of Ise Grand as well as Library of Zhaoti Temple use the open ground floor technique to adapt to Japan’s damp and hot climate.
To restore the “lost but perfect transition space” in the city, Japanese architect Kisho Kurokawa referred to the concept of “edge side space” in traditional Japanese culture, and designed a huge open opened space in the Fukuoka Bank headquarters- an urban public open space between indoor and outdoor, and between public and private (Figure 2.3).

With the development of construction technique, the form of opened space is constantly enrich, showing universality and adaptability. Open ground floor is a special type of urban public open space, usually expressed as the space form of pillar layer. This technique makes the city ground floor a transparent and continuous space. Some are large-area column-free space and others are spaces with “proof” but without enclosure. Combined with landscaping and rest facilities, this technique is widely used in the tropical and subtropical countries such as Singapore. (Figure 2.4)

2.2 Resident Behavior

“Behavior” is considered to be a reaction to the external environment (Thordike, 1905; Skinner, 1953) [2]. There are also some behaviors that can be interpreted as people’s

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cultural and social attributes as well as physical characteristics factors (Michelson, 1977). Therefore, the environments designed by designers and planners are of great importance to stimulate and influence people’s a series of “behaviors”. People who conduct the same daily travel behavior will cluster together due to some special reasons such as their own needs or narrower social distance (Knox, McCarthy, et al., 2004).

2.2.1 Communication and Space

In the book Life between buildings written by Jan Gehl, he sorted people’s activities into three types, namely necessary, spontaneous and social activities, and based on this, he studied the relationship between people’s activity and physical environment in the city. Furthermore, he explained the relationship between people’s behavior and behavior of public space, and proposed that the design of external environment could support or block communications between people. In the aspect of promoting communications, the positive effect of public space can generate positive effect, while the negative effect could further bring negative effect. In addition, he pointed out the different needs of different groups of people for material environment of public space and it was necessary to design the public space according to different features of different residents in a targeted manner. He also systematically introduced what kind of urban public space could stimulate more social activities and found some effective ways to create a vibrant community.

2.2.2 Spirit of Space

Aldo van Eyck first proposed the concept of place in the 1950s and believed that the experiences of space and place were two sides of a thing. Afterwards, Christian Norberg-Schulz proposed the differences between “place” and “space” in the 1980s, and pointed out that relative to space, place carried the social needs of more people. The order and organization, form and element,
and material and symbol of space passed different values to people. This constituted the interaction between humans and place, and this interaction constituted daily activity. These events were the signs of space becoming place. In the Intensions in Meaning of the Built Environment, Amos Rapoport proposed that the significance and role of the space environment are reflected in people’s cognition of environment. Social culture is the origin of space. These theories laterally reveal why people are unwilling to leave some space and why some spaces can meet people’s psychological needs.

2.2.3 Pleasure of Architecture

In his book The Origins of Architectural Pleasure, the American architectural theorist Grant Hildebrand proposed that, based on the long history of human evolution, people tend to have a “shelter”, but need to have a good vision to readily observe the dynamics of the outside world. This is not only a psychological need of self-protection but also a way to meet human curiosity. He also pointed out that the space that is closely related to natural environment is very attractive, and the parts of a building close to and open to nature are often favored. Even if they cannot get the real natural environment, people will seek for natural environment by material metaphor and interior decoration. According to Grante’s theory, the desire for the outside and nature is the basic psychological need of all people, regardless of necessity of activity. The space surrounded by natural environment or with vision will stimulate people to come and do activities.  

2.2.4 Family Classification Based on Behavioral Requirements

According to different family characteristics, the American sociologist Wendell Bell

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divided the lifestyles and needs of American people into three categories. The residents in a familistic family tend to spend a lot of time with their children, so they will pay more attentions to schools and parks in the community; the residents in a occupation-type family will pay attention to whether the public transport station nearby the community is convenient due to commuting need; the residents in a consumption-type family will focus on whether there are sound recreational facilities in the community.\(^5\)

### 2.3 Relevant Theories for Resident’s Travel

For most people, the travel mode is determined by many factors. The travel mode can become a symbol of a certain lifestyle to a large extent. Therefore, the travel mode in the sociological context is related to beautiful life. When discussing the influence factors of travel mode, we cannot avoid the situations that an ideal life should contain because travelling means a way to obtain the ideal life. (Mobilities in Daily Life, Pedersen, 2009)

#### 2.3.1 Classification of Travel Activities

The travel necessities of citizens are influenced by the distance between the origin and the destination needed to accomplish their tasks. It is also the case that the need for and availability of travel generates additional trips for various purposes.\(^6\)

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The general features of urban mobility include work trips, shopping trips, social or recreation trips, business trips and school trips (Meyer and Miller, 2001). Although the nature of these trips varies from city to city, most classifications include the following (Hanson, 1995):

1. work trips made to a person’s place of employment, e.g., public or private institutions, manufacturing plants, retail stores or shopping malls;

2. shopping trips to any retail outlet, regardless of the size of the store and whether or not a purchase was actually made;

3. social trips made for social activities, e.g., to go to parties or visit friends;

Figure 2.5 Residents travel type
Source: Author

Figure 2.5 Residents travel type
Source: Author
(4). recreation trips made to go to entertainment, cultural or other 5. school trips made
by students at any level to a learning institution;

(5). business trips usually defined to include trips made from a place of employment
to another destination in the city; and

(6). home trips include any trip ending at home.

For moderate and longer travel distances, motorized transport is generally required.
This means that citizens’ choice of a motorized or non-motorized transport mode is
affected by land use. If there is “no origin-destination separation” or if a trip is “within
walking distance separation”, motorized transport is not required. Consequently, no energy
(non-human) is required for transportation purposes, no emissions are released and better
urban air quality is achieved. 7

2.3.2 Appropriate Walking Distance

In 1929, the American sociologist Clarence Perry created the “Neighborhood Unit”8
theory, namely considering the size of neighborhood unit at the radius of 1/2 mile (1
mile=1.6093 km). The commercial service facilities necessary for daily are set up near the
elementary school to meet the needs. The purpose of the neighborhood unit is to create a
well-equipped, comfortable and convenient residential community environment under the
condition that motor traffic begins to be developed.

After the neighborhood unit theory was proposed, in 1928, the design of Radburn
New City in American New Jersey brought the concept of large neighborhood. In each

7 Amin, A. N. "Reducing Emissions from Private Cars: Incentive measures for behavioural
change." Prepared for economics and trade branch, Division of technology, Industry and economics,
8 Neighborhood and community planning. Regional plan of New York and its environs, 1929.
large neighborhood, there is a complete pedestrian system, which is completely separated from automobile traffic. The main roads of the city are the borders of settlements and a number of residential buildings form a garden. Residential buildings face the garden and sidewalks, back to end-typed motor road, forming a safe, orderly and spacious living environment with more garden lands.

The discussion about walking in the living area has a new development today. In his book Towards a Sustainable Neighborhood, Turning the Vision into Reality, Shahameh Parhizgar pointed out that in the past 50 years, the residential area planning in North America was designed for cars, thus making people’s time in a motor vehicle longer. Out of emission reduction, residential areas should free residents from motor vehicle. Daily requirements and public transport stations should be settled with the residential area as the center at the radius of 5-minute walking distance, basically 400-meter distance. He also pointed out that this distance could be adjusted according to the quality of environment on the way, so it was necessary to provide good and suitable footpaths or bicycle paths in the design. In his book Seven Rules for Sustainable Communities: Design Strategies for the Post Carbon World, Condon took Vancouver, Canada as an example to indicate that in the case that residents can meet their daily needs by walking, Vancouver reduced 30% of car use relative to some vehicle-oriented cities such as Sydney. Meanwhile, the total number of private cars in Vancouver was 0.45 vehicle/household less than Sydney (Condon, 2010).

It can thus be seen that the travel mode selected by people to conduct above activities is closely related to use of land. Meanwhile, the cultural facilities in the city and tightness of relationship between park and residents will largely affect the transportation mode. He believed that the urban lands should be compact and the improper way of land use would not only bring inconvenience to people’s work and life, but also force people to select
motor vehicle to travel, thus increasing the carbon emission of transportation.

2.3.3 Long and Short Distance Travel Demand Study

Erling Holden and Ingrid T. Norland in his research: Three Challenges for the Compact City as a Sustainable Urban Form: Household Consumption of Energy and Transport in Eight Residential Areas in the Greater Oslo Region argued that there are three distinct findings indicate that decentralized concentration urban planning could lead to even lower energy use in households: while the extent of everyday travel decreases in densely populated areas, the central urban areas represent the highest level of leisure-time travel by plane; the access to a private garden limits the extent of leisure travel; and, the difference in energy use for housing between single-family and multifamily housing is reduced in housing built after 1980, indicating that the established conclusions on the most energy-efficient housing should be questioned.9

2.3.4 Status of Emissions of Travel

As can be seen from above-mentioned theoretical review on the travel, due to the importance of selection of transport means for emission reduction, foreign theories are closely related to the emission reduction of travel and transportation.

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Transportation emission reduction is the focus of emission reduction (Table 2.1). In developed countries, the carbon dioxide emission of transportation accounts for 1/3 of the total. According to the statistics of the US Environmental Protection Agency (EPA) in 2006, the carbon emissions of transportation account for about 29% of the total in America, almost all from vehicle fossil fuels. At the same time, the carbon emissions of transportation increase fastest among the greenhouse gas emission factors in America. Since 1990, the increase rate has been 47%. In 2005, the carbon emission of transportation accounted for 23.1% of the total in Japan. The statistics made by China in 2008 showed that the total carbon emission of transportation resources was 4.38 million tons, accounting for 5.05% of the total. Although, it was less than that in developed countries, compared with 3.19% in 1990, its increase was significantly. Meanwhile, at present, the motor vehicle market grows fastest in Asia (Table 2.2). Therefore, starting from the emission reduction of motor vehicle is one of the inevitable choices to alleviate environmental capacity pressure.

Table 2.1 Global carbon emissions index

<table>
<thead>
<tr>
<th>Department</th>
<th>Percentage(%)</th>
<th>Department</th>
<th>Percentage(%)</th>
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<td>Electricity generation</td>
<td>44.4</td>
<td>Home</td>
<td></td>
</tr>
<tr>
<td>Industrial</td>
<td>6.0</td>
<td>Daily Activity</td>
<td>9.5</td>
</tr>
<tr>
<td>Steel</td>
<td>3.0</td>
<td>Other</td>
<td>3.4</td>
</tr>
<tr>
<td>Cement</td>
<td>0.8</td>
<td>Trips</td>
<td></td>
</tr>
<tr>
<td>Paper Industrial</td>
<td>0.5</td>
<td>Motor Vehicle</td>
<td>18.5</td>
</tr>
<tr>
<td>Other metal</td>
<td>10.9</td>
<td>Others</td>
<td>2.9</td>
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</tbody>
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Table 2.2 Global carbon emissions index

<table>
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<th>HIGH (AI&gt;60%)</th>
<th>MEDIUM (AI: 30-60%)</th>
<th>LOW (AI&lt;30%)</th>
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<td>UNITED STATES</td>
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<td>KOREA</td>
<td>FRANCE</td>
<td>AUSTRIA</td>
</tr>
<tr>
<td>PHILIPPINES</td>
<td>ITALY</td>
<td>HOLLAND</td>
</tr>
<tr>
<td></td>
<td>ENGLAND</td>
<td>FINLAND</td>
</tr>
<tr>
<td></td>
<td>BELGIUM</td>
<td>DANMARK</td>
</tr>
<tr>
<td></td>
<td>PORTUGAL</td>
<td>JAPAN</td>
</tr>
<tr>
<td></td>
<td>NEW ZEALAND</td>
<td></td>
</tr>
</tbody>
</table>

Source: Reducing Emissions from Private Cars: Incentive measures for behavioral change

2.4 Relevant Theories for Reference Standards on Carbon Emission

2.4.1 Study and Reference Standards for Carbon Emission

There are a series of relatively mature green building evaluation system with relatively extensive applications. These systems have gradually become the effective tools for status of carbon emission in the architectural design through constant application and exploration in the actual projects. Through constant revision and improvement, these systems have gradually become mature, too. At present, the international systems with wide applications mainly include Life Cycle Assessment (LCA), Green Guide for Healthcare (GGHC), Labs21, Living Building Challenge, CO2 balancing, Ecological footprint, Natural Step, SB Tool from International Initiative for a Sustainable Built Environment (IISBE), American LEED, British BREAM and Japanese CASBEE.

Britain has been playing a leading role in the foreign carbon emission research. British Standards Institution (BSI) is a national institution independently responsible for developing British standards and other relevant publications, information and services. BSI
shows that Britain occupies a position in the European and international standards. In October 2008, based on ISO14044, ISO/TS14048 and other international standards, BIS issued the PUBLICLY AVALABEL SPECIFICATION 2050: 2008 Specification for the Assessment of the Life Cycle Greenhouse Gas Emissions of Goods and Services, which became the world’s first norm of commodity carbon footprint. PAS2050 gave a strict definition to calculation of product carbon footprint. With the calculation method of building carbon emission on this platform, the uncertainty was basically eliminated and the calculation method was clearer [10]. Due to its versatility and authority, after issuance, it became an important international reference standard and is widely adopted and applied. Then, in 2010, BSI issued the PUBLICLY AVALABEL SPECIFICATION 2060: 2010 Specification for the Demonstration of Carbon Neutrality. PAS 2060 noted that to achieve carbon reduction, in addition to reducing greenhouse gas emissions as well as offsetting carbon emission in some ways, the means to offset residual greenhouse gas emissions can be introduced to achieve carbon neutrality.

LCA is one of carbon emission evaluation systems widely applied in the international sector. LCA is evaluating the impact of the full life cycle of a product from production, usage to destruction (Figure 2.6). The impact of a product on the environment is not limited to the material production process. The analysis approach of LCA is very conducive to macro understanding of carbon emission (Badino and Baldo 1998). Therefore, LCA is widely used in various industries as a reliable tool to measure the degree of impact of a product on the environment, thereby helping people better understand the environment-friendly industry chain and more effectively control the

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carbon emission (Carlo, 2010).

2.4.2 Data Sources for Carbon Emission

The focus of this dissertation is on studying the impact of open ground floor as an architectural technique on the carbon emission of residential buildings. The research scope is the first three parts of full life cycle of buildings, namely production of building material, construction as well as usage and maintenance. The demolition phase is not in this research scope.

(1) Data sources of carbon emission in the production phase of building material

In recent years, the evaluation on carbon emission of building material has gradually changed to evaluation on some products. Thus, data obtained will be more accurate and specific. The data is generally obtained from the Environmental Protection Declarations (EPD) provided by companies. The EPD contains environmental impact data of full life cycle of the product, as well as carbon dioxide equivalence as the index of global warming potential. (Figure 2.7)

Product Classification Rule (PCR) generates the industry standard (ISO-based), which provides the scope and method of carbon emission measurement, equivalent to the role of raw materials; LCA provides the definitions of carbon emission measurement units in the phases of full life cycle of the product; EPD is the specification of carbon emission of a complete product, equivalent to the role of the list of ingredients on the product package, which provides the basis for the buyer to choose the product.
(2) Data sources of carbon emission in the construction phase

The carbon emissions in the construction phase mainly include the carbon emissions generated by the energy consumption from materials transportation to construction site as well as the operation of construction equipment constituted by building materials. In this phase, the carbon emission of material transportation to construction site is relatively important. The carbon emission generated by the operation of construction equipment constituted by building materials is generally emitted because it is not convenient to estimate due to different types of construction equipment. For carbon emission of material transportation, there are defined conditions and estimated results in the EPD.

(3) Data source of carbon emission in the building usage phase

In general, the carbon emission sources in the building usage phase mainly include the operation and energy consumption of HVAC, lighting and appliances in the building. In general, the usage of electricity is converted to the numerical value of carbon emission. Meanwhile, the carbon emission sources of air conditioning refrigerant are included. For heat-supplying area in North China, the carbon emissions of fire coal in the building
heating period are included. In this research, the carbon emissions of air conditioner, lighting and appliances equivalent to energy consumption are not taken into account due to larger difference between using habits of residents. Only the carbon emissions generated in the heating period and in the room temperature maintained by the air conditioner in the operation phase of air conditioner room. This data is obtained through simulation analysis of building energy consumption analysis software PKPM developed by the Shanghai Institute of Building Sciences.

In addition, in this research, the carbon emissions generated by resident’s behaviors such as resident’s travel by motor vehicle are taken into account in the building usage phase so as to consider the impact of open ground floor on carbon emission in a more macro perspective.

2.5 The Relationship Between Human and Nature

2.5.1 Biophilia

Being close to nature will engage more of the things close to the human heart and spirit. Human beings are used to live in nature from the very beginning, so they tend to have greens in public spaces around where they live. Humanity is exalted not because we are so far above other living creatures, but because knowing them well elevates the very concept of life.11 E. O. Wilson stressed the importance of the plants in the existing environment. The theory of biophilia reveals the principals and necessities of landscape design. People want more nature, they would create nature or natural elements. For example, When people are confined to crowded cities or featureless land, they go to

considerable lengths to recreate an intermediate terrain. At Pompeii the Romans built gardens next to almost every inn, restaurant, and private residence, most possessing the same basic elements: artfully spaced trees and shrubs, beds of herbs and flowers, pools and fountains, and domestic statuary. When the courtyards were too small to hold much of a garden, their owners painted attractive pictures of plants and animals on the enclosure walls- in open geometric assemblages. Japanese gardens, dating from the Heian period of the ninth to twelfth centuries (and hence ultimately Chinese in origin), similarly emphasize the orderly arrangement of trees and shrubs, open space, and streams and ponds.  

2.5.2 Prospect Refuge

Exposure to natural environments can improve mood, reduce blood pressure and heart activity and improve people’s ability to concentrate. The restorative benefits of natural settings (as compared to built settings) is well documented. (for reviews see Bowler et al., 2010 and Health Council of The Netherlands, 2004).

Kaplan’s (1995; Kaplan and Kaplan’s, 1989) Attention Restoration Theory (ART) adopts a cognitive framework to explain the restorative process. Two types of attention are distinguished; directed and involuntary. Directed attention forces the mind to actively engage and focus attention (for instance on a difficult task) even in the presence of more exciting stimuli (Kaplan, 1989).

These theories shows that it is essential for human to seek natural images in their daily life, especially in the urban high density residential projects, we need shared spaces to grow plants , it can not only bring the space to life and absorb the carbon dioxide and clean the air in the surrounding environment, it can also indirectly improve the physical

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and mental health of the residents so that the quality of the life could be also improved.
Chapter 3 | Case Studies

The beautiful and elegant public place should be treated as the necessary social service facilities, and the open ground floor space has the potential to become the public space in the community. In many cases, the open ground floor space of residential building can not only become an independent activity place, but also link with other opened spaces to constitute a flowing spatial sequence. In addition, the open ground floor space and sidewalks, streets and stores can jointly form a diversified system combining traffic, urban life and community life. This system integrates urban commercial atmosphere, constitutes traffic crossing and stimulates linkages of various activities. Its sense of place is very strong. In this dissertation, three cases are selected to show the advantage of the shared spaces in building, one is a residential community in Shanghai---Xin Fukangli, which has a couple of buildings with opened floor. The second one is a commercial real estate in Honolulu, Hawaii---Pualeilani Atrium Shops, and the third one is a hotel estate in Honolulu---. The three cases are selected as the major research cases. By investigating the space of the case, the spatial features of open ground floor are explored and the behavioral need traits of residents are obtained from their use of opened space.

3.1 Xin Fukangli

Xin Fukangli is located in Jing’an District, Shanghai, which is one of representative residential areas with open ground floor in Shanghai. Its total construction area is 118,000 m2. It is mostly residential buildings and supported by commercial facilities. Its master plan is shown in Figure 3.1. Six residential buildings with open ground floor in the center.
of the community form a highlight. The greenbelts between opened space and residential buildings as well as the main roads throughout the community form the multi-level space and rich landscapes. The main roads serve as outdoor space, which are decorated by bright preach trees. In spring. They are the extremely vivid spaces of transportation and communication. The open ground floor space serves as the semi-outdoor space, with some privacy, which can be used in rainy days. In the open ground floor space, residents can appreciate green grasses and trees. Combined with changeable building details as the background, a green picture is framed (Figure 3.2 ). Though they have their own features, road space, building space and landscape space complement each other. People will be moved by and linger on the exquisite scale and smooth layers.
3.2 Pualeilani Atrium Shops

The Pualeilani Atrium Shops is located in 2424 Kalakaua Avenue Honolulu, Hawaii. In there, over three levels of unique one-of-a-kind boutiques and specialty stores encircling the open-air Atrium.
The Pualeilani Atrium Shops is the podium of the Hyatt Regency Waikiki Beach Resort & Spa. Under the two towers is the opened first floor. The first floor has several functions. It not only act as the entrance of the hotel.
but also plays a role of a commercial area with elegant shops inside, furthermore, it provide seats for the visitors. The entrance of this
space is of 3 floors height, which gives people a wide sight of view, the entrance works well to bring people into the building.(Figure 3.5)

Moreover, besides all the functions above, it is also a urban transit space, it connects the Koa Avenue and Kalakaua Avenue---is the most important Avenue in Waikiki, where have a view of the sea and beach. In other words, it is the visual corridor connecting the street and beach. Pedestrians can go under through this building as a shortcut.(Figure 3.6)
3.3 Manoa Surfrider
Manoa Surfrider is a resort which is located on 2365 Kalakaua Ave, Honolulu, Hawaii, its layout is like a “C”, embracing the beach view with a lively space behind the Kalakaua Ave. Which is one of the most famous resort in Waikiki. It also has a very well-designed opened first floor area.

Similar with the Pualeilani Atrium Shops, the shared spaces of Manoa Surfrider also works for both the building itself and for the urban context. Form the street side to the beach side, the first floor can be divided into three layers(Figure3.10). The first layer (A) is the porch of the hotel (Figure 3.11 left), the second layer(B) is the lobby of the hotel, it has reception desks and tables for guests , a crystal chandeliers makes this space elegant and
warm, it act well both as a transit space as well as sitting space (Figure 3.11 right);

The third layer (C) is brighter space, which lead the visitors and guests to the back of this resort, where a creation space to the beach is located. (Figure 3.12)

Figure 3.10 Three layers  
Source: Author

Figure 3.11 layer A and layer B  
Source: Author
To sum up, the elevated first floor space of this resort forms a multi-layered, mix-functioned public space (Figure 3.12).
Chapter 4 | Physical Impact of Open Ground Floor on Carbon Emission of Residential Building

4.1 Selection of Research Problems and Concerns

4.1.1 Research Problems

(1) Operation of building equipment system; (2) use of building materials, components, parts and equipment; (3) transportation of building materials, components, parts and equipment. (Over-striking part in Table 4.1)

The open ground floor will change the shape of a building. Therefore, to maintain the indoor temperature, the energy consumption of a building in the operation phase will be changed. In addition, to meet the requirements of relevant specifications, the thermal insulation materials of maintenance structure outside the building will be added, too. This is the main reason why the above-mentioned three carbon emission units are closely related to open ground floor of the residence. In this dissertation, the impacts of these three carbon emission units on carbon emission are summarized as two problems, namely (1) change of carbon emission caused by open ground floor to operation of building equipment system; (2) change of carbon emission caused by open ground floor to production and transportation of materials of maintenance structure outside the building. Their relationships can be expressed by the Equation 4.1

4.1.2 Basic Information of Research Case

In this part, first floor elevated area will be taken as a typical example of shared space in high density urban residential projects, and this dissertation will pick up the hot summer and cold winter zone in china as the climate zone to focus. The projects are from Shanghai
and the standard is based on Shanghai’s regulation and China’s national regulation.

Table 4.1 Basic information of the selected project

<table>
<thead>
<tr>
<th>Location</th>
<th>Shanghai (31°N 121°E)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate zone</td>
<td>Hot summer, cold winter zone</td>
</tr>
<tr>
<td>Orientation</td>
<td>26° south by east</td>
</tr>
<tr>
<td>Structure type</td>
<td>Shear wall structure</td>
</tr>
<tr>
<td>Shape coefficient</td>
<td>0.36</td>
</tr>
<tr>
<td>Floor area</td>
<td>4640.08m²</td>
</tr>
<tr>
<td>Volume</td>
<td>14226.24m³</td>
</tr>
<tr>
<td>Surface area</td>
<td>5174.89m²</td>
</tr>
<tr>
<td>Building stories</td>
<td>18</td>
</tr>
<tr>
<td>Building height</td>
<td>52.55m</td>
</tr>
<tr>
<td>External wall (from outside to inside)</td>
<td>Cement mortar (6.0mm) + eps insulation (40.0mm) + cement mortar (12.0mm) + reinforced concrete (200.0mm) + eps insulation (20.0mm) + cement mortar (5.0mm)</td>
</tr>
<tr>
<td>Elevated floor (from outside to inside)</td>
<td>Fine aggregate concrete ±1 (40.0mm) + reinforced concrete (120.0mm) + cement mortar (12.0mm) + eps insulation (25.0mm) + cement mortar (6.0mm)</td>
</tr>
<tr>
<td>Normal floor</td>
<td>Gravel. Fine aggregate concrete ±1 (40.0mm) + reinforced concrete (120.0mm)</td>
</tr>
<tr>
<td>Operation hours</td>
<td>24 hours</td>
</tr>
<tr>
<td>Indoor base load (summer)</td>
<td>13.46kwh/m²</td>
</tr>
<tr>
<td>Indoor base load (winter)</td>
<td>17.53kwh/m²</td>
</tr>
<tr>
<td>Annual electricity load</td>
<td>30.99kwh/m³</td>
</tr>
</tbody>
</table>

Source: Author

In order to compare the impact of the three factors on carbon emission, this research chose a real project for more specific imitation and calculation. Table 4.1 shows the basic information of the project. And Figure 3.1 is the standard floor plan of the project.
4.2 Change of Carbon Emission Caused by Open Ground Floor to Operation of Building Equipment System

4.2.1 Introduction of Building Codes

To better study the relationship between the size and energy consumption of the building, Depecker proposed the concept of shape coefficient, namely the ratio of surface area of the building to the volume of the building \[^{[13]}\]. In the Energy Consumption Standards for Shanghai Residential Buildings (DGJ08-205-2011 / J10044-2011) issued by Shanghai in 2011, the shape coefficient of the residential building is defined as shown in Table 4.3.

<table>
<thead>
<tr>
<th>Building</th>
<th>Floor≤3, and building height≤10m</th>
<th>Floor: 4 ～ 11</th>
<th>Floor:≥12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compact Index</td>
<td>≤0.55</td>
<td>≤0.40</td>
<td>≤0.35</td>
</tr>
</tbody>
</table>

Source: Energy Consumption Standards for Shanghai Residential Buildings

According to Article 4.0.4 of Energy Consumption Standards for Shanghai Residential Buildings, for residential buildings with over 12 floors, the shape coefficient shall not exceed 0.35. In addition, Energy Consumption Standards for Shanghai Residential Buildings states that if a building does not meet this requirement, the comprehensive judgment of thermal performance of specific building envelope shall be made. \[^{[14]}\] This comprehensive judgment can be achieved by simulating the annual dynamic energy consumption (AD) of the building with the help of computer simulation software.


\[^{[14]}\] Energy Consumption Standards for Shanghai Residential Buildings (DGJ08-205-2011/J10044-2011)
The simulated designed energy consumption and the specified reference energy consumption are compared to judge whether the building meets the requirement.

In Shanghai, the energy consumption of the building mainly occurs in the two periods. One is the heating period in winter; another is the air-conditioning period in summer. The dynamic energy consumption simulated by computer software is also aiming at these two periods. Energy Consumption Standards for Shanghai Residential Buildings states that the heating period is from December 1 in the current year to February 28 in the next year and the indoor temperature is 18 °C, the air-conditioning period is from June 15 to August 31 and the indoor temperature is 26 °C. As long as shape coefficient or annual dynamic energy consumption of the detected building meets the requirement, the buildings can be considered to meet the design requirement of the energy consumption.

4.2.2 Introduction of Energy Consumption Simulation Software

To explore the impact of open ground floor on annual energy consumption of the residential building, in this research, the PKPM energy saving series software (PBECA) will be used to measure the annual energy consumption of the residential building in different open ground floor forms. By controlling variables, namely the proportion of area of open ground floor in the first-floor building area, and keep factors of other floors unchanged (or control the change in the allowable range), thereby simulating the relationship between open ground floor ratio and annual energy consumption of the residential building.

PKPM software (PBECA) is independently developed by China Institute of Construction Sciences. The building energy-saving analysis software based on AUTOCAD platform supports over 80 local and national standards. Meanwhile, its
module can be timely upgraded with the introduction of new energy-saving standards. Therefore, it is widely used. The Building Energy-Saving Design Standards for Residential Buildings in Hot-Summer and Cold-Winter Zones (JGJ134-2010) issued by the state and the Energy Consumption Standards for Shanghai Residential Buildings (DGJ08-205-2011/J10044-2011) issued by Shanghai Urban and Rural Construction and Transportation Commission give the mandatory provisions to building envelop enclosure and energy consumption index of Shanghai residential buildings. The calculation results of PBEC can clearly meet the above standards and its operation interface is simple and clear. Therefore, it becomes one of main tools software of designers of Shanghai design agencies. In this research, the location of the case is Shanghai. PBEC is loaded with the latest standards and it has the visual function, so in this study, it is used as the main software to explore the energy consumption of residential buildings in the usage phase. The data obtained in this phase is the energy consumption value, which can be further converted into the value of carbon dioxide emission value for horizontal analysis and comparison. (Figure 4.3)

Figure 4.3 The interface of PKPM
Source: Author

4.2.3 Experimental Data Collection and Analysis

In this study, the residential buildings with open ground floor or partial open ground
floor are taken as the basic reference. In the premise of complete data and information about building energy consumption measurement, by changing the state of first floor of the building, namely changing the opened open form to the same closed form at over two floors, and keeping other properties of the building unchanged, the difference in energy consumption between before and after change of ground floor layer can be measured.

Figure 4.4 The illustration of different percentage of opened first floor
Source: Author

In order to highlight the impact of first elevated floor, the first floor in the model is
not calculated in the floor area and surface area, thus, the floor area will not change too much in the experiment. Figure 4.4 shows the different percentage of the first floor.

After undertaking the dynamic energy consumption calculation, the result is shown on table 4.2.

**Table 4.3** The dynamic energy consumption calculation result

<table>
<thead>
<tr>
<th>The percentage of open first floor (%)</th>
<th>0</th>
<th>11.8</th>
<th>17.2</th>
<th>25.6</th>
<th>33.5</th>
<th>50</th>
<th>66.5</th>
<th>74.4</th>
<th>86.2</th>
<th>88.3</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>The floor area of open first floor (m²)</td>
<td>0</td>
<td>31.97</td>
<td>46.57</td>
<td>69.44</td>
<td>91</td>
<td>135.8</td>
<td>180.5</td>
<td>202.1</td>
<td>233.95</td>
<td>239.6</td>
<td>271.52</td>
</tr>
<tr>
<td>Shape coefficient</td>
<td>0.36</td>
<td>0.37</td>
<td>0.37</td>
<td>0.37</td>
<td>0.37</td>
<td>0.37</td>
<td>0.37</td>
<td>0.37</td>
<td>0.38</td>
<td>0.38</td>
<td>0.38</td>
</tr>
<tr>
<td>Annual energy consumption (KWh/m²)</td>
<td>30.98</td>
<td>31.14</td>
<td>31.2</td>
<td>31.28</td>
<td>31.4</td>
<td>31.71</td>
<td>31.93</td>
<td>32</td>
<td>32.07</td>
<td>32.13</td>
<td>32.29</td>
</tr>
<tr>
<td>Increased annual energy consumption (compared with 0%) (KWh/m²)</td>
<td>0</td>
<td>0.16</td>
<td>0.22</td>
<td>0.3</td>
<td>0.42</td>
<td>0.73</td>
<td>0.95</td>
<td>1.02</td>
<td>1.09</td>
<td>1.15</td>
<td>1.31</td>
</tr>
<tr>
<td>Increased annual energy consumption of the entire building (KWh) (compared with 0%)</td>
<td>0</td>
<td>740</td>
<td>1017.5</td>
<td>1387.5</td>
<td>1942</td>
<td>3376</td>
<td>4394</td>
<td>4718</td>
<td>5041.3</td>
<td>5319</td>
<td>6058.7</td>
</tr>
</tbody>
</table>

Source: Author

According to the result, compared to the condition of totally closed first floor, the totally opened first floor has 1.31 KWh/m² more electricity load annually. And when the percentage of the opened first floor is changed, the corresponding change of the electricity load can be seen in figure 4.5.
The increment of the annual carbon emission can be calculated as equation 4.1

\[ \Delta E_{OPR} = \Delta AD \times E_{ELECTRICITY} \]  \hspace{1cm} (4.1)

\( \Delta E_{OPR} \) is the changed carbon emission of the heating and cooling;

\( \Delta AD \) is the changed annual electricity load per square meter;

\( E_{ELECTRICITY} \) is the emission factor of the electricity.

In China, the emission factor varies by the different zone of electricity supply grid, table 3.4 illustrated different emission factor of all the electricity zone of China, and in this dissertation we choose the southeast zone, which is where Shanghai is located.
Table 4.4 The grid zone of China

<table>
<thead>
<tr>
<th>GRID ZONE</th>
<th>$E_{\text{grid,OM,Y}}$ (tCO$_2$/MWh)</th>
<th>$E_{\text{grid BM,Y}}$ (tCO$_2$/MWh)</th>
<th>Weighted Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>North China</td>
<td>1.058</td>
<td>0.541</td>
<td>0.7995</td>
</tr>
<tr>
<td>Northeast China</td>
<td>1.1281</td>
<td>0.5537</td>
<td>0.8409</td>
</tr>
<tr>
<td>Southeast China</td>
<td>0.8095</td>
<td>0.6861</td>
<td>0.7478</td>
</tr>
<tr>
<td>Central China</td>
<td>0.9724</td>
<td>0.4737</td>
<td>0.72305</td>
</tr>
<tr>
<td>Northwest China</td>
<td>0.9578</td>
<td>0.4512</td>
<td>0.7045</td>
</tr>
<tr>
<td>South China</td>
<td>0.9183</td>
<td>0.4367</td>
<td>0.6775</td>
</tr>
</tbody>
</table>

Source: http://cdm.ccchina.gov.cn/

According to Equation 4.1, compared with the entirely closed building, the one with entirely opened ground floor with have more carbon emission caused by the energy, the value is as following.

$$\Delta E_{\text{OPR}} = 1.31 \times 0.7478 = 0.979618 \text{ (kgCO}_2\text{eq/m}^2\text{)}$$

4.3 Change of Carbon Emission Caused by Open Ground Floor to Production and Transportation of Building Envelope Material

![The detail of elevated floor](image1)

![The detail of normal floor](image2)

**Figure 4.6** The detail of elevated floor and the normal floor

Source: Author
When the percentage of the open first floor is changed, the ceiling of first floor will be exposed area, according to the standard, when the floor is not exposed to outside, it do not need insulation in construction layer, but if it become exposed part, it need insulation. we can compare the difference of the construction of the elevated floor and normal floor (Figure 4.6).

4.3.1 Environmental Protection Declaration (EPD)

Since more shared space would cause more usage of insulation, the way to know the embodied carbon of insulation material is important. when assessing the environmental impact of a building product, the evaluation has to be extended throughout all the life cycle.

Nowadays, Environmental Product Declarations (EPDs) are gradually becoming more known and operational on the US and Europe market, which has considerably gained importance during the last decade. EPD is a communication tool that provides environmental data on products and services using predetermined parameters and, where relevant, additional environmental information.

Environmental product declarations (EPDs) are important for a number of reasons. The EPD is not just an idea about how to “grade the greenness” of products; it is a well-developed, globally recognized way, based on International Organization for Standardization (ISO) standards, to make responsible comparisons and decisions regarding sustainable material design.

The EPD is becoming an important tool in emerging green guidelines, building codes, and product standards, and critical to global initiatives involving energy efficiency, climate
change and other important environmental issues, such as carbon emissions. In addition, EPDs drive continuous improvement and innovation in the way in which materials are produced and how buildings are designed.

Building insulation has been evaluated in a number of recent EPDs covering different types of buildings with a goal of determining how they can help in the design of sustainable buildings. The researcher's choice of using insulation as an example in this dissertation was due to availability of information documenting major impact by insulation in carbon emissions reduction.

EPDs are an area of opportunity for future researchers to build upon the current research in this dissertation as architects and designers world-wide anticipate and being using EPDs as a materials selection guide.15

4.3.2 Estimation of Change of Carbon Emission Caused by Open Ground Floor to Production and Transportation of Building Envelope Material

Table 4.5 Characteristics of polystyrene insulation board for unit area and transport conditions

<table>
<thead>
<tr>
<th>Declared unit</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross density</td>
<td>25</td>
<td>kg/m³</td>
</tr>
<tr>
<td>Conversion factor to 1 kg</td>
<td>1/25</td>
<td>-</td>
</tr>
<tr>
<td>R-value</td>
<td>3.4</td>
<td>cm</td>
</tr>
<tr>
<td>Volume per m³</td>
<td>0.034</td>
<td>m³</td>
</tr>
<tr>
<td>Conversion factor to 1 kg</td>
<td>1/0.85</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Transport to the building site (A4)</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Litres of fuel (truck, per 1m³)</td>
<td>0.15</td>
<td>1/l100km</td>
</tr>
<tr>
<td>Transport distance</td>
<td>200</td>
<td>km</td>
</tr>
<tr>
<td>Capacity utilisation (including empty runs)</td>
<td>60</td>
<td>%</td>
</tr>
<tr>
<td>Gross density of products transported</td>
<td>25</td>
<td>kg/m³</td>
</tr>
</tbody>
</table>

Source: The EPD of polystyrene insulation board (EUMEPS)

In the EPD of polystyrene insulation board product provided by EUMEPS, the material properties of this product in the unit area are shown, and the conditions about

15 http://www.usgbc.org/credits/mr41
transportation distance and fuel consumption in the transportation phase are set (Table 4.5).

According to Table 4.5, the density of this finished product is 25 kg/m3, $K^{16}$ is 1 and thickness is 34mm. The product’s default thickness is 34mm, but the thickness of this polystyrene insulation board in this research is 25mm. Thus, it is necessary to make the corresponding reduction according to ratio during energy consumption calculation. The increment of carbon emission of opened floor in the unit area relative to that of ordinary floor insulation material can be calculated by Equation 4.2:

$$\Delta E_{\text{EPS}} = \Delta T_{\text{EPS}} \times EF_{\text{EPS}} \times \frac{1}{34}$$  \hspace{1cm} (4.2)

$\Delta E_{\text{EPS}}$ is the increment of carbon emission of 1m2 opened floor relative to that of ordinary floor insulation layer;  
$\Delta T_{\text{EPS}}$ is the thickness of EPS 
$EF_{\text{EPS}}$ is the carbon emission factor of EPS in material production and transportation phase

### Table 4.6 Whole life cycle phase subdivision of polystyrene insulation board for unit area

<table>
<thead>
<tr>
<th>PRODUCT STAGE</th>
<th>CONSTRUCTION PROCESS STAGE</th>
<th>USE STAGE</th>
<th>END OF LIFE STAGE</th>
<th>BENEFITS AND LOADS BEYOND THE SYSTEM BOUNDARIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw material supply</td>
<td>Transport</td>
<td>Manufacturing</td>
<td>Transport</td>
<td>Construction-installation process</td>
</tr>
<tr>
<td>A1</td>
<td>A2</td>
<td>A3</td>
<td>A4</td>
<td>A5</td>
</tr>
<tr>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Source: The EPD of polystyrene insulation board (EUMEPS)

---

16 Heat transfer coefficient is previously called as total heat transfer coefficient. The unified name in current national standard specification is heat transfer coefficient. Heat transfer coefficient $K$ refers to the heat transferred by 1m² within 1 hour when the difference between air temperatures of two sides of the building envelope under steady heat transfer conditions (W/m², K)
According to the Table, in the EPD, the life cycle of the product is divided into 16 phases. A1-A3 is the production phase; A4-15 is the construction phase; B1-B7 is the operation phase; C1-C4 is the demolition phase. In this research, the carbon emissions in the production phase and construction phase, namely A1-A4 are selected as the carbon emission factors of the EPS. (Table 4.6)

**Table 4.7** The GWP of polystyrene insulation board for unit area

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>A1-A3</th>
<th>A4</th>
<th>A5</th>
<th>C2</th>
<th>C3/L¹</th>
<th>C3/L²</th>
<th>C4/L</th>
<th>C4/L</th>
<th>D/I</th>
<th>D/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>GWP [kg CO₂-eq]</td>
<td>5.0E+01</td>
<td>8.0E-01</td>
<td>1.4E+00</td>
<td>1.2E-01</td>
<td>8.6E+01</td>
<td>0</td>
<td>0</td>
<td>1.7E+00</td>
<td>1.7E+00</td>
<td>-4.8E-01</td>
<td>-4.8E-01</td>
</tr>
<tr>
<td>AP [kg SO₂-eq]</td>
<td>1.4E+01</td>
<td>3.0E-03</td>
<td>1.5E-04</td>
<td>5.4E-04</td>
<td>5.4E-04</td>
<td>0</td>
<td>0</td>
<td>5.9E-03</td>
<td>5.9E-03</td>
<td>-1.1E-03</td>
<td>-1.1E-03</td>
</tr>
<tr>
<td>EP [kg PO₄₂⁻-eq]</td>
<td>1.6E-02</td>
<td>8.1E-04</td>
<td>4.7E-05</td>
<td>1.2E-04</td>
<td>2.9E-05</td>
<td>0</td>
<td>0</td>
<td>6.6E-03</td>
<td>6.6E-03</td>
<td>-1.3E-04</td>
<td>-1.3E-04</td>
</tr>
<tr>
<td>POCO₂ [kg Ethanol Eq]</td>
<td>2.9E-01</td>
<td>3.8E-04</td>
<td>2.5E-05</td>
<td>5.3E-05</td>
<td>8.2E-04</td>
<td>0</td>
<td>0</td>
<td>7.4E-04</td>
<td>7.4E-04</td>
<td>-1.2E-04</td>
<td>-1.2E-04</td>
</tr>
<tr>
<td>ADFF [kJ]</td>
<td>1.9E+03</td>
<td>1.1E+01</td>
<td>4.9E-04</td>
<td>1.7E+00</td>
<td>2.5E+01</td>
<td>0</td>
<td>0</td>
<td>2.5E+01</td>
<td>2.5E+01</td>
<td>-7.3E+01</td>
<td>-7.3E+01</td>
</tr>
</tbody>
</table>

Source: The EPD of polystyrene insulation board (EUMEPS)

After condition setting, the global warming potential values, namely carbon emissions, in the phases of production and construction can be found in the EPD of EPS of EUMEPS, and on this basis, the carbon emission factor of the EPS in the material production and transportation phase can be determined (Table 4.7).

The GWP of each phase, namely the carbon emission, can be known from the Table. By Equation 3.2, the increment of carbon emission of opened floor in unit area relative to that caused by insulation material of ordinary floor is

$$\Delta E_{EPM} = 25 \times (59+0.8) \times \frac{1}{34} = 43.97\text{ (kgCO}_2\text{eq)}/\text{m}^2$$

Similarly, in the EPD of B30 dry-mixed mortar of WEBER, the compositions of the product are given and the transportation mode is set (Table 4.8).
The difference from EPS is that the dry mortar needs mixing with water (Figure 4.7). The experience value in construction is. For the cement mortar layer with 1mm thick, 1.4kg of dry mortar is needed to make 1m² cement mortar.

![Figure 4.7 The manufacturing processes of cement mortar](source: The EPD of dry mortar (WEBER))

The global warming potential values, namely carbon emissions, in the phases of production and construction can be found in the EPD of B30 dry-mixed mortar product of WEBER, and on this basis, the carbon emission factor of the product in the material production and transportation phase can be determined. Similar to EPS, the full life cycle of the dry-mixed mortar product is divided into 16 phases. In this research, the GWPs in A1-A4 are selected as the carbon emission factors (Table 4.9).
Table 4.9 The GWP of dry mortar for unit area

LCA: Results

System boundaries (X=included, MND=module not declared, MNR=module not relevant)

<table>
<thead>
<tr>
<th>Product stage</th>
<th>Construction installation stage</th>
<th>User stage</th>
<th>End of life stage</th>
<th>Beyond the system boundaries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw material</td>
<td>Transport</td>
<td>MANUFACTURING</td>
<td>Use</td>
<td>MANUFACTURING</td>
</tr>
<tr>
<td>A1</td>
<td>X</td>
<td></td>
<td>B1</td>
<td>B2</td>
</tr>
</tbody>
</table>

Environmental impact

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>A5</th>
<th>C1</th>
<th>C2</th>
</tr>
</thead>
<tbody>
<tr>
<td>GWP</td>
<td>kg CO₂ eqv</td>
<td>1.07E-061</td>
<td>9.83E-003</td>
<td>1.72E-004</td>
<td>3.69E-003</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ODP</td>
<td>kg CFC11 eqv</td>
<td>4.36E-009</td>
<td>3.95E-003</td>
<td>2.18E-001</td>
<td>3.30E-003</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POCP</td>
<td>kg CFC-141</td>
<td>2.90E-004</td>
<td>2.18E-004</td>
<td>1.22E-004</td>
<td>1.03E-005</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AP</td>
<td>kg SO₂ eqv</td>
<td>1.30E-004</td>
<td>1.44E-004</td>
<td>6.30E-004</td>
<td>2.00E-006</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EP</td>
<td>kg PO₄³⁻ eqv</td>
<td>4.52E-005</td>
<td>4.00E-006</td>
<td>5.42E-006</td>
<td>2.00E-006</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADPM</td>
<td>kg Sr eqv</td>
<td>2.55E-007</td>
<td>3.00E-003</td>
<td>4.00E-012</td>
<td>3.00E-003</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADPE</td>
<td>MJ</td>
<td>9.57E-001</td>
<td>1.33E-001</td>
<td>1.46E-003</td>
<td>4.84E-002</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

GWP: Global warming potential; ODP: Depletion potential of the stratospheric ozone layer; POCP: Formation potential of tropospheric photochemical oxidants; AP: Acidification potential of land and water; EP: Eutrophication potential; ADPM: Abiotic depletion potential for non fossil resources; ADPE: Abiotic depletion potential for fossil resources

Source: The EPD of dry mortar (WEBER)

The increment of carbon emission of opened floor in unit area relative to that of cement mortar layer of ordinary floor can be calculated by Equation 4.3:

$$\Delta E_{MORTAR} = \Delta T_{MORTAR} \times EF_{MORTAR} \times 1.4$$  \hspace{1cm} (4.3) \hspace{1cm}

$\Delta E_{MORTAR}$ is the increment of carbon emission of opened floor in unit area relative to that of cement mortar layer of ordinary floor;

$\Delta T_{MORTAR}$ is the thickness of cement mortar layer of opened floor;

EF$_{MORTAR}$ is the carbon emission factor of dry mortar in the material production and transportation phases.

According to Equation 4.3,

$$\Delta E_{MORTAR} = (6+12) \times (0.177002 + 0.00369) \times 1.4 = 4.553438 \text{ (kgCO}_2\text{eq)/m}^2$$

According to Equation 4.3, the relationship between change of carbon emission
caused by open ground floor of residential building in unit area to material production and transportation of building envelope and the opened ratio can be obtained.

When the ground floor layer is fully opened, the change of carbon emission caused by open ground floor of residential building in unit area to material production and transportation of building envelope is

$$\Delta E_{MAT} = (43.97 + 4.553438) \times \frac{271.52}{4625} = 2.8487(\text{kgCO}_2\text{eq})/m^2$$

According to Equation 4.1, the impacts in above two aspects can be added. According to conclusions obtained by the two parts, the physical impact of open ground floor on carbon emission of residential building can be obtained (Table 4.10)

**Table 4.10** The overall physical impact of opened first floor

<table>
<thead>
<tr>
<th>Floor: 18</th>
<th>Building height: 52.55m</th>
<th>Floor area: 4625.2m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>The percentage of open first floor (%)</td>
<td>0 11.8 17.2 25.6 33.5 50 66.5 74.4 86.2 88.3 100</td>
<td></td>
</tr>
<tr>
<td>The floor area of open first floor (m²)</td>
<td>0 31.97 46.57 69.44 91 135.8 180.5 202.1 233.95 239.6 271.52</td>
<td></td>
</tr>
<tr>
<td>Increased emission caused by transportation and manufacturing of enclosure materials per square meter (compared with 0%) (kgCO₂ eq/m²)</td>
<td>0 0.3354 0.4886 0.7285 0.955 1.424 1.894 2.12 2.4545 2.513 2.8487</td>
<td></td>
</tr>
<tr>
<td>Increased emission caused by annual energy consumption per square meter (compared with 0%) (kgCO₂ eq/m²)</td>
<td>0 0.1196 0.1645 0.2243 0.314 0.546 0.71 0.763 0.8151 0.86 0.9796</td>
<td></td>
</tr>
<tr>
<td>The physical impact of the first elevated floor (compared with 0%) (kgCO₂ eq/m²)</td>
<td>0 0.4551 0.6531 0.9529 1.269 1.97 2.604 2.883 3.2696 3.373 3.8283</td>
<td></td>
</tr>
</tbody>
</table>

Source: Author

When the ground floor layer is fully opened, the change of physical impact of open ground floor in unit area on carbon emission of residential building is

$$\Delta E_{PHY} = \Delta E_{OPR} + \Delta E_{MAT} = 2.8487 + 0.9796 = 3.8283(\text{kgCO}_2\text{eq})/m^2$$
Chapter 5 | Relationships of Open Ground Floor of Residential Building and Resident’s Daily Activity

5.1 Classification of Urban Residents’ Outdoor Activities

5.1.1 Human Beings Need Outdoor Activities

As Nick Baker argued in We are all outdoor animals: Although we spend most of our time indoors, we are really outdoor animals. The forces, which have selected the genes of contemporary man are found outdoors in the plains, forests and mountains, not in centrally heated bedrooms and at ergonomically designed workstations. Fifteen generations ago, a period of little consequence in evolutionary terms, most of our ancestors would spend the majority of their waking hours outdoors, and buildings would primarily provide only shelter and security during the hours of darkness. Even when inside, the relatively poor performance of the building meant that the indoor conditions closely tracked the outdoor environment.

That dissertation asserts that we have a deep hereditary affinity for the natural world and that modern life in the built environment increasingly isolates us from it. We have presented two types of evidence for this – unconscious behavior such as, for example the circadian rhythm, and conscious behavior such as our house plant buying habits.

In the mean time, a brief, which requested a “rich and varied environment with a close relationship with nature” is hardly likely to raise objections. Not only does it beg for a creative and architectural response, but it is far more compatible with low energy passive design, then the highly engineered artificial environment buildings. The looser control of environmental conditions should not be seen as a weakness provided that the means and
freedom of responding are also present. Rather, the denial of the need and freedom to respond to natural stimuli should be regarded as seriously as any cultural deprivation.\footnote{Baker, Nick. "We are all outdoor animals." \textit{Architecture City Environment, Proceedings of PLEA} 2000 (2000)}

\subsection*{5.1.2 Three Types of Residents’ Outdoor Activities}

According to theories proposed by Jan Gehl in \textit{Life Between Buildings}, residents’ outdoor activities can be divided into three types. Each activity has different requirements for site surroundings.

The first type is the necessary activities, mainly necessary activities in daily life, such as going to school, going to work and going shopping. Such activities will occur under any condition. Relatively speaking, the impacts of climate and environment on them are smallest and the frequency of them is relatively fixed.

The second type is spontaneous activities, that people are willing to take part in, such as walking, stopping, practicing and entertainments. Such activities will occur when outside climate and environment are appropriate and the surrounding places are suitable. Such activities are generally good for resident’s physical and mental health, and have higher requirements for place quality, which are closely related to outside environment.

The third type is social activities, which are developed from above two types of activities. If above two types of activities can be individually done, such activities are interactions between people, such as chatting, saying hello and showing up. As long as there are two people in the same space, such activities can be done. The good material and natural environment is the premise of occurrence of such activities.\footnote{Gehl, Jan. \textit{Life between buildings: using public space}. Island Press, 2011.}

Among above three types of activities, spontaneous activities and social activities are
most closely related public place in the settlements and they have higher requirements for space place quality, and they are vulnerable to environment and climate. The features shown by residents at different ages and under different backgrounds when selecting the places for these two types of activities are most obvious.

5.2 Requirements of Different Ages of Residents in for Public Space

The Declaration of (Fourth Congress for the New Urbanism (CNU) 1996) had noted that many activity needs in daily life should be met in the walking distance, which enabled old people and children who rarely travel by motor vehicle to be strongly independent in activity. The open ground floor space of residential building is the public place in the walking distance. It has certain advantages in adapting to activities of residents at all ages.

5.2.1 Adaptability of Open Ground Floor Space to Activity of Senior Citizens

Undoubtedly, a good community environment should be able to meet the needs of senior citizen’s spontaneous and social activities. The open ground floor space can well meet senior citizen’s needs.

Firstly, the open ground floor space provides convenient exercising space for the elderly. As mentioned above, the first-floor opened space of the residential building belongs to the second type, namely the “semi-public” outside environment with certain privacy. It is not a “place” with certain functions, but a “space” with uncertain features. It is located in the walking distance and surrounded by some green trees and flowering shrubs, so it has the advantages of safety, convenience and quietness. Thus, the elder do not need to worry about the weather. Though it has no fixed purposes, with semi-transparent vision, fresh air and scattered fitness facilities, chairs and other objects, it
attracts the elderly to do activities here (Figure 5.1).

![Figure 5.1](image-url) The exercising old people in the open floor

Source: Author

According to the investigation of residence communities with open ground floor in Shanghai, it is found that almost all open ground floor spaces are equipped with fitness equipment. Take the open ground floor space of Xin Fukangli in Jing’an District as the example. The elderly frequently use these facilities. An old person who is doing exercise says that the utilization rate of these facilities from 9:00 to 11:00 am and from 3:00 to 5:00 pm is the highest, and he will come here to do exercise in these two periods regardless of weather.

Secondly, the open ground floor space provides opportunities for the elderly to contact with other residents. It not only has the space potential of producing spontaneous activity, but also can promote social activity to be done. In the open ground floor space of Shanghai Zhongyuan Liangwan City, there are retired people who do square dancing. It is
the best place for their party. It is not only close to their homes, but also invulnerable to weather. In addition to social activity of the elderly, the opened space provides opportunities for the elderly to contact with the young. In his book Architectural Pattern Language, Alexander pointed out that “the elderly need the elderly, but they also need the young. Therefore, it is necessary to keep the elderly in contact with the young”.

![Figure 5.2 The sitting area of the opened ground floor](image)

The public space of open ground floor is integrated in the residential zone. The ages of people passing here contain those of residents here. Therefore, it provides opportunities for the elderly to directly and indirectly contact with people at different ages. The open ground floor space provides “space that can be seated”. When people select chairs in the public space, the chairs that enable people to observe others are most frequently used. The place that can be seated in the opened space usually faces the roads of the community. The
elderly who sit in the space can easily observe others (Figure 5.2), such as children who are playing in the streets, neighbors who are chatting, adults who commute or community residents who come back after going shopping in the stores and markets. For the elderly, these are the vivid and vigorous scenes. The elderly can observe different people. They can say hello or quietly observe the behaviors of strangers. It is a good place to meet demands of the elderly in mind. Their sense of loneliness will be eliminated due to these visual and auditory feelings or slight contact mode. In the residential buildings of Xin Fukangli, chairs are generally set at the edge between opened space and outside. The opened space edge is close to the roads of the community, and there is sunshine, so it meets the psychological needs of the elderly. In addition, the multi-level green landscapes are placed between residential buildings. Semi-transparent and semi-enclosed, the opened space has certain privacy, and it does not disturb the elderly who observes things occurring in the streets. Between spring and summer, there are green scenes around seats; in winter, the sunlight is genial and the elderly feel relaxed and happy under the sunlight. (Figure 5.2)

5.2.2 Adaptability of Open ground floor to Children’s Activity

The children’s outdoor activity space should meet three standards below: easily approached, easily seen and easily heard. (Anne-Marie Pollowy, 2007). The open ground floor space meets the above standards.

Firstly, the open ground floor space is “easily approached”. Compared with children’s activity space with clear purposes, the places created suitable for children’s game by fully using the external environmental space of residential zone often lead to more spontaneous activities of children. The open ground floor space of residential building is a game space that extends from internal to external environment of the residential building. This place is very convenient and easily approached.
Secondly, the open ground floor space is “easily seen and heard”. There is a Scandinavian proverb, “People walk upwards”. Research shows that children are more inclined to play at two sides of streets, exit of residential areas and near the parking lot because these are the places that pedestrians and residents must go through and where there are always people. In contrast, for places of recreation designed for children, because there is no traffic, there are few people passing by and they are left without anybody.

Thirdly, there are pavements in the open ground floor space, which are suitable for some special sports events. Ball games and parent-children outdoor sports activities are usually carried out in the sports ground of the community. When there is no activity place in the community, ball games are often carried out on the roads of the community. The skidding activity is often carried out in the room or semi-indoor place with smooth
pavements. There are generally pavements on the ground in the open ground floor space, conducive to implementation of skidding activity. (figure 5.3)

Fourthly, the open ground floor space can resist against bad weather. The outdoor parent-children sports activities often occur in the weekends. Some parents say that they are very busy, but they will spare the activity time in every week, even if in the rainy day, they will do activities with children in the opened space. The open ground floor space can reduce the barriers caused by weather factors to outdoor activity, thus ensuring weekly activity level and frequency. (Figure 5.4)

5.2.3 Adaptability of Open ground floor Space to Activity of Young People

Firstly, its accessibility is strong and it helps urban young groups use the fragmented
time. For urban young people, time is the most crucial consideration. The survey shows that up to 42% urban white-collar young people are not satisfied with their time of entertainment in leisure. These interviewees think that the working pressure is large, the rest time is little and the time of entertainment and leisure is more precious. Through interview, the interviewees think that due to limited time, the less the time spent on entertainment and travel is, the better it is. In addition, for young people who have children, the open ground floor space can meet the their needs of doing outdoor activities with children.

Figure 5.5 The young people playing around the public space in community
Source: Author

Secondly, it is in the walking distance, people can stay in it and it can help urban young groups relieve pressure. Urban young people have certain psychological pressure. In life, the joyful and relaxing activities mainly occur during walking, staying and sitting. The survey shows that some white-collar workers in Shanghai People’s Square prefer taking a longer way to go to work, and like going through People’s Park. It can be seen that life
begins with one step and so does the wonderful experience. Only slow behavior and scale can create favorable conditions for communication and information acquisition, making people relaxed and have time to experience, stay and participate, and well relieve their pressure.

In this chapter, the advantages of open ground floor space are demonstrated and the potential of the open ground floor space to become a good outdoor activity place in the residential zone. Such spatial place characteristics can lead residents to carry out some activities in the residential area, thereby reducing the frequency of motorized travel to finish such activities. The theoretical basis is provided for estimation of positive influence of open ground floor on emission reduction.
Chapter 6 | Exploration of Effect of Open ground floor of Residential Building on Emission Reduction of Resident’s Travel

6.1 Overview of Resident’s Motorized Travel

According to statistics, the total travel volume in Shanghai is 45.4 million people per day. The considerations of living, entertainment and other non-commuting travel modes selection are largely different from commuting. In addition to convenient and timely transportation, there are higher requirements for comfort. This means that in case the distance of travel is beyond certain distance, relative to public transport, residents’ are more inclined to private motor vehicle and taxi in the selection of entertainment travel.

According to the survey, the average car traffic volume in the city is 4.17 million vehicles per day, with an increase of 68% compared with the year 2004. The car traffic volume caused by passenger cars increases by nearly one time compared with the year 2004, which brings very large pressure to urban traffic. The use intensity of cars is still very high. Each car runs 39km per day, about 1.3 times that in London, 2.1 times that in Tokyo. The private car mainly serve the middle- and long-distance travel, while the short-distance travel below 5km still occupies a larger proportion, up to 15%. The Table below reflects the distribution of different travelling modes adopted by Shanghai residents with different travel purposes.

6.2 Survey on Resident’s Motorized Travel to Public Space as the Primary Activity

After obtaining the general information on residents’ travel, in this study, the
questionnaire method is adopted to further obtain the intensity of motorized travel of Shanghai households. Combined with the carbon emission factor of each travel mode, the numerical value of yearly carbon emission caused by motorized travel of each household based on need of public space can be estimated. The survey has been conducted in Shanghai, China during May to June, 2015.

6.2.1 Family Structure and Lifestyle

The carbon emission factors of different transport means are different, so the carbon emission of motorized travel is the result of running distance of motorized transport means multiplied by carbon emission factor. Therefore, the survey is divided into four parts according to transportation tools of motorized travel, namely private car, taxi, urban bus and subway. In each part, the travel frequency and time is calculated. According to average speed and carbon emission factor provided by Conor Walsh [19] et al. in 2008, the total carbon emission of resident’s motorized travel can be estimated. The sub-item statistical results of frequency (%, single-way) and time (% single-way) of motorized travel for above outdoor activities done by family members in each week are shown in Figure 6.1.

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A comparison of carbon dioxide emissions associated with motorized transport modes and cycling in Ireland

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[19] A comparison of carbon dioxide emissions associated with motorized transport modes and cycling in Ireland
**Figure 6.1** Motorized travel for above outdoor activities done by family members in each week  
Source: Author  
The correlation between travel frequency of four transport tools and average single-way travel time is shown in Figure 6.2.

<table>
<thead>
<tr>
<th>Motorized travel frequency for above outdoor activities done by family members in each week (single trip) (%)</th>
<th>Motorized travel time for above outdoor activities done by family members in each week (single trip) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trip on private cars’ frequency for above outdoor activities done by family members in each week (single trip) (%)</strong></td>
<td><strong>Trip on private cars’ time for above outdoor activities done by family members in each week (single trip) (%)</strong></td>
</tr>
<tr>
<td>0</td>
<td>2.1</td>
</tr>
<tr>
<td>1</td>
<td>6.8</td>
</tr>
<tr>
<td>2</td>
<td>13.5</td>
</tr>
<tr>
<td>3</td>
<td>17.7</td>
</tr>
<tr>
<td>4</td>
<td>21.8</td>
</tr>
<tr>
<td>5</td>
<td>26.6</td>
</tr>
<tr>
<td>6</td>
<td>31.8</td>
</tr>
<tr>
<td>7</td>
<td>37.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Trip on taxis’ frequency for above outdoor activities done by family members in each week (single trip) (%)</strong></th>
<th><strong>Trip on taxis’ time for above outdoor activities done by family members in each week (single trip) (%)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.1</td>
</tr>
<tr>
<td>1</td>
<td>6.8</td>
</tr>
<tr>
<td>2</td>
<td>13.5</td>
</tr>
<tr>
<td>3</td>
<td>17.7</td>
</tr>
<tr>
<td>4</td>
<td>21.8</td>
</tr>
<tr>
<td>5</td>
<td>26.6</td>
</tr>
<tr>
<td>6</td>
<td>31.8</td>
</tr>
<tr>
<td>7</td>
<td>37.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Trip on buses’ frequency for above outdoor activities done by family members in each week (single trip) (%)</strong></th>
<th><strong>Trip on buses’ time for above outdoor activities done by family members in each week (single trip) (%)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.1</td>
</tr>
<tr>
<td>1</td>
<td>6.8</td>
</tr>
<tr>
<td>2</td>
<td>13.5</td>
</tr>
<tr>
<td>3</td>
<td>17.7</td>
</tr>
<tr>
<td>4</td>
<td>21.8</td>
</tr>
<tr>
<td>5</td>
<td>26.6</td>
</tr>
<tr>
<td>6</td>
<td>31.8</td>
</tr>
<tr>
<td>7</td>
<td>37.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Trip on subways’ frequency for above outdoor activities done by family members in each week (single trip) (%)</strong></th>
<th><strong>Trip on subways’ time for above outdoor activities done by family members in each week (single trip) (%)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.1</td>
</tr>
<tr>
<td>1</td>
<td>6.8</td>
</tr>
<tr>
<td>2</td>
<td>13.5</td>
</tr>
<tr>
<td>3</td>
<td>17.7</td>
</tr>
<tr>
<td>4</td>
<td>21.8</td>
</tr>
<tr>
<td>5</td>
<td>26.6</td>
</tr>
<tr>
<td>6</td>
<td>31.8</td>
</tr>
<tr>
<td>7</td>
<td>37.0</td>
</tr>
</tbody>
</table>

**Figure 6.2** The correlation between travel frequency of four transport tools and average single-way travel time  
Source: Author  
If the travel intensity is defined as the product of travel frequency and time, then the intensity relationship when above four transportation tools serve the travel activity related
to public space is shown in Figure 6.3.

![Figure 6.3 The trip intensity](image)

Source: Author

From the perspective of travel intensity, the travel intensity of private car is highest, followed by bus, subway and taxi. Results show that private car is the travel mode with largest intensity, while the passenger capacity of private car and taxi is small and the carbon emission caused by each person at each time is larger. Therefore, it also indicates the urgency of advocating urban green travelling.

### 6.3 Estimation of Carbon Emission of Resident’s Motorized Travel to Public Space as the Primary Activity

According to survey results in above section, the frequency and time of motorized travel of the sample related to public space can be estimated. According to average speed of transport tools, the travel distance of each tool can be estimated. The travel carbon emission can be estimated through overlapping after multiplied by carbon emission factor of each transportation tool.
6.3.1 Open Ground Floor as Public Space

The open ground floor space is the activity place in the community, where the activities can be various, and it meets the condition of ideal community public facility in 5-minute walking distance. Admittedly, it cannot be determined that if the residential building has the open ground floor space, residents will replace the origin motorized travel destination with the open ground floor space, thus completely eliminating carbon emission in this part. However, according to survey and interview on residents, it can be observed and understood that Residents are still interested in outdoor or semi-outdoor activities surveyed in their residential zones, and the open ground floor space can provide a place for these activities. In the survey, relevant questions are designed to understand if there are above activity places in the residential area, whether residents will directly select the activities in the residential area. Results show that 57.2% of residents will directly do activities in the residential area, 5.2% of residents will not do this and 37.6% of residents may do this (Figure 6.6).

If there is some places act as the replacement of the public place in the community, would you choose them?

![Figure 6.4](image_url) The possibility for opened first floor are act as a replacement of the public place

Source: Author
cars. For sample households with private cars, 47 persons say they will use the public space in the residential zone for activities, accounting for 60% of such sample households; 9 persons say they will not use, accounting for 5.2% of such sample households; 45 persons say they are uncertain to use, accounting for 33.3%. For households without private cars, 18 persons say they will use the public space in the residential zone for activities, accounting for 52.6% of such sample households; 20 persons say they are uncertain to use, accounting for 47.4%. According to the statistical results, the sample households are greatly willing to use the public space in the residential zone for activities. The households with private cars do not reduce their willingness due to car ownership. In contrast, they are more inclined to do activities in the accessible public space in the residential area.

6.3.2 Determination of Carbon Emission Factor

In the dissertation “A Comparison of Carbon Dioxide Emissions Associated with Motorized Transport Modes and Cycling in Ireland” written by Conor Walsh in 2008, he summarized the per capita carbon emission factor per km of passengers by different transportation means in full-load and ordinary states. It is worth mentioning that, in the study, he divided the carbon emission of motor vehicle into direct carbon emission and indirect carbon emission. Direct carbon emission comes from car gasoline consumption, mainly depending on model and engine size of the car; indirect carbon emission is generated in the process of production, transportation, repairing and scrapping. The estimation methods come from the report published by Australian Environment and Heritage Department in 2003 (Conor Walsh, 2008). In addition, the carbon emissions of motor vehicle in full-load and non-full-load states are listed in Table 6.1 From the Table, it
can be seen that the per capita carbon emissions of SUV and ordinary family sedan are 10 times higher than that of metro (rail), bus and other urban public transportation means.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Emissions at max occupancy kg CO₂ Pass km⁻¹</th>
<th>Emissions at normal occupancy kg CO₂ Pass km⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Direct</td>
<td>Indirect</td>
</tr>
<tr>
<td>Cyclist</td>
<td>0.005</td>
<td>0.0061</td>
</tr>
<tr>
<td>DART</td>
<td>0.011</td>
<td>0.0006</td>
</tr>
<tr>
<td>Intercity bus</td>
<td>0.015</td>
<td>0.0006</td>
</tr>
<tr>
<td>Dublin bus</td>
<td>0.016</td>
<td>0.0008</td>
</tr>
<tr>
<td>City bus</td>
<td>0.025</td>
<td>0.0015</td>
</tr>
<tr>
<td>Private car</td>
<td>0.042</td>
<td>0.0103</td>
</tr>
<tr>
<td>SUV</td>
<td>0.052</td>
<td>0.0162</td>
</tr>
</tbody>
</table>

Source: A comparison of carbon dioxide emissions associated with motorized transport modes and cycling in Ireland

### 6.3.3 Estimation of Carbon Emission of Resident’s Motorized Travel to Public Space

According to survey results and carbon emission factors in the above section, the weekly average carbon emission and total emission of each transportation means can be obtained (Table 6.3).

<table>
<thead>
<tr>
<th>Mode</th>
<th>Frequency of travel weekly (single trip)</th>
<th>Average speed (km/h)</th>
<th>Average time single trip (h)</th>
<th>Emission factor (kg/km)</th>
<th>Value of carbon emission weekly (round trip) (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subway</td>
<td>2.603</td>
<td>30</td>
<td>0.355</td>
<td>0.029</td>
<td>1.5172887</td>
</tr>
<tr>
<td>Bus</td>
<td>3.246</td>
<td>20</td>
<td>0.449</td>
<td>0.053</td>
<td>3.68980248</td>
</tr>
<tr>
<td>Taxi (normal occupancy)</td>
<td>0.612</td>
<td>66</td>
<td>0.548</td>
<td>0.149</td>
<td>6.596175168</td>
</tr>
<tr>
<td>Private car (normal occupancy)</td>
<td>3.186</td>
<td>66</td>
<td>0.512</td>
<td>0.149</td>
<td>32.08307098</td>
</tr>
<tr>
<td>SUV (normal occupancy)</td>
<td>0.821</td>
<td>66</td>
<td>0.512</td>
<td>0.242</td>
<td>13.42772429</td>
</tr>
<tr>
<td>Sub total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>56.71406161</td>
</tr>
</tbody>
</table>

Source: Author

In estimation, the carbon emissions of resident’s motorized travel can be calculated by the Equation 6.1:

$$E_{TRIP} = \sum_{i=1}^{n} (2 \times F \times S \times T \times EF \times R) \times \frac{365}{7} \times \frac{U}{FA}$$

(6.1)
$E_{\text{TRIP}}$ is the change of carbon emission caused by open ground floor of residential building to resident’s motorized travel:

- $i$ is the type of motorized travel;
- $F$ is the frequency of travel in each week (time);
- $S$ is the average speed of transportation means (km/h);
- $T$ is the time of single-way travel (h);
- $EF$ is the carbon emission factor (kg/km) of transport means. In this research, the carbon emissions of taxi and small family sedan are calculated according to the same carbon emission factor;
- $R$ is the use ratio of transport means (mainly used to differentiate small private car and SUV private car. According to survey results, for sample households with private cars, the use rate of small sedan is 79.5%, while the use rate of SUV is 20.5%);
- $U$ is the number of households in a single residential building;
- $FA$ is the construction area of a single residential building;

If the No.10 Building of a residence community in Shanghai Jiading District is still taken as the example, according to the Table, it can be know that the total number of households is 34, the total construction area is $4,625m^2$. According to Equation 6.1 as well as data in Table 1 and Figure 2, the annual carbon emission of resident’s travel in per square meters of residential building:

$$E_{\text{TRIP}}=2\times(2.603\times30\times0.335\times0.029+3.246\times20\times0.449\times0.053+0.612\times66\times0.548+4.007\times66\times0.512$$

$$\times0.149\times79.5%+4.007\times66\times0.512\times0.242\times20.5%)\times\frac{367}{7}\times\frac{271.52}{4625}=21.67(\text{kgCO}_2\text{eq/m}^2)$$

Figure 6.5 shows that the frequency of resident’s travel by the urban public traffic system consisting of subway and bus is totally 5.849 times/week, while the travel
frequency of taxi and private car is lower, namely 4.619 times/week. However, from the angel of carbon emission, the carbon emission of public transportation means at the travel frequency of 55.8% accounts for 8.1% of total emissions, while the carbon emission of taxi and family private car at the travel frequency of 44.1% accounts for 91.9% of total emissions. Thus, the effect of public transportation on emission reduction can be easily seen. (Figure 6.5)

If the travel intensity is still defined as the product of travel frequency and distance, at the same travel intensity, assuming the motorized travel of residents who use public space is supported by any one of subway, bus, small private sedan or SUV, then according to corresponding carbon emission factor, the weekly carbon emission of household travel by a single transport means can be obtained as follows:
From the Figure, it can be seen that at the same travel volume, 20%-40% of carbon emission will be reduced if the urban public transport system is used rather than taxi and private car. This is the important reason why the establishment of a convenient and effective public transportation system can achieve urban emission reduction.

**Figure 6.6** The comparison of single mode and multi-mode
Source: Author
Chapter 7 | Summary and Discussion

Energy saving and emission reduction of residential buildings with building design as the guidance is an important part of the whole social energy saving and emission reduction. In this dissertation, the shared space of residential buildings is evaluated from the angel of carbon emission. Firstly, the open ground floor as the typical shared space of residential buildings is selected and the research scope is focused on Shanghai in Yangtze River Delta region. Secondly, in the Chapter 4, the impact of open ground floor on residence energy saving and physical carbon emission unit is explored. Thirdly, in Chapter 5, the resident’s needs for social public space are listed and that the open ground floor space can replace the pubic spatial place outside the community that can be reached through resident’s motorized travel to certain extent, thus indirectly promoting the emission reduction of resident’s travel. Finally, in Chapter 6, through survey, the characteristics data of Shanghai resident’s travel based on pubic space is obtained to estimate the carbon emission of family’s motorized travel based on public space. This estimated value can be considered as the maximum emissions reduced by open ground floor to resident’s travel. The data in the dissertation can be summarized as Table 7.1.
Table 7.1 Impacts of Open ground floor on building energy saving and carbon emission units

<table>
<thead>
<tr>
<th>Floor, 1B</th>
<th>Building Height: 52.55m</th>
<th>Floor area: 4625m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic info</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The percentage of first floor(%)</td>
<td>0</td>
<td>11.8</td>
</tr>
<tr>
<td>The floor area of opened first floor(m²)</td>
<td>0</td>
<td>31.97</td>
</tr>
<tr>
<td>Energy consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon emission changes caused by energy consumption (KWh/m²) (compared to 0%)</td>
<td>0</td>
<td>0.16</td>
</tr>
<tr>
<td>Carbon emission changes caused by energy consumption of the entire building (KWh/m²) (compared to 0%)</td>
<td>0</td>
<td>740</td>
</tr>
<tr>
<td>Material</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon emission changes caused by material manufacturing (kgCO₂eq/m²) (compared to 0%)</td>
<td>0</td>
<td>0.33541</td>
</tr>
<tr>
<td>Carbon emission changes caused by material manufacturing (kgCO₂eq/m²) (compared to 0%)</td>
<td>0</td>
<td>0.11965</td>
</tr>
<tr>
<td>Physical effect caused by the elevated first floor (kgCO₂eq/m²) (compared to 0%)</td>
<td>0</td>
<td>0.45506</td>
</tr>
<tr>
<td>Physical effect caused by the elevated first floor (kgCO₂eq/m²) (compared to 0%)</td>
<td>0</td>
<td>2104.67</td>
</tr>
<tr>
<td>Social</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The largest influence caused by elevated first floor for the entire building (per square meter) (kgCO₂eq/m²)</td>
<td>100224</td>
<td>100224</td>
</tr>
</tbody>
</table>

Source: Author

According to Table 7.1, if the case the ground floor fis not opened is compared with that the ground floor s fully opened, (1) the difference in annual electricity consumption of per unit area of buildings is 1.31 KWh/m², the difference in annual power consumption of the entire building is 6058.75 KWh; (2) the difference in per unit area of building equipment operation is 0.98 kgCO₂eq/m², the carbon emissions of production and transport of per unit area of building envelop is 2.85 kgCO₂eq/m², and the physical change of residence’s carbon emission is the sum of above two figures, and the difference in physical
carbon emission of the whole building is 3.83 kgCO$_2$eq/m$^2$. (3) Impact of open ground floor on carbon emission of resident’s travel. If it is converted into unit building area, it is 21.67 kgCO$_2$eq/m$^2$; for the whole building, it is 100,224 kgCO$_2$eq/m$^2$. Based on the above data, the energy consumption and conceptual relationship between carbon emission units can be obtained (Figure 7.1)

**Figure 7.1** Energy consumption and conceptual relationships between carbon emission units

*Source: Author*

Wherein, the carbon emission of operation of building equipment system is the reflection of building energy consumption. Figure 7.1(Above) shows that if the measurement time is 1 year, then the emission reduction effect of resident’s travel is most obvious. The carbon emissions of material production and transportation of building envelope are the main sources of increase of carbon emissions. The carbon emission added by the operation of building equipment is about 1/3 that of material production and transportation of building envelop. If the service life of residential buildings is designed as
50 years, by fully considering carbon emission unit and the term, the resident’s travel and equipment operation are related to time. The building envelope material will not change with the time of use of building. Impact on carbon emission weighted with time can be seen in Figure 7.1 (Below).

![Overall results]

**Figure 7.2** Overall results  
Source: Author

From above data, the following conclusions can be made:

1. Compared with the physical attribute of open ground floor, namely shared space, its social attribute has more obvious impacts on carbon emission. From overall angle, the effect of shared space of residential buildings on the total carbon emission reduction is not ignorable.

2. Though the energy consumption is added to the practice of shared space, the increment of carbon emission related to energy consumption is only 13% of decrement of carbon emission caused by social attribute of open ground floor. It can be seen that energy consumption is not the main contradiction between open ground floor space and shared space of residential building in the aspect of continuity.
(3) From the perspective of full life cycle of buildings, through time weighing, the effect of shared space on emission reduction is more prominent. (Figure 7.2)
Chapter 8 | Design of Tongji New Village

This dissertation would do a project design as a solid evidence. I would apply this conclusion to a project design, in order to show that shared space could be attractive enough to be used by people, then, it can real save carbon for the community.

In terms of the climate and energy saving issue, I finally chose a site in Shanghai, China, a residential community named “Tongji new village”.

![Tongji New Village](image)

**Figure 8.1** Tongji new village  
Source: Author

8.1 Site Analysis

There were three main causes why the new regime carried out a mass of workers' new village construction in 1950s. In the socialism reform process in 1930s, there were many
contradictions and incoherences in the Shanghai urban policy. The state industrialization policy that "inland is superior to littoral" and "elimination of regional imbalance in development" confined the state fiscal input to Shanghai for a long period. On the other hand, the local fiscal policy that "production is major to life" also sacrificed residential needs to pursue a rapid growth in industrialization. Thus, except two short durations of new village construction climax in year 1952-1954 and 1957-1958, the non-production investment, such as housing, kept in a relatively low level in the whole thirty years. Finally, as the subject of Shanghai urban renewal - during the socialism period - workers' new village had shown up as the critical urban practice for the new regime to achieve their political wills, economic policies and social ambitions. The layout of the new village targeted merely at the principle of "serving for production", it accommodated the commuting of workers and at last shaped a new life style of "taking factory as home". The new village's construction in suburb carried forward the "center-border" style of power and space in old Shanghai city. Besides, influenced by the tough economic development, the construction standard of new village continued to descend, which greatly affects the family life and neighborhood relationship of the workers living in the new village. The mass construction of new village kept these long last and far reaching impacts on urban special structure and social life of the working class so far.

Tongji new village is especially built for the young professors and faculty of tongji university at that time. Now young professors have become retired professors and the residents in this community now is composed of senior citizens and the young people who rent the apartment. As time passing by, this old community is no longer suit for some of the residents here.
Tongji new village right opposite to Tongji university, mainly composed of middle-rise buildings, sharing the same infrastructures as tongji university. It is near from the subway, which is very convenient.
Figure 8.3 The range of the site area  
Source: Google

The site has been chose from on of the groups of Tongji new village, it is located in the north of the community. This group is composed of four buildings.

8.2 Design Concept

8.2.1 Selecting a Group of Buildings as an Engine of the Entire Community

Figure 8.4 The “open first floor buildings” in the site  
Source Author
As a matter of fact, even if this study picked up a group of buildings in the whole community, this study would still only elevate two of them, making it the center of this small group. This public space would serve residents in the eight building, thus it is convenient for us to calculate their activities, trips on cars etc.

Figure 8.5 The existing situation of the site
Source Author

This site is in a pretty good environment, but since this community is built 50 years ago, they are in poor condition, and the roads and paths are occupied by the cars, with low utilization of the public space and the lack of parking, this area has become a negative space (Figure 8.5).

8.2.2 Bringing Green and Nature Elements into the Community

According to 2.5, Edward O Wilson pointed out that human beings tend to have greens in public spaces around where they live. Humanity is exalted not because we are so
far above other living creatures, but because knowing them well elevates the very concept of life (Edward O Wilson, 1984). Thus, bringing green and nature elements into this community is a very important concept.

Exposure to natural environments can improve mood, reduce blood pressure and heart activity and improve people’s ability to concentrate. There is much evidence that natural environments can be more restorative than built environments (for reviews see Bowler, Buyung-Ali, Knight & Pullin, 2010 and Health Council of The Netherlands, 2004).

Kaplan’s (1995; Kaplan & Kaplan’s, 1989) Attention Restoration Theory (ART) adopts a cognitive framework to explain the restorative process. Two main types of attention are distinguished; directed and involuntary. Directed attention forces the mind to actively engage and focus attention (for instance on a difficult task) even in the presence of more exciting stimuli (Kaplan & Kaplan, 1989). Like a battery, our directed attention capacity is limited and can be depleted by completing an intense task. ART 3 proposes that our directed attention is best recharged through exposure to a source of involuntary attention. Attention Restoration theory attributes particular value to natural settings as settings for directed attention restoration. This has been supported by several studies (Hartig et al., 2003; Tenessen & Cimprich, 1995; Berto, 2005). Following these theories, all the open space in this project is related to nature, some of them are planted with plants, and some of them are the scenic focal point of the green spaces, in this way, residents could be able to either experience the nature or see the nature.

People tend to recover more quickly from stress and mental fatigue in natural than in urban environments. (Gatersleben, B & Andrews, 2013), let alone in a international metropolis like Shanghai, the concrete and cement built city together with the rapid growth of economy forced people into a huge pressure of living and working. The basic idea in
this project is also turning this old community into a “park” for the residents, bringing life to this aged structure.

Figure 8.6 Basic design concept
Source Author

8.3 Design Strategy

The existing buildings are arranged separately, the spaces in between the buildings is negative, and the connection of the buildings is weak (Figure 8.7 left). By elevating two of the buildings, the ground floor is open, the connection of the buildings can be enhanced, the project also give the green space back to the residents by keeping the ground floor open (Figure 8.7 middle). Third, adding the corridors in the sky, the buildings become closer to each other, furthermore, the corridors can work together with the elevators to solve the problem of vertical circulation. The under-ground parking is also added to solve the park problem in the existing community (Figure 8.7 right).
8.3.1 Strategy of Programming

In this design, new programs have been brought into this old community. Since the residents are getting old and some of the apartments have been rented to young people who work nearby, the demands of the function is no longer just for living.

The major new program which has been added to this community is obviously the open space on different layers of this community, not only the open first floor, but also the platforms and the “boxes” in the middle floor, the platforms are semi-open space while the “boxes” are meant to be indoor recreation spaces and home offices. Furthermore, the gable roofs have also been turned to flat ones, in order to provide recreation spaces for residents.
By transforming the gable roofs to flat roofs, a couple of roof gardens could become real. In the open space between the buildings, so as to meet the old women’s dancing requirement, this design even provide a stage for them to do square dancing. Moreover, a running path has also been created for residents to jogging. To sum up, these new programs into the old community could also enhance the continuity and connection of the ground floor (Figure 8.9).

Figure 8.9 Site plan

Source Author
Figure 8.10 First floor plan before renovation
Source Author

Figure 8.11 Façade before renovation
Source Author
Figure 8.12 First floor plan after renovation
Source Author

Figure 8.13 First floor plan after renovation
Source Author
Figure 8.14 Section A before renovation
Source Author

Figure 8.15 Section A after renovation
Source Author

Figure 8.16 Section B before renovation
Source Author
8.3.2 Strategy of Making Spaces

In this project, public spaces are created in diversity hierarchies. According to Jan Gehl, attractive open spaces have an order, which can lead people gradually from outdoor to indoor. To realize this, space need to have soft edges, the opened first floor is a soft edge for outdoor and indoor, in this space, people could sit down and observe what is happening outside with a feeling of safety. That is why these semi-open space are often more popular that the open space.

In order to reduce the Sense of oppression in the open first floor, some part of the
buildings are opened by two floors. And varieties of the section of the space also brings vitality to this community.

Since this community is now largely occupied by senior citizens, the solution of their vertical circulation is also considered in this design. Two elevators on the corner bring them up and the buildings are connected by six sky bridges. These bridges are not only just transit space, but also acting as bridging sky gardens link the two stepping towers and create a series of interconnected streets, gardens, and terraces in the air, which provide a variety of areas for common recreation and congregation.
Figure 8.20 The semi-open spaces in the first floor and platform of the buildings

Source: Author
Figure 8.21 The open spaces on the first floor

Source Author

95
Figure 8.22 The open spaces on the skybridge

Source Author
Chapter 9 | Estimation of the Carbon Emission Reduction of the Project and Conclusions

The household consumption shows a kind of segregation phenomenon, which means specific residential patterns corresponding to a kind of social class. The study argues that residents of social structure and facility-using behaviors is the main factor affecting residential mode of low carbon effect, and internal facilities accessibility of residential services plays a decisive role in supporting for residents’ daily life functions and reducing transportation emissions. Thus, by the reconstruction of Tongji new village, residents’ travel behavior would be to some degree changed.

This dissertation will be working on the calculation of how much carbon this project may save according to the conclusion. By knowing the amount of units of this group of 8 buildings and the distance of trips they may need to find infrastructures they need nearby, I can obtain the carbon of trips it could save if we have a shared space in this group that could serve as infrastructures.

Based on the questionnaire, several facilities that required by the residents has been chosen to help estimate the carbon emission reduction, this study picked up the nearest facility from Tongji new village.

9.1 Sports Center

Even though Tongji new village is near two universities---Tongji University and Fudan University, the sports center in school is not open to the public. The nearest public sports center is in Jiangwan Stadium, which is north to the community.
Figure 9.1 The distance from Tongji new village to the nearest sports center by car

Source: Google Earth

Figure 9.2 The distance from Tongji new village to the nearest sports center by subway and bus

Source: Google Earth
This sports center is 3.5km away from Tongji new village by private car or taxi when the shortest route is chose. The color on the route also shows the real time traffic information on the road.

In terms of public traffic, the sports center is one-stop distance away by subway, so it takes 5 minutes by subway (the time for walking is excluded). At the same time, if taking a bus, the distance is the same with the cars, this information can provide the geographic proof for the carbon emission estimation.

9.2 Chess dominoes room

In China, playing Chinese chess and Mahjong is a very traditional way for senior citizen to enjoy themselves in spare time, and it is also a very important social life. In the old days, people got together in homes and on street. Nowadays, some communities has their own chess room, while some are profit ones outside communities. Tongji new village do not have a chess room, if the senior citizen want to play Chinese chess or Mahjong, the nearest one is in the south of the community, 1.6km away, there is no direct bus to go there, since 1.6km is either too far nor near for the senior citizens, the best way to get there is still by car.
9.3 Public Parks

Parks are important to the physical and mental health for human beings, if there is no adequate green space for residents, they would need to find parks for natural landscape.

The nearest public park from Tongji new village is Heping Park in Hongkou District, which is 1.6km by car, when taking a subway or bus, one need to walk a pretty long distance while only travel 5 minutes on the subway.
Figure 9.4 The distance from Tongji new village to the nearest park by car

Source: Google Earth

Figure 9.5 The distance from Tongji new village to the nearest park by public transportation

Source: Google Earth
9.4 English Education Institution

More than 70 percent of Chinese parents want their children to learn English just for entering better schools, according to a recent survey report on English education in China. The online survey was conducted by the 21st Century Education Research Institute in Beijing, based on the questionnaires sent in by 45,758 Chinese parents from around the country. Released on Nov.3, 2013, the survey report shows that, although 90 percent of the parents believe that learning Chinese and traditional culture is more important than English, their children still pay more attention to the study of English than Chinese.

English craze is still existing among Chinese parents, thus, they would send their children to English education institutions during weekends. So classrooms is a new kind of facility in community. This project provide indoor spaces which has the potential to become a small classroom for the children in the community, if there’s not such facilities in the community, parents need to bring their children to the nearby English education institution, but these institution is always more expensive and not worth the price.

The location of the nearest the English education institution is in Wujiaochang, which is 2.7km away, taking 9 minutes drive. If go by subway, it is still one stop.
Figure 9.6 The distance from Tongji new village to the nearest English education by car
Source: Google Earth

Figure 9.7 The distance from Tongji new village to the nearest English education by public transportation
Source: Google Earth
### 9.5 Carbon Emission Estimation and Conclusion

Table 9.1 The information of the typical buildings in Tongji new village

<table>
<thead>
<tr>
<th>YEAR OF BUILT</th>
<th>NAME OF BUILDING</th>
<th>AMOUNT OF BUILDING</th>
<th>FLOOR AREA (SQUARE METER)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1953</td>
<td>XINYU BUILDING</td>
<td>4</td>
<td>11.56</td>
</tr>
<tr>
<td>1955</td>
<td>NO.1 DORM FOR FACULTY</td>
<td>4</td>
<td>61.79</td>
</tr>
<tr>
<td>1955</td>
<td>NO.2 DORM FOR FACULTY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1955</td>
<td>NO.4 DORM FOR FACULTY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1957</td>
<td>TONG BUILDING AND JI BUILDING (TYPE A/B/C)</td>
<td>23</td>
<td>41.8</td>
</tr>
<tr>
<td>1957</td>
<td>NO.32-33 TONG BUILDING</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1957</td>
<td>NO.28-31 TONG BUILDING</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1960</td>
<td>SECOND TONG BUIDLING</td>
<td>3</td>
<td>55.34</td>
</tr>
<tr>
<td>1975</td>
<td>DORM FOR FACULTY(1974)</td>
<td>2</td>
<td>37.58</td>
</tr>
<tr>
<td>1981</td>
<td>FACULTY’ S HOME</td>
<td>5</td>
<td>53.14</td>
</tr>
<tr>
<td>1982</td>
<td>HOME IN 1981</td>
<td>7</td>
<td>53.14</td>
</tr>
<tr>
<td>1984</td>
<td>83-I BUIIDLING</td>
<td>3</td>
<td>51.89</td>
</tr>
<tr>
<td>1985</td>
<td>TONGJI SHOP AND RESIDENTIAL</td>
<td>1</td>
<td>32.87</td>
</tr>
<tr>
<td>1986</td>
<td>DORM FOR SPECIALIST</td>
<td>2</td>
<td>59.6</td>
</tr>
<tr>
<td>1987</td>
<td>THE THIRD TYPE HOME FOR FACULTY</td>
<td>1</td>
<td>58.4</td>
</tr>
<tr>
<td>1987</td>
<td>SINGLE-ROOM SPECIALIST HOME</td>
<td>1</td>
<td>27</td>
</tr>
<tr>
<td>1987</td>
<td>83-II BUIIDLING</td>
<td>2</td>
<td>25.25</td>
</tr>
<tr>
<td>1991</td>
<td>FACULTY’ S HOME(83-I)</td>
<td>5</td>
<td>51.89</td>
</tr>
<tr>
<td>1991</td>
<td>FACULTY’ S HOME(89-I)</td>
<td></td>
<td>55.2</td>
</tr>
<tr>
<td>1994</td>
<td>XIN BUILDING</td>
<td>6</td>
<td>51.04</td>
</tr>
<tr>
<td>1995</td>
<td>FACULTY’ S HOME(93)</td>
<td>3</td>
<td>54.03</td>
</tr>
<tr>
<td>1997</td>
<td>FACULTY’ S HOME(95)</td>
<td>3</td>
<td>54.48</td>
</tr>
</tbody>
</table>

Source: Cong Dong, The Disquisition on the Design of Residential Model with Small and Medium size in Tongji New Village
Tongji new village now has a total floor area of 179800m², the year of built of these buildings are from 1953 to 1995, 132 buildings have been built over these 40 years (20 of them had been demolished and new ones have taken place of them). There are over 51 kinds of housing types in this community, the biggest flat—“cun building” is 62 m² per home, and the smallest “yuanyang building” is 26 m² per home. Table shows the information of typical buildings of Tongji new village.

Tongji new village now has totally 3286 families, the permanent resident population is 9010, which are consist of faculty of tongji university and their relatives and renters. The residents over 60 years old accounts for 26.9% of the population, which, is much higher than the average 17.8% of Shanghai. 20

According to the survey of the travelling behavior of residents in Tongji new village, the weekly emission could be estimate as the following table.

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20 The population census of Tongji new village conducted by neighborhood committee in 2010
Table 9.2 The carbon emission reduction of the trips to 4 major facilities

<table>
<thead>
<tr>
<th>Facility</th>
<th>Method</th>
<th>Average Frequency /weekly</th>
<th>Average speed (km/h)</th>
<th>Time (h)</th>
<th>Emission factor (kg/km)</th>
<th>Weekly emission (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sports center</strong></td>
<td>Subway</td>
<td>0.15</td>
<td>30</td>
<td>0.083</td>
<td>0.029</td>
<td>0.0108315</td>
</tr>
<tr>
<td></td>
<td>Bus</td>
<td>0.24</td>
<td>20</td>
<td>0.466</td>
<td>0.053</td>
<td>0.1185504</td>
</tr>
<tr>
<td></td>
<td>Private car/Taxi</td>
<td>0.31</td>
<td>66</td>
<td>0.2</td>
<td>0.149</td>
<td>0.609708</td>
</tr>
<tr>
<td><strong>Chess dominoes room</strong></td>
<td>Subway</td>
<td>0</td>
<td>30</td>
<td>0.083</td>
<td>0.029</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Bus</td>
<td>0.29</td>
<td>20</td>
<td>0.1</td>
<td>0.053</td>
<td>0.03074</td>
</tr>
<tr>
<td></td>
<td>Private car/Taxi</td>
<td>0.11</td>
<td>66</td>
<td>0.1</td>
<td>0.149</td>
<td>0.108174</td>
</tr>
<tr>
<td><strong>Parks</strong></td>
<td>Subway</td>
<td>1.82</td>
<td>30</td>
<td>0.083</td>
<td>0.029</td>
<td>0.1314222</td>
</tr>
<tr>
<td></td>
<td>Bus</td>
<td>1.01</td>
<td>20</td>
<td>0.467</td>
<td>0.053</td>
<td>0.4999702</td>
</tr>
<tr>
<td></td>
<td>Private car/Taxi</td>
<td>2.19</td>
<td>66</td>
<td>0.1</td>
<td>0.149</td>
<td>2.153646</td>
</tr>
<tr>
<td><strong>English education institution</strong></td>
<td>Subway</td>
<td>0.06</td>
<td>30</td>
<td>0.083</td>
<td>0.029</td>
<td>0.0043326</td>
</tr>
<tr>
<td></td>
<td>Bus</td>
<td>0.09</td>
<td>20</td>
<td>0.467</td>
<td>0.053</td>
<td>0.0445518</td>
</tr>
<tr>
<td></td>
<td>Private car/Taxi</td>
<td>0.74</td>
<td>66</td>
<td>0.15</td>
<td>0.149</td>
<td>1.091574</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>4.8035007</strong></td>
</tr>
</tbody>
</table>

Source: Author

From the table, we can tell before the renovation, the facilities demand could cause 4.8 kg CO₂ emission per week by private and public travel.

According to the statistics and the equation in previous chapter,
\[ \Delta E_{PHY} = \Delta E_{OPR} + \Delta E_{MAT} = 0.9796 + (43.97 + 4.55) \times \frac{1}{4} = 13.01 \text{ (kg CO}_2\text{eq/m}^2) \]

\[ E_{TRIP} = \sum_{i=1}^{n} (2 \times F \times S \times T \times EF \times R) \times \frac{365}{7} \times \frac{U}{FA} = 2 \times 4.80 \times \frac{365}{7} \times \frac{1}{4} = 125.22 \text{ (kg CO}_2\text{eq/m}^2) \]

Since the buildings that have been renovated is only 3, if this open area could be used by the group of 8 buildings well, then the CO\textsubscript{2} emission reduction amount should be 8/3 times of the increment caused by physical change. (Figure9.8)

**Figure 9.8** The carbon impact of one of the 3 buildings (above), the carbon impact of the group of 8 buildings (below).

Source: Author
Bibliography


[32] Gatersleben B, Andrews M. When walking in nature is not restorative—The role