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# The Spatio-Temporal Pattern and Spatial Effect of Installation of Lifts in Old Residential Buildings: Evidence from Hangzhou in China

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**Abstract:** In recent years, in order to improve the quality of living, China has carried out a series of urban renewal projects, such as adding elevators to old communities. Taking Hangzhou as an example, this paper studies the decision to install elevators in old residential buildings. This study used cold spots and hot spots, local autocorrelation and fishnetting analysis to show the spatial and temporal patterns of lift retrofitting in old communities. Finally, the spatial lag model is used to test whether there is a spatial spillover effect in the behavior of residents installing elevators. The research shows that: (1) Hot spots areas for retrofitting lifts are clustered in the central urban areas of Hangzhou, such as the intersection of Shangcheng District, Xiacheng District, Jianggan District, Gongshu District and Xihu District (scenic area); (2) The trend of retrofitting areas spreading from the center to the periphery; (3) In different communities, the number of elevators added in neighboring communities has a positive effect on the decision of adding elevators in other local communities. Therefore, the neighborhood effect cannot be ignored in the topic of community renovation, in which residents spontaneously participate.

**Keywords:** lift installation; neighborhood effects; spatial diffusion; old communities; urban renewal



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## 1. Introduction

Urban renewal program is an important approach for urban sustainable development to improve the living environment and life quality of old urban residents. There were nearly 160,000 aging communities across the country, with a total of about 8 billion square meters of new housing area, according to data from the National Bureau of Statistics and the Ministry of Housing and Urban-Rural Development of China between 1980 and 2000 [1]. Due to factors, such as backward construction standards and aging residential buildings and infrastructure, most communities have deteriorating conditions in residential functions and living conditions that could no longer reach a comfortable level and people's pursuit of quality of life. The land supply constraints and the high costs of demolishing old communities limits the development of urban residential areas. The regeneration of ageing urban communities is an inevitable move in line with historical trends and has received widespread attention from the government and the public, as it relates to livelihood issues. However, large-scale demolition will cause a great waste of social resources, which is not in line with the concept of sustainable development in China. Therefore, the renovation is the main way to solve the problem of old residential incompatibility. The addition of elevators in old multi-story residential buildings is an effective improvement of housing functions, which can facilitate residents' travel and improve residents' happiness. It is an inseparable part of urban renewal projects.

The aging communities in Hangzhou are very concentrated and these communities are quickly aging. According to statistics, more than 9800 residential buildings and

25,000 units in Hangzhou are eligible for the installation of lifts. Hangzhou government strongly supports the work of installing lifts in existing residential buildings. In terms of institutional protection, the Hangzhou government stipulates that that the installation of lifts should be agreed by more than two-thirds of the owners of the involved units. In terms of financial security, the government provides a subsidy of CNY 200,000 per unit, and the costs involved in the relocation of pipelines are jointly borne by the respective pipeline units and the government. In terms of application for the addition of lifts, the principle of voluntary application is adopted, requiring only the consent of more than two-thirds of the owners of each unit and the absence of written objection from other owners in real names. In terms of cost sharing, generally the owners of the first and second floors do not have to bear the cost, the third floor shares 10% of the cost, increasing layer by layer until the sixth floor, which shares 40%, and the subsequent maintenance costs are shared equally by the owners, other than the first and first floors. Up to now, a total of 1627 buildings have been completed in Hangzhou, benefiting nearly 20,000 households.

The retrofitting of lifts to multi-story residential buildings has had many successful experiences in many developed countries. After 1977, Sweden provided lifts for buildings higher than two stories and retrofitting of all multi-story residential buildings began [2]. The Swedish government and parliament set up a special fund and a working group on lift retrofitting to provide funding for the retrofitting of lifts and to promote the process of retrofitting multi-story residential buildings with lifts [3]. In Singapore, the government has implemented the Home Ownership Scheme and the government HDB flats are clustered high-rise buildings. Inadequate supply of lifts in HDB flats in the early days meant the government started to renovate and retrofit lifts in 2004, with residents bearing 5–12% of the cost of retrofitting lifts, and the rest being borne by the government [4]. In Japan, a survey committee for the development of lifts for unit-type public housing was established in 1999, and in 2000, a code for the identification of lifts for unit-type public housing was formulated and the installation and renovation of lifts for public housing began [5]. There seems to be no difference between the elevator installation of multi-story residential buildings in old residential areas in China and those in developed countries. Both are government policies and economic compensation to stimulate the installation of existing residential elevators. However, it is worth noting that this is the first time in China that residents are the main focus of community renewal in terms of public service facilities. Residents negotiate their own installation costs, choose their own brand of lift addition and manage their own lifts, ultimately reaching a decision on lift retrofitting.

This paper studies the factors that affect elevator installation decisions from the microscopic and spatial levels. Taking about 1616 aging communities in eight urban areas of Hangzhou as the object, this paper analyzes the spatiotemporal pattern of elevators installed in old communities in Hangzhou and examines whether there is a spatial effect in the installation of elevators. The study found that the number of elevators installed in a community had a large positive impact on the decision to install elevators in other buildings in the community. The study also found that the decision to add elevators within a neighborhood was also positively influenced by the number of elevators added to surrounding neighborhoods. This study refers to the positive impact as the “neighbor effect”. Neighborhood effects are spread through social interaction and visibility.

A paucity of urban community renewal research focus on the participatory behavior of owner groups. Minimal research reveals the mechanisms of household participatory behavior from a micro perspective. This paper considers the influence of community characteristics and spatial effects on the decision of lift installation from the perspective of different groups of residents. The main contribution of this paper is that we systematically collect lists of buildings that lifts are installed and transform these data into geographical information. This helps to analyze the diffusion dynamics of lift installation. The influence of the diffusion effect on the behavior of lift installation in the community is verified by the residents of the neighborhood. This study contributes to the literature on the participation behavior of households for urban regeneration in Chinese cities using a bottom-up approach. Compared to the traditional top-down model of urban community regeneration, this study on the installation of lifts in aging communities uses a bottom-up model. The model that residents organize themselves to participate in the installation of lifts in their communities can serve as a new model of community building and provides a new reference and basis for urban regeneration governance in China.

This paper is organized as follows. Section 2 provides a brief review of the literature. Section 3 describes the experimental areas, data, and variable selection. Section 4 details trends in the diffusion of lift installation in residential units in ageing communities. Section 5 gives a measurement description of the factors affecting the elevator installation decision. The analysis results are presented in Section 6. Sections 7 and 8 provide discussion and conclusion, respectively.

## 2. Literature Review

### *2.1. Urban Renewal*

Urban renewal is an inevitable issue in the process of urban development. As the stages of urban development are not consistent across the country, the content of urban renewal is evolving and showing diversified development trends. As an effective way to deal with various conflicts and problems in the process of urban development, urban renewal covers economic, social, environmental, cultural and public management dimensions and has received attention and research from scholars in different fields, becoming a hot research topic in related fields.

Urban renewal has had a positive impact on the development of many cities, mainly on the economic, social, environmental and cultural fronts. On the economic side, government-led urban renewal projects have improved urban building conditions and led to small increases in surrounding house prices [6]. It has also been shown in the literature that the magnitude of positive externalities from urban renewal depends on the size of the urban renewal project and the amount of commercial space included in the project [7]. In terms of social impacts, urban renewal can reduce urban property crime and violent crime rates [8], which has a positive and important impact on the overall well-being of residents [9]. In terms of the environment, studies have shown that urban renewal through demolition and reconstruction and maintenance and renovation may have negative impacts on the surrounding environment in the short term but can be beneficial in the long term for the improvement and enhancement of the surrounding environment. In terms of culture, urban renewal is positioned as an integral part of the integration process and practice and has revitalizing effects on urban education and cultural exchange [10].

When carrying out urban renewal activities, it is important to first clarify the subject of urban renewal. In the early stage of urban renewal development, the government and developers mainly adopted the implementation mode, but with the development of urban economy and the residents' defense of their own interests, urban renewal planning has changed from the traditional government–developer-led approach to a joint governance mode that focuses on multi-party consultation and cooperation [11–13]. In particular, in the renovation of older housing, renewal plans should pay attention to the wishes and ideas of residents, so that they can actively participate in the renovation process and better improve the living environment of the community [14]. In the process of urban community renewal, the retrofitting of elevators in old neighborhoods is a typical example of the transformation of the main body of urban renewal. Unlike traditional urban renewal projects that are government-led, elevator retrofitting in old neighborhoods is a new form of urban renewal that is led by residents [15,16]. Combining with the existing Chinese and foreign literature, urban renewal seems to focus more on studying the impact of urban renewal on urban development from the macro and government levels. In contrast, urban renewal has not been sufficiently studied at the micro level from the perspective of changes in urban renewal subjects, such as residents and community specific projects. To fill this gap our study aims to explore how factors related to the behavior of retrofitting elevators in old neighborhoods affect the successful retrofitting of elevators in old neighborhoods. We will use elevator retrofitting in urban areas of Hangzhou, China as the experimental field.

### 2.2. Spatial Diffusion

Economists and geographers have long been interested in the factors that govern the way new technologies spread. Many authors have explored the characteristics of where technologies spread and the role of policy, economic factors and social interactions in influencing the wave of diffusion of many new technologies. A number of recent studies have explored the diffusion of new technologies in different settings. McEachern and Hanson (2008) studied the adoption process of PV systems in 120 villages in Sri Lanka and found that the adoption of PV systems was driven by the following factors: incentive policies for the government and the number of PV systems adopted around the village [17]. These findings suggest that social interactions may influence the spread of life habits, which is consistent with an amount of large literature on neighborhood or peer effects of spatial knowledge spillovers [18]. Scholars, such as Lee Biao, have studied word-of-mouth effects, such as the 'neighbour effect' in the diffusion of low-carbon energy technologies in rural areas and the dissemination of information [19]. R. Oldakowski and J. W. McEwen argue that social ties and spatial agglomeration are key factors in the popularity of golf courses [20].

Research on spatial diffusion has mainly focused on the spread of new technologies. However, the literature is less focused on the impact of spatial diffusion on the decision of urban renewal, especially on the decision of elevator installation in old residential areas. Adding elevators to old residential areas has been promoted for a long time in China, but many residents have been holding a wait-and-see attitude toward adding elevators. Only through observation, communication and other forms of residents obtaining the information of the installation of elevators can the uncertainty of the installation of elevators be effectively reduced. Alternatively, residents could get more information about elevators from their neighbors and find out from their own observation that the use of elevators improves their happiness. Only in this way will the probability of these residents making the decision to install elevators become more likely, and the diffusion trend of installing elevators will gradually be formed.

### 2.3. Influencing Factors of Urban Renewal

In the existing literature on urban renewal influencing factors, most scholars have studied them from a single dimension, while only a few scholars have conducted comprehensive and specific studies on urban renewal-influencing factors, and their research perspectives and dimensions are different.

In terms of the influence of existing conditions on urban renewal, Chan et al. obtained that social welfare, conservation of existing resources, living environment and public space are conducive to the promotion of urban renewal through a study of planners, architects, real estate managers and residents related to urban renewal in Hong Kong [21]. In terms of the influence of existing policies on urban renewal, Turcu found that government incentive policies, government management, government subsidy support and urban renewal regulations are also important influences on urban renewal [22]. In addition, in terms of urban community renewal, Hemphill et al. found that the degree of public participation in the area, the economic level of the community, the neighborhood environment and the basic characteristics of the community all influence whether the community is successfully renewed, and the progress of renewal by evaluating three European urban community renewal projects is shown in [23].

Based on the existing literature, it can be seen that most scholars have analyzed the direct influence of factors on the promotion of urban renewal projects, ignoring the influence of the "neighborhood effect", i.e., not considering the spatial dependence of urban renewal decisions [24]. Therefore, it is necessary and meaningful to investigate the influencing factors of elevator retrofitting in old neighborhoods, which can better examine the influencing factors of urban renewal from a microscopic perspective. What are the factors influencing the retrofitting of elevators? Is elevator retrofitting influenced by the “neighbor effect” and how strong is the influence? All these questions need to be further studied.

## 3. Data and Variable Selection

### 3.1. Data

Hangzhou is a city with a long history and a high degree of urbanization. The main urban area of Hangzhou is selected as the research area, with a total area of 3068 km$^2$. The main urban area of Hangzhou is mainly composed of Shangcheng District, Xiacheng District, Jianggan District, Gongshu District, Xihu District, Binjiang District, Xiaoshan District and Yuhang District. This area is the old urban area of Hangzhou, with a concentration of old communities, an active housing transaction market in the old communities and a high degree of ageing of the residents in the communities, who are in great need of lift installation to improve their living environment. Therefore, this paper selects the eight urban areas of Hangzhou as a typical case to study the addition of lifts in old communities.

The data needed for this study includes a list of neighborhoods in the eight urban areas of Hangzhou that will be retrofitted with lifts from 2018 to 2020, as well as the properties of the communities built before 2000, i.e., the old communities, and the communities where the lift addition units are located. (1) The list of communities with added elevators is the basic data of this study, which is obtained from Hangzhou Housing Security and Renewal Affairs Center. (2) The identification of old residential areas in Hangzhou comes from Hangzhou policy. According to the Implementation Opinions of the General Office of Zhejiang Provincial People’s Government on Comprehensively Promoting the Transformation of Old Residential Areas in Urbanization, the residential areas built before the end of 2000 are regarded as old communities. (3) The attributes of the lift installation community mainly include the basic characteristics of the community, the economic status of the community and the neighborhood environment. The basic characteristics of the community and the economic situation of the community come from the second-hand house transaction record data obtained from Lianjian net (https://sn.lianjia.com accessed on 7 May 2021). Neighborhood environment consists of data on the distance from the elevator addition community to the surrounding infrastructure. The thesis locates the latitude and longitude coordinates of the extra-staircase communities determined from 2018 to 2020 and uses Baidu Maps to obtain distance data from each extra-staircase neighborhood to hospitals, parks and other infrastructures. The thesis is based on the old communities in eight urban areas of Hangzhou where lifts were added. Based on the data obtained and after eliminating the outliers, the thesis finally arrived at a sample of 1616 old communities with lifts.

### 3.2. Variable Selection

The dependent variable in this paper is the number of lifts installed in old communities in Hangzhou (2018–2020), as a measure of the number of residents in the community who make the decision to add an elevator. The paper divides the factors that influence making the decision to add an elevator into two categories.

The first category is the influence of neighborhood variables on the absolute number of installations. Communication between residents is an important channel for obtaining information on production, policy, technology and so on [25]. As residents generally live in adjacent communities and maintain certain social ties between them, the decision to add a lift is also influenced by the number of lifts already added in the surrounding communities. This also means that the number of lifts added in neighboring communities has a certain demonstration effect on the neighboring communities. The number of lifts installed in a certain distance from the community is chosen to study the influence of the neighborhood effect on the installation behavior of lifts in the community, as the behavior of lifts installation in a community is easily influenced by the surrounding social network and the communication between neighbors. We calculate the number of lifts installed in the communities within 500 m, 1000 m, 1500 m and 2000 m in the neighborhood of the target community as the number of neighbor installations.

The second category is the influence of the community environment on the absolute number of installations. The community environment consists of the basic characteristics of the community, the economic situation of the community and the surrounding community infrastructure. The basic characteristics of the community include age, size, plot ratio, greening rate. The basic characteristics of a community can measure how old the community is, the number of people living in the community, the greenery of the community, etc. It has been shown in the literature that residents are more willing to invest more in their homes when the neighborhood is younger and has a better environment. According to the survey, it is often more difficult to reach a consensus on the decision to install elevators in the community with a large population. The economic situation of the community includes the price per square meter. Residents are more willing to upgrade their residence and surrounding amenities to enable them to get a better return on their housing if prices in the community are still affordable. Neighborhood environment refers to the convenience of the community, i.e., the distance to hospitals, cultural and sports centers, commercial centers, scenic parks. As each community is an independent system and the installation of lifts is the individual behavior of the residents of the community, the number of elevators installed in the community is also used as a control variable. The definition and descriptive statistics of the variables are shown in Table 1.

**Table 1.** Summary Statistics.

| Variables | Obs | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Lift installations | 4848 | 0.114 | 0.871 | 0 | 36 |
| Neighboring installations, 500 m, | 4848 | 1.170 | 1.714 | 0 | 24 |
| Neighboring installations, 500–1000 m | 4848 | 3.051 | 3.703 | 0 | 36 |
| Neighboring installations, 1000–1500 m | 4848 | 5.106 | 5.707 | 0 | 58 |
| Neighboring installations, 1500–2000 m | 4848 | 6.438 | 6.643 | 0 | 59 |
| Installed number | 4848 | 0.1687 | 2.071 | 0 | 64 |
| Building age | 4848 | 29.749 | 6.754 | 21 | 80 |
| Size | 4848 | 451.855 | 614.629 | 19 | 7349 |
| Plot ratio | 4848 | 2.462 | 2.2 | 0 | 12 |
| Greening ratio | 4848 | 0.268 | 0.143 | 0.001 | 0.9 |
| Log-housing price | 4848 | 10.528 | 0.42 | 9.032 | 11.603 |
| Log-housing rent | 4848 | 3.997 | 0.423 | 2.585 | 5.436 |
| Log-Hospital | 4848 | 7.093 | 0.869 | 3.83 | 11.722 |
| Log-cultural and sports center | 4848 | 6.731 | 0.923 | 3.375 | 11.731 |
| Log-shopping mall | 4848 | 6.442 | 0.979 | 1.952 | 11.693 |
| Log-scenic park | 4848 | 6.736 | 0.83 | 4.195 | 11.663 |

## 4. Spatial Patterns of Lift Installation

### *4.1. Hot and Cold Spots in Lift Installation Diffusion*

To get a clear picture of the spatial distribution characteristics of lift installations in aging communities, two spatial techniques are used: optimized *Getis–Ord* method (OGO) and Anselin's cluster and outlier analysis (COA) [26–28]. OGO can reflect the cumulative effect of high and low values in a range of spatial data. The statistical significance of where clustering of high or low value elements occurs in space is obtained by calculating for each element in the dataset. Just because an element has a high value does not mean it is a significant hotspot, this is only the case if the high-value element is surrounded by other elements that also have a high value. In this paper, we use OGO analysis to measure the clustering relationship between each observed lift addition plot and the surrounding lift addition communities and to measure the relationship between the amount of lift addition in the community and the amount of lift addition in the surrounding communities. The mathematical formula for *Getis–Ord Gi** is as follows.

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j} x_j - \overline{X} \sum_{j=1}^{n} w_{i,j}}{S\sqrt{\frac{n\sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2}{n-1}}}$$

where: $x_j$ is the attribute value of element $j$; $w_{i,j}$ represents the spatial weight between elements $i$ and $j$ (1 for adjacent, 0 for non-adjacent); $n$ is the total number of sample points; $S$ is the standard deviation; $G_i^*$ the statistical result is the z-score, if the z-score value is +2.5, it means the result is 2.5 times the standard deviation. A statistically positive z-score indicates a hot spot, with a higher z-score indicating a tighter concentration of hot spots; a negative value indicates a cold spot, with a lower z-score indicating a tighter concentration of cold spots. The GIS map can show the spatial location of the attribute values and analyze whether they have a clustering effect. The figure shows the *Getis–Ord* z-score of the selected attribute value of a geographical object. The higher the z-score, the more the color tends to be red, indicating that the attribute is a hot spot in space; the lower the z-score, the more the color tends to be blue, indicating that the attribute is a cold spot in space.

COA reflects the degree of correlation between a region and its neighbors for the same indicator. In the field of spatial econometric analysis, the spatial autocorrelation coefficient is often used to determine whether there is spatial dependence between data, i.e., whether there is a neighborhood effect [29]. In this study, the local Moran index was chosen to verify the guiding effect of the surrounding lift retrofitting communities on the decision to retrofit. The formula is as follows:

$$I_i = \frac{(x_i - \bar{x}\ )}{S^2} \sum_{j=1}^{n} w_{i,j}(x_i - \bar{x}\ )$$

Positive local Moran index indicates a positive clustering effect between sample $i$ and the surrounding samples, i.e., the addition of lifts in the surrounding neighborhoods shows a positive influence relationship on the decision to add lifts to the neighborhood. Otherwise, vice versa.

This article is analyzed and illustrated graphically through ArcGIS. The paper takes the sub-district as a unit and analyses the spatial hot spots presented by the lift installation in the aging communities. The results are shown in Figure 1A,B. As can be seen from the figure, the analysis results of the two methods are consistent. The hot spot of elevator installation is concentrated in Hangzhou's Shangcheng District, Xiacheng District, Jianggan District, Gongshu District and Xihu District (scenic area) intersection zone, namely the central city. These areas are also clusters of old communities, relatively densely populated, with high property prices, and are centers of economic development in the city.

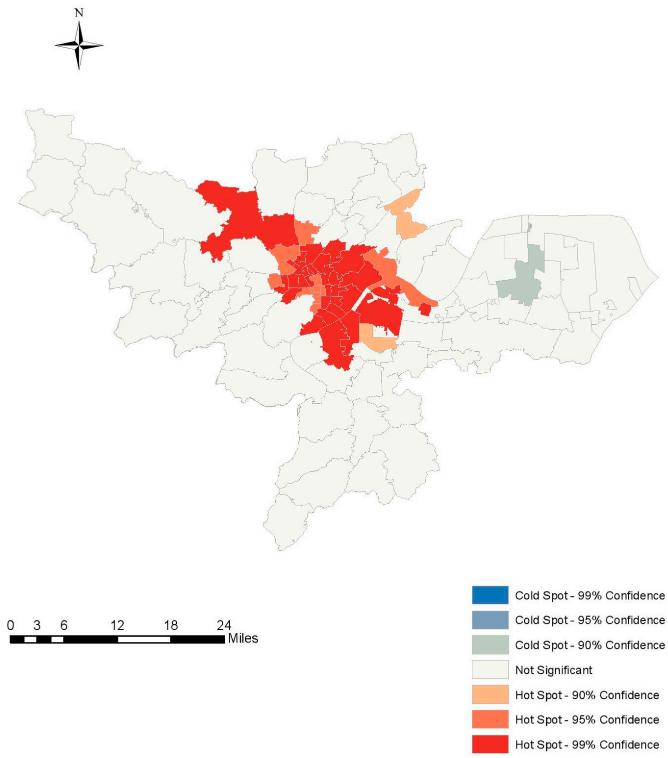
*4.2. Spatial Diffusion Patterns over Time*

To study the spatial diffusion patterns over time, this paper uses the fishnetting method [30]. The fishing net divides the area into cells with fixed size, and these cells are represented according to the number of lifts installed in the cell.

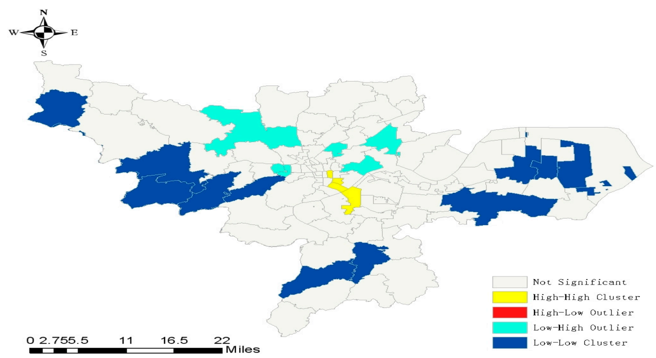
We specify the size of the basic cell in each net as 1.5 km in order to capture as many lift installation units in each cell as possible with an efficient disaggregation of the community. Figures 2 and 3 show the analysis of the fishnet at the end of 2018 and 2020, respectively, with each colored cell showing the number of lift installations in an area of 2.25 km$^2$.

Figure 2 shows that the majority of lift installation units are concentrated in the city center and are roughly centered on Wulin Square and radiate outwards with a few number of lift installations in the peripheral areas of the city and almost no lift installation in Yuhang and Xiaoshan districts. Comparing Figure 2 with Figure 3, the areas with high number of lift installations in 2018 remain high in 2020, while the areas with low lift installations in 2018 remain low in 2020. The number of lifts installed in the southern part of Xiacheng

District keep rising significantly from 2018 to 2020 and many of its neighbors that did not have lifts have also installed lifts. The northern part of Gongshu District with no lifts installed in 2018 keeps low level of lift installation in 2020. We find the same situation in neighboring areas. It is obvious that the number of lift installations at the end of 2020 are based on the areas with lift installation in 2018. There is a clear trend of spreading from the city center to peripheral areas.




**(A)**




**(B)**

**Figure 1.** Spatial distribution of Lifts installation hot spots and cold using different approaches. (**A**) Optimized Getis–Ord (OGO) (**B**) local Moran's I (COA) results.

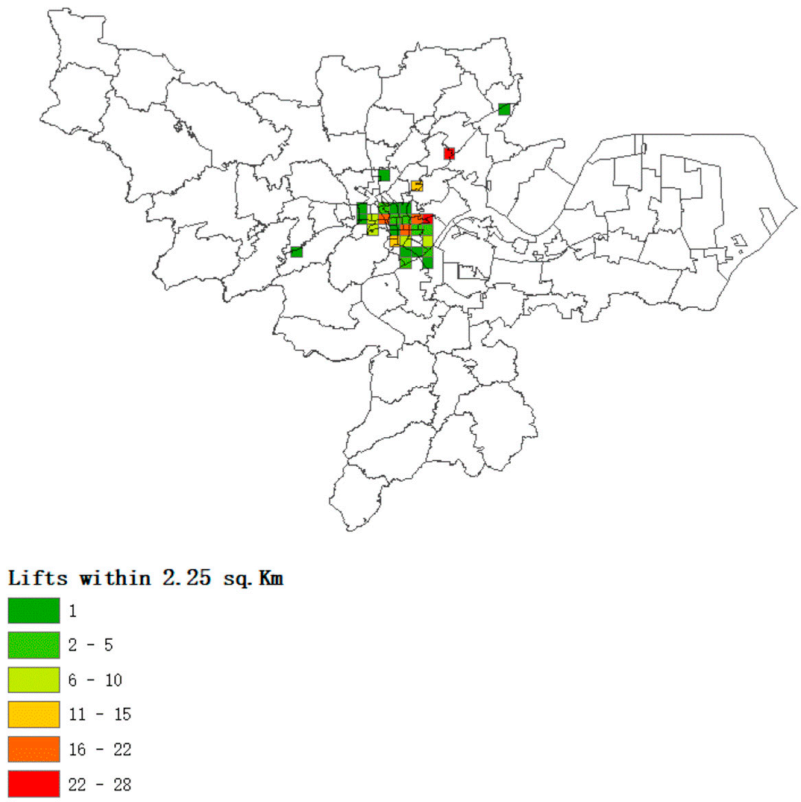



**Figure 2.** Fishnetting reveals the patterns of adoption of Lifts in 2018.

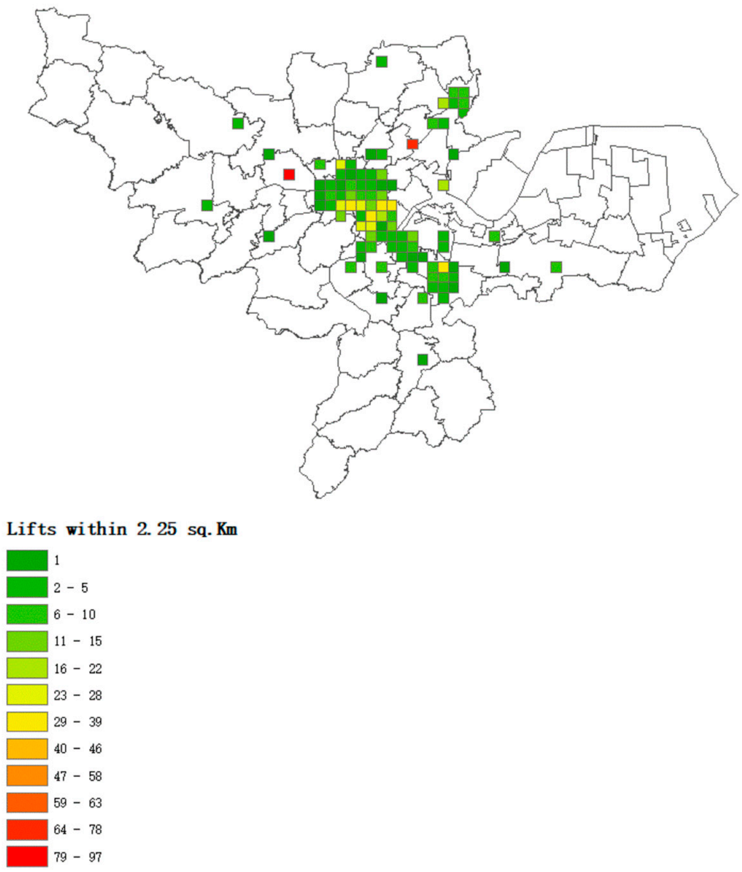



**Figure 3.** Fishnetting reveals the patterns of adoption of Lifts in 2020.

## 5. Empirical Approach

### *5.1. Creation of the Spatiotemporal Neighbor Variables*

The presence of spatial neighborhood effects may be a major factor contributing to the diffusion of lift installation spots [31]. The core empirical approach is to use spatiotemporal variables to capture the impact of prior project installations in the neighborhood on the decision to make lift installation in that community.

We used a certain installation spot as the center of a circle and adopted 500 m, 1000 m, 1500 m and 2000 m as the radius, respectively, to record how many aging communities within its boundaries have completed lift installation. We removed the lift installation spots in the relocated houses where lift installation is carried out in a uniform manner. This is done to avoid simultaneity issues and to greatly reduce the possibility of the determination to install before other neighbors choose to do so [7].

In other words, for a certain lift installation community, $k$, in 2020, we calculate the number of neighboring installation spots, $j$, such that:

$$d_{k,j} \leq D, t_k - t_j \leq T$$

$d_{k,j}$ is the distance (in meters) between the community of lift installation, $k$, and neighboring installation spot, $j$. $D$ is the distance specification (500, 1000, 1500 or 2000 m), $t_k$ is the installation time of $k$, $t_j$ is the installation time of the neighboring installation spot, $j$, and $T$ is the time lag (e.g., 1 year).

To examine the effect at each distance more precisely, we subtract the internal distance from the outer radius to see the effect within a radius of 500 m, from 500 to 1000 m, from 1000 to 1500 m and from 1500 m to 2000 m [32]. This method is a multi-ring buffer method, where the buffer is both spatial and temporal, as shown in Figure 4.

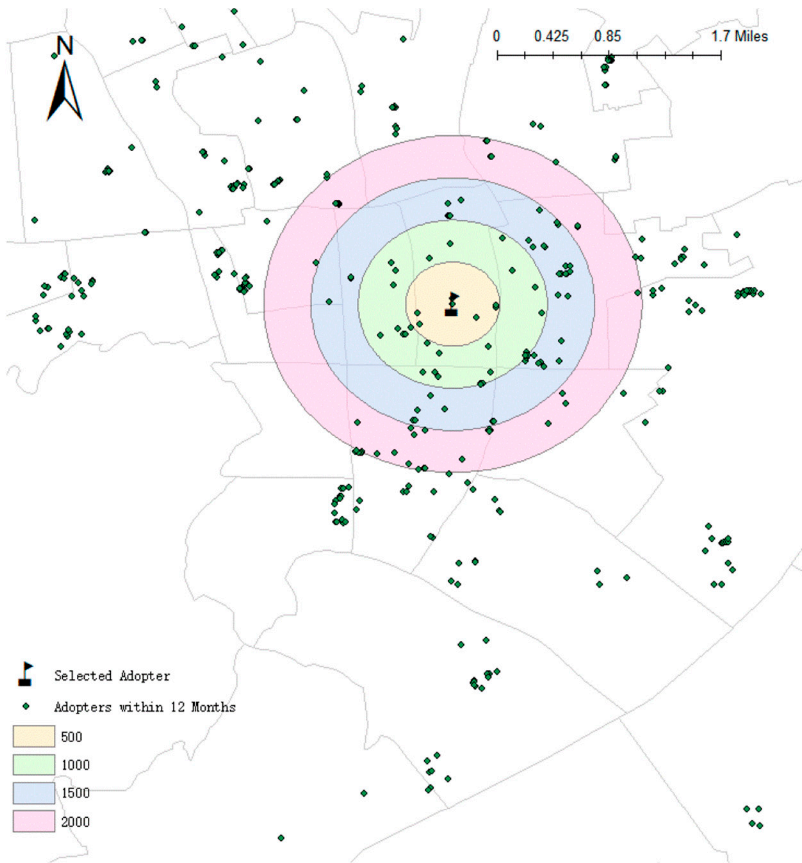



**Figure 4.** Selection of all neighbor adopters within 12 months.

*5.2. Model of Demand for Lift Installation*

This paper first reports the results of a spatial lag model for the relationship between neighborhood effect and the decision to install elevators. The core explanatory variable is neighbor effect. Paper characteristics of control variables, including district (fixed number of year of the community building, community scale, community plot ratio, village green area), district economy (house prices and the monthly rent per square meter) and neighborhood environment to the convenience degree of the village to the infrastructure.

To study the factors that influence the decision to install lifts for residents in aging communities, we use the following specification:

$$Lift\ number_{i,t} = \lambda W Lift\ number_{i,t} + N_{i,t}\,\beta + B_{i,t}\gamma + D_{i,t}\theta + E_{i,t}\partial + S_{i,t}\pi + \varepsilon_{i,t} \quad (1)$$

where $Lift\ number_{i,t}$ is the number of new lift installation spots in community $i$ at time $t$; $N_{i,t}$ is a vector of spatiotemporal neighbor variable; $B_{i,t}$ is vector of the number of lifts already installed in the community; $D_{i,t}$ is a vector of basic community characteristics; $E_{i,t}$ is a vector of community economic situation; $S_{i,t}$ is a vector of community characteristics variable that indicates the convenience of the infrastructure around that community in time $t$; and $\varepsilon_{it}$ is a mean-zero error term. In one of our models, we consider the number of new adoptions in a year, so $t$ is the year.

The vector $B_{i,t}$ contains vectors of variables for the number of lifts already installed in the same community. As the installation of lifts in aging communities is carried out on a community basis, the intensity of implementation varies from community to community. Using the base variable of installed units as an important control variables helps to explain the spatial neighborhood effect between different communities.

The $D_{i,t}$ vector of community characteristics includes the age of the community, the number of people living in the community, the plot ratio, the greening rate of the community and the price of the community. These variables control the differences in the communities in which the lift installation spots are located.

## 6. Empirical Results

Before estimating the model parameters, we first need to compare two models, the spatial lag model and the spatial error model. This is usually done by the (robust) LM test, where the model with the more significant LM statistic is the more preferred model. If the LM statistics of both models have the same level of significance, then the significance of the robust LM statistic is used to determine the form of the model setting. As can be seen from Table 2, the robust LM test for the spatial lag model is significant at the 1% level for the geographic distance spatial weight matrix setting, while the robust LM test for the spatial error model is not significant, thus indicating that the spatial lag model is superior to the spatial error model. Therefore, in the following we only report and discuss the estimation results based on the spatial lag model. The calculated Hausman test results failed the 1% significance test and the random effects model was chosen as the better model

**Table 2.** LM test of spatial panel model (old residential buildings to install the number of lifts).

| LM Test | Statistic | *p*-Value |
|---|---|---|
| Spatial error: | | |
| Lagrange multiplier | 24.461 | 0.000 |
| Robust Lagrange multiplier | 0.013 | 0.910 |
| Spatial lag: | | |
| Lagrange multiplier | 32.097 | 0.000 |
| Robust Lagrange multiplier | 7.648 | 0.006 |

We need to measure the parameter β, the effect of the spatial community on the decision to install a lift in a community. We also follow the coefficients of many other control variables to understand the impact of the number of units installed, the basic characteristics of the community, the economic situation of the community and the neighborhood environment on the decision to install a lift. As shown in Table 3, we present our primary results using the spatiotemporal variable that includes installations from the previous 1 year. Column (1) is the result obtained by panel regression. (2) The dependent variable, neighborhood effect, is regressed by spatial lag model. Column (3) uses spatial lag model regression to add spatial neighborhood variables to the model together with all control variables of regression analysis.

**Table 3.** Empirical Results.

| | (1) | (2) | (3) |
|---|---|---|---|
| **Variables** | **Install the Number of Lifts** | **Install the Number of Lifts** | **Install the Number of Lifts** |
| Neighbors within 500 m | 0.0185 ** | 0.0214 ** | 0.0215 ** |
| | (0.00799) | (0.00921) | (0.00897) |
| Neighbors within 500–1000 m | 0.00173 | 0.00396 | 0.00490 |
| | (0.00244) | (0.00242) | (0.00423) |
| Neighbors within 1000–1500 m | −0.000220 | 0.00103 | 0.00113 |
| | (0.00179) | (0.00175) | (0.00227) |
| Neighbors within 1500–2000 m | −0.000249 | -0.000278 | 0.000246 |
| | (0.00148) | (0.00160) | (0.00167) |
| Installed number | 0.193 *** | | −0.0136 |
| | (0.0178) | | (0.192) |
| Building age | −0.00830 *** | | −0.00943 *** |
| | (0.00264) | | (0.00277) |
| Size | −0.0198 | | −0.0113 |
| | (0.0218) | | (0.0345) |
| Log-housing price | 0.000877 | | −0.0126 |
| | (0.0234) | | (0.0367) |
| Log-Shopping mall | 0.0159 | | 0.0210 |
| | (0.0120) | | (0.0155) |
| Log-Scenic park | −0.00640 | | −0.00814 |
| | (0.0120) | | (0.0156) |
| Log-Hospital | −0.0141 | | −0.0159 ** |
| | (0.0200) | | (0.0221) |
| Log-Scenic park | 0.00566 | | 0.0165 |
| | (0.0116) | | (0.0184) |
| plot_ratio | −0.00492 | | −0.00176 |
| | (0.00305) | | (0.00385) |
| greening_ratio | −0.0137 | | −0.00173 |
| | (0.0452) | | (0.0567) |
| Constant | 0.421 | 0.0686 *** | 0.465 |
| | (0.338) | (0.0188) | (0.383) |
| Spatial | | | |
| rho | | 0.0479 *** | 0.0432 * |
| | | (0.0177) | (0.0247) |
| Variance | | | |
| lgt_theta | | 0.422 * | 0.372 |
| | | (0.245) | (1.084) |
| sigma2_e | | 0.475 ** | 0.468 *** |
| | | (0.227) | (0.137) |
| Observations | 4848 | 4848 | 4848 |
| R-squared | 0.09 | 0.008 | 0.004 |

Robust standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

To sum up, the empirical results show the impact of the spatial neighborhood effect on lift installation decisions. The finding suggests that the number of lift installations around a community increases the number of lift installations in that community, positively influencing the decision of lift installation. According to Table 3, under the weight of geographical distance, the influence coefficient of installing elevators in neighboring communities within 500 m on the decision of installing elevators in the communities is significantly positive, which indicates that installing elevators in neighboring communities significantly promotes the level of installing elevators in the communities. Furthermore, the results vary with distance. When we consider installations in more distant communities, the coefficients are usually no longer significant, e.g., beyond 500 m, none of the coefficients for the neighborhood variables are significant. This may be explained by that the range of interaction between different communities is relatively small, communities are not so close to each other and the visibility of lift installation is lower beyond 500 m from different communities, so the coefficients are not significant. Our results also emphasize the important role of the community basic characteristics variables.

The results in column (3) show that each additional year of housing age in the community reduces the number of lift installations. This is in line with the results of the visits and surveys. The majority of households in particularly aging communities have moved out, rented out or are waiting to be demolished and will not increase the housing input in this community. Our results are less statistically significant when it comes to the neighborhood environment variable. There is weak evidence showing that the further the community is from the hospital, the less favorable it is to the installation of lifts, which is not surprising as the majority of people living in older communities are elderly. When the hospital is far away from the community, they will not regard convenience to the hospital as a reason for lift installation.

In summary, we find that the spatial neighborhood effects, the number of lifts already installed in the community and the basic characteristics of the community have a strong influence on the decision to install a lift, while the economic situation of the community and the neighborhood environment have a relatively weak influence on the decision. This result coincides with the expectation, as the decision to install lifts depends more on the personal willingness of the residents in the community and is mainly concerned with solving the problem of access to and from the building, so the decision is more likely to be influenced by the surrounding installation of lifts and the original environment of the community.

## 7. Discussion

### *7.1. Limitations and Further Possibilities of the Methodology Used in This Study*

Firstly, the volume of elevator installation in Hangzhou from 2018 to 2020 was used as the external representation of elevator diffusion in old communities. Although these data are accurate data based on government department statistics and can reflect the spatial distribution of lift retrofitting over three years, the three-year volume of lift retrofitting is still limited, and only the diffusion trend of lift retrofitting in old urban districts can be seen. This is in no way specific to each urban area of the diffusion trend, especially from the urban area to the county, as village diffusion trends did not appear.

Secondly, based on relevant theories and previous studies, the thesis discusses the influence on the decision to add a lift in a neighborhood at two levels: the neighborhood effect and the neighborhood environment. However, in addition to the influence of the neighborhood effect and the neighborhood environment, the decision to add a lift is also related to the proportion of elderly people in the community, household income, family structure and social network. The thesis does not have the means to include these influencing factors at the moment due to the difficulty of collecting personal data and household data on the residents of the community. Finally, as the list of lift retrofitting plots compiled by the Hangzhou Urban Renewal Center is counted once a year at the end of the year, the thesis has no way to refine the list of lift retrofitting communities to a quarterly or monthly basis and can only study it on a yearly basis.

In response to these shortcomings, the thesis will carry out further research in the following areas. Firstly, it could take the form of a questionnaire to further refine the factors that influence decision making. This is now also being undertaken by the authors. The questionnaire is designed with questions on household information, housing conditions, housing values, neighborhood environment, lift construction and maintenance and social networks. This is to make up for the lack of influencing factors. Secondly, it is clear from previous cases of lift additions that the decision to add a lift requires the consent of two-thirds of the residents in the building. However, during the negotiation process, the uneven distribution of interests among floors and the complexity of administrative procedures can also make it difficult to reach a unanimous decision to add a lift. Based on this, the authors need to further explore issues, such as conflicts and coordination of interests among those involved in the retrofitting of lifts, to explore the key conflicts in the process of retrofitting lifts clearly and to coordinate interests effectively. Finally, as the scope of the study continues to expand and multiple research methods are explored, the authors believe that ultimately the decision to retrofit lifts can be better facilitated for residents in old communities.

### *7.2. Possible Innovations of This Study*

This paper describes the diffusion trend of adding elevators in Hangzhou for the first time by using the list of adding elevators in the Hangzhou Urban Renewal Center. Based on GIS, this study uses Baidu map data to construct a basis for the factors influencing the number of lifts retrofitted based on POI data, map data from eight urban areas in Hangzhou, urban infrastructure data (hospital data, school data, map routes and bus route data) and multi-source data.

This study conducted a targeted research on lift retrofitting projects in Hangzhou, combining the neighborhood effect with the community environment. The spatial lag model was used to explore the causal relationship between the influencing factors. The spatial neighborhood effect is applied to the renovation of old communities, providing a new research perspective for subsequent studies.

## 8. Conclusions and Implications

The paper examines lift installation projects in old communities in the main urban area of Hangzhou, where unit communities have been installed with lifts. This paper explores the spatial and temporal trends in lift installation and the influence of community characteristics on lift installation decisions. We find that the neighborhood effect and the community environment significantly influence the decision to install lifts in the community.

Firstly, the geospatial analysis shows that the diffusion pattern of elevator facilities radiates around Wulin Square. This shows that the old community to install elevators from the city center to the surrounding spread.

Based on lift installation data from the last three years, this paper applies a spatial lag model to analyze the neighborhood effect as an influencing factor on lift installation behavior in aging communities. The basic characteristics of the community, such as age, size and type of ownership of the community houses, play a significant role in the lift installation decision. The results show that the number of elevators installed in the same community has a significant positive impact on the decision of other buildings to add elevators. In different communities, the number of elevators added in neighboring communities has a positive effect on the decision of building to add elevators in the community, which decreases with distance. The results are consistent with the results of the spatial analysis that there is indeed a diffusion effect of lift installation in aging communities. It also illustrates how social interactions lead to changes in the timing of lift installation decisions that are not explained by community characteristics and neighborhood environment [33]. Because the decision to install a lift is made by the residents, the decision is made more dependent on their existing interactions. Residents rely on their social experience (what they have observed, heard and understood) to make their judgement on whether or not to retrofit lifts. This judgment is just consistent with the empirical results, that is, the number of lifts installed in neighboring communities within 500 m has a significant positive impact on the installation of lifts in the community, while the number of lifts installed in neighboring communities beyond 500 m has no significant impact on the installation of lifts in the community.

In addition to providing evidence on the diffusion process of lift installation in aging communities, our findings also have important policy implications for lift installation in aging communities. The importance of the spatial community effect has proven to be very useful for policy makers. Lift companies and residents interest in promoting lift installation in aging community, as it suggests that measures to exploit this spatial neighborhood effect should be carefully considered. First, government can use neighborhood effect to promote the installation of lifts by promoting the exchange of knowledge, information and experience of lift installation among residents at community events and regular seminars. Second, enterprises can make use of various methods, such as bringing in newcomers by old ones to motivate those who have already installed lifts to promote the use of lifts to their friends and neighbors and emphasizing the installation rate in their own area during the marketing campaign. In the process of marketing, the installation rate in the area will be highlighted, and the neighborhood effect will increase the willingness of other potential lift users to buy. Finally, for residents in the community, those who live in buildings without lifts should be open to accept the real experiences of others who live in buildings with lifts.

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