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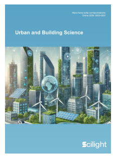

Article

Hidden Impacts of Elevator Addition on Community Microclimate: A Simulation-Based Case Study

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Abstract: Urban microclimate plays a critical role in sustainable aging-friendly community design, yet the impacts of small-scale morphological modifications like elevator additions remain underexplored. This study innovatively integrates multi-domain simulation approaches to address this gap, employing GBSware's coupled modules (TERA for thermal environment, SUN for solar irradiation, VENT for wind field analysis, and SEDU for acoustic modeling) to holistically assess the hidden effects of elevator retrofitting in high-density residential areas. Simulations reveal that elevator additions reduce urban heat island intensity by 0.38–0.67 °C through enhanced shading effects, while demonstrating minimal impacts on wind ventilation patterns. However, the intervention decreases facade solar irradiation by 10%–20% on affected elevations and elevates A-weighted sound pressure levels by 10–25 dB during operation. These findings provide new insights into the paradoxical microclimate impacts of vertical transportation infrastructure in aging communities, advancing the methodology for evaluating small-scale urban form modifications.

Keywords: building simulation; urban microclimate; heat island effect; horizontal irradiation; outdoor wind field; outdoor noise

1. Introduction

Urban microclimate, including temperature, wind velocity, and radiation, is crucial for determining urban living quality, making its understanding and management increasingly important [1–3]. Among various urban design elements, three-dimensional urban morphology has been identified as a critical factor influencing the outdoor thermal environment [4,5]. However, the impact of small-scale modifications to urban morphology, such as the addition of elevators to existing residential buildings, remains largely unexplored.

Elevator addition to old residential quarters is a growing trend in many countries, especially developing countries [6], driven by the need to improve accessibility for aging populations [7]. While the social benefits of elevator installation are evident, their potential impacts on the urban microclimate have not been sufficiently examined. Small changes in urban morphology can subtly yet significantly alter the thermal environment, thereby affecting the thermal comfort and energy consumption of residents [8]. Therefore, investigating the hidden impacts of elevator addition on community microclimate is crucial for sustainable urban planning and design [9,10].

1.1. Common Solutions For Installing Elevators in Existing Residential Buildings

To minimize structural and indoor comfort disturbances, elevator shafts are typically attached to building facades. The rare scheme of enclosing elevator shafts with opaque walls contrasts with various steel-supported observation elevator addition methods (Figure 1). These are classified as direct-access or half-level access [11] based on elevator lobby location and further categorized by connection type (adjacent or with bridges) and bridge

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enclosure (enclosed or open) [7,12]. Each scheme uniquely impacts the built environment, necessitating tailored selection and comprehensive assessment for scientific and sustainable design.

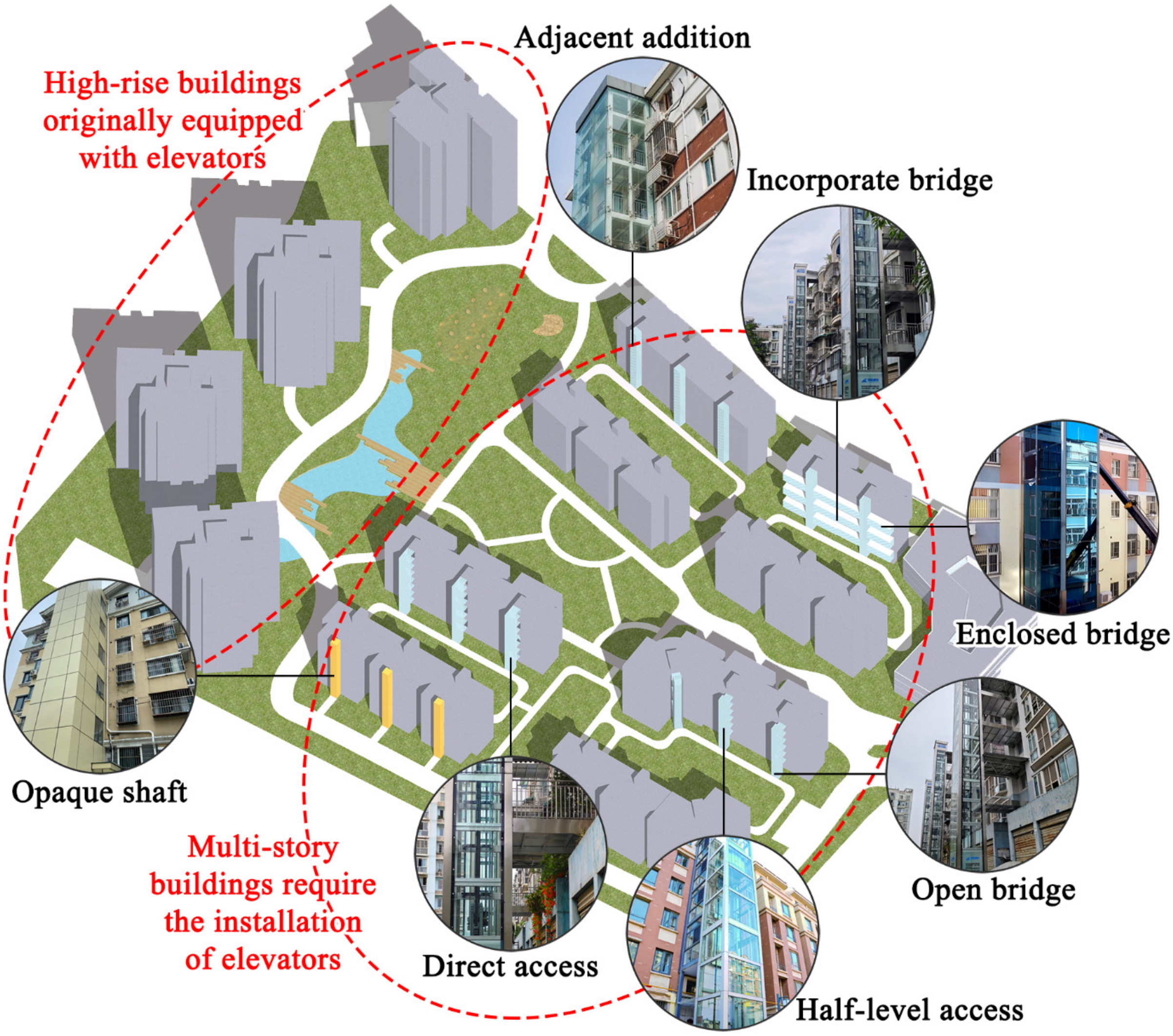

Figure 1. Common solutions for installing elevators in residential buildings.

1.2. Built Environment Impacted by Elevator Addition

First, outdoor microclimate. The installation of elevators on the exterior of existing buildings complicates the architectural form and the three-dimensional urban morphology. Changes in parameters such as sky view factor, building density, floor area ratio, complete aspect ratio, and the ratio of building surface area to floor area lead to alterations in the outdoor microclimate of the whole residential area. Although this impact is not significant when a small number of elevators are added, as urban renewal becomes more widespread, the installation of a sufficient number of elevators will have a noticeable effect on the outdoor thermal environment. For instance, studies on summer conditions indicate that adding elevators to the exterior of buildings may result in the deterioration of the outdoor microclimate in adjacent green spaces [13].

Second, indoor thermal comfort. In the high-temperature environment of summer, due to the electrical and mechanical components such as elevator control cabinets and drive motors being arranged in a confined space, heat accumulation easily occurs, leading to overheating of the shaft and the elevator car, which finally affects the comfort and safety of residents [14,15]. In winter, the stack effect and elevator piston effect also have impacts on the indoor wind and thermal environments of the building [16]. On the one hand, because of the large temperature difference between indoors and outdoors, hot air rises and cold air sinks, creating a stack effect. This effect causes indoor hot air to rise, forming a vertical temperature gradient between different floors of the building, resulting in a phenomenon where it is warmer at the top and cooler at the bottom [17]. On the other hand, there is a large temperature difference between the inside and outside of the elevator shaft in winter, causing air within the shaft to flow due to density differences and exacerbating the stack effect, further affecting the normal operation of the elevator [18].

Third, indoor lighting conditions. The installation of elevators may reduce the spacing between buildings, encroach upon roadways and green spaces, subsequently affecting the overall lighting coefficient and natural illuminance within indoor spaces [19,20]. Particularly, the use of opaque shaft significantly impacts local lighting performance [21]. This impact further leads to negative consequences. On one hand, due to decreased sunlight exposure, neighboring residences may need to rely more on indoor lighting, thereby increasing energy consumption. On the other hand, the installation of elevators may alter the building appearance and overall visual effect, influencing the visual comfort and psychological perception of the residents [22].

Fourth, indoor noise levels. The impact of installing elevators on indoor acoustic environments primarily manifests in two aspects: vibration and noise. During normal operation, the vibration generated by the friction and collision between the elevator car and the guide rails is transmitted through the shaft walls into the interior, causing vibrations in indoor walls, floor slabs, and other structural elements. This process, in turn, induces secondary structural noise within the living spaces [23]. The secondary noise may affect the normal rest of the residents and, more severely, cause issues such as headaches, tinnitus, fatigue, insomnia, and memory decline for some residents [24].

1.3. Research Gap and Hypotheses

Previous studies have demonstrated the influence of urban morphology parameters, such as sky view factor, building density, floor area ratio, and aspect ratio, on the outdoor thermal environment [25]. For instance, sky view factor, which represents the proportion of the sky visible from a point on the ground, has been shown to affect both temperature and wind velocity [26]. Building density and floor area ratio are known to influence air temperature and thermal comfort in urban areas [27]. Similarly, a higher aspect ratio may reduce solar radiation, thereby lowering the temperatures of streets and walls and improving thermal comfort [28]. Despite these insights, there is a dearth of research on how small variations in these parameters, resulting from elevator addition, affect the microclimate.

Although existing studies have achieved certain results in the impact of urban morphology on the microclimate, research on such small-scale morphological changes as elevator addition in old residential areas still has deficiencies. Therefore, the aim of this study is to fill this gap by investigating the hidden impacts of elevator addition on the outdoor thermal environment of a residential area in China. Specifically, this work focuses on how small changes in three-dimensional urban morphology influence key microclimate parameters such as heat island effect, horizontal irradiation, outdoor wind filed, and outdoor noise. To achieve this goal, this paper formulated the following research hypotheses:

- Elevator addition exacerbates the heat island effect: The installation of elevator shafts and connecting corridors may increase the surface area and heat-absorbing capacity of buildings, leading to higher temperatures and exacerbating the urban heat island effect.
- Elevator addition has a negative impact on solar energy utilization: The additional shaded areas created by elevator shafts may reduce the amount of sunlight reaching nearby buildings, particularly on the facades where elevators are installed, thereby negatively affecting solar energy utilization.
- Elevator addition has a negative impact on the outdoor wind environment: The installation of elevator shafts and corridors may alter the airflow patterns within the residential area, potentially leading to reduced wind speeds and poorer ventilation conditions, especially in areas immediately surrounding the elevators.
- Elevator addition has a negative impact on the outdoor sound environment: The operation of elevators generates noise, which may lead to increased sound pressure levels in the vicinity of the buildings where elevators are installed. This increase in noise may negatively affect the acoustic comfort of residents, particularly those living on lower floors.

By conducting a case study using GBSware software v. 2020 [29–31], this study simulates different scenarios of elevator addition and analyze their impacts on the microclimate, hoping to provide valuable insights into the sustainable planning and design of aging-friendly urban environments.

2. **Methods**

This study establishes a systematic framework for microclimate parameter selection by integrating four environmental dimensions with their corresponding physical drivers. The parameter matrix aligns with internationally recognized standards to ensure scientific validity (Table 1). Crucially, the framework accounts for cross-dimensional interactions—for instance, vertical elevator shafts simultaneously alter wind patterns through Venturi effects while creating acoustic reflection surfaces that amplify noise propagation. This multi-physics approach ensures comprehensive evaluation of how micro-morphological changes from elevator additions cascade through coupled environmental systems. Therefore, this study mainly adopts the method of simulation analysis, and the research flow is shown in Figure 2.

Table 1. Microclimate parameter selection matrix.

Environmental Dimension	Core Parameters	Selection Basis	Interaction Mechanisms
Thermal environment	Urban heat island intensity	Design Standard for Thermal Environment of Urban Residential Areas (JGJ 286-2013)	Shading effects reduce longwave radiation
Light environment	Horizontal irradiance	Design Standard for Thermal Environment of Urban Residential Areas (JGJ 286-2013)	Vertical structures block direct radiation
Wind environment	1.5 m Height wind speed, pressure difference	Assessment Standard for Green Building (GB/T 50378-2019)	Corridor structures generate Venturi effects
Acoustic environment	A-weighted sound pressure level	Environmental Quality Standard for Noise (GB 3096-2008)	Elevator shaft reflections amplify traffic noise

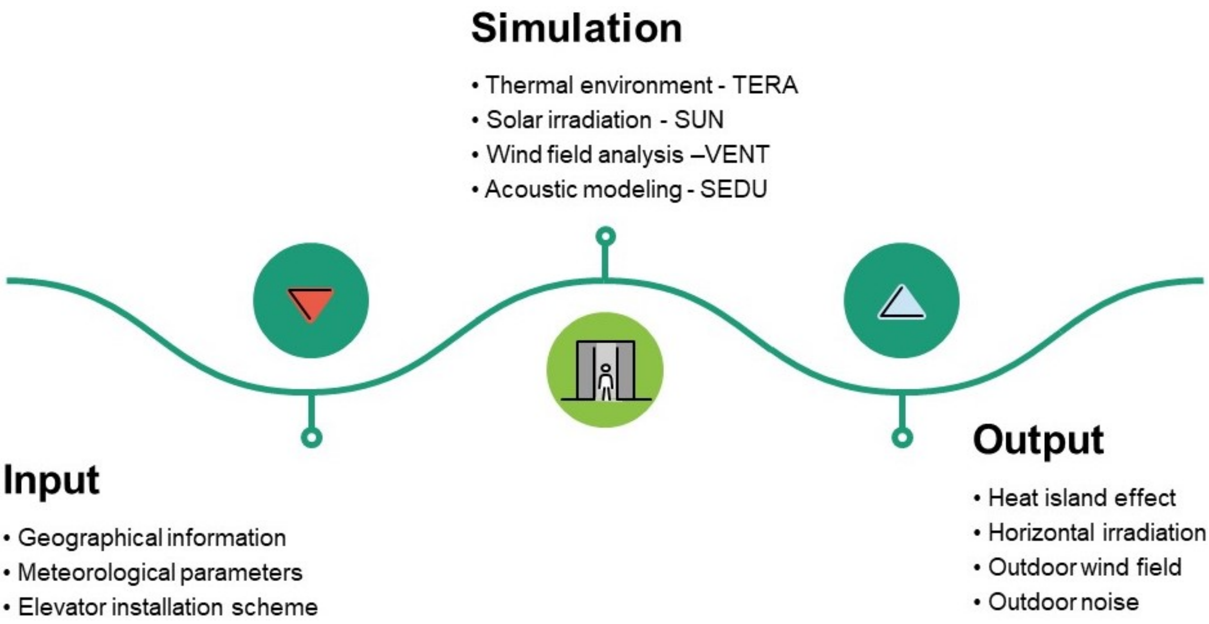

Figure 2. Research flow.

2.1. Research Site

The research site is a residential area located in Chengdu, China (104.000591 N, 30.613936 E). This complex, constructed in 2005, occupies an area of approximately 90000 m^2 and consists several six-story residential buildings without elevators (Figure 3). As the aging of the complex has become increasingly evident, residents frequently express difficulties in mobility. Consequently, the complex planned to add 40 elevators to address the issue of the access between floors. By September 2024, 12 elevators have been installed, 9 more are in the process of installation, and an additional 19 are expected to be installed.

Chengdu has a subtropical humid monsoon climate, characterized by abundant heat, ample rainfall, and distinct seasons. The average annual temperature is around 16 °C, with the highest temperatures generally not exceeding 35 °C during summer, although they can reach up to 37 °C in extreme cases. Winters are mild with average temperatures above 5 °C, but they are often damp and chilly due to frequent cloudy days [32].

The climatic conditions at the research site exhibit distinct seasonal variations (Figure 4). T_a ranges from a minimum of 4.53 °C in January to a maximum of 26.41 °C in July, reflecting a warm summer and cold winter pattern. *RH* remains relatively high throughout the year, with values fluctuating between 65.63% in May and 81.73% in September, indicating a generally humid environment. The wind speed (V_w) varies moderately, with the lowest average speed of 2.03 m/s in October and the highest of 2.63 m/s in April, suggesting a range of wind conditions throughout the year. Overall, the climate at the research site can be characterized by its seasonal temperature extremes, high humidity, and moderate V_w, which should be considered in planning and conducting research activities.

(**a**) Satellite map of the research site (**b**) Model of the research site

Figure 3. Research site.

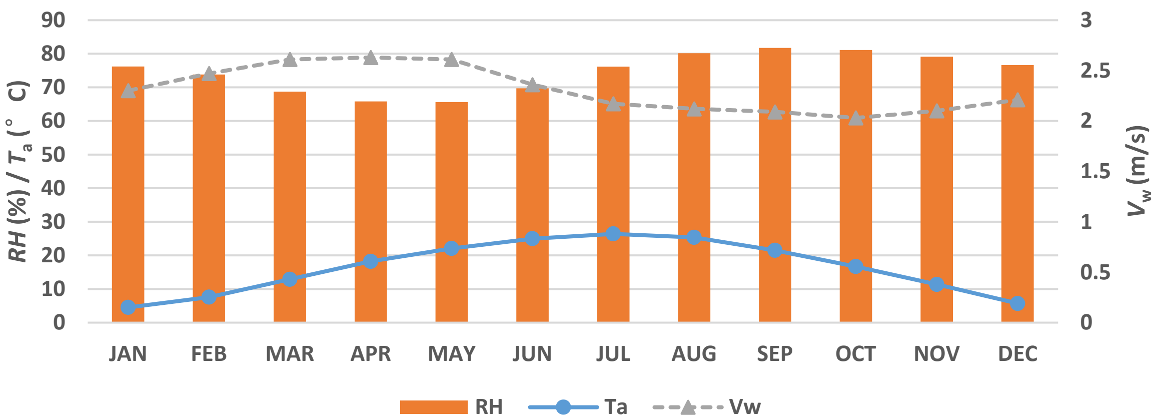

Figure 4. Climatic conditions at the research site.

2.2. Elevator Installation Scheme

The elevator installation in this residential area is divided into three phases. First (current situation), 12 elevators, one for each unit, have been installed in the two bar-shaped buildings located at the northwest and southeast ends. Second (short-term plan), an additional 9 elevators will be installed in the two bar-shaped buildings on the northeast side, bringing the total number of elevators installed in the area to 21. Third (long-term plan), elevators are planned to be installed in all eligible units, with the total number of elevators installed internally reaching 40. (Note: Due to the existing building spacing constraints, it is not feasible to install elevators outdoors for a small number of units.)

In terms of building structure, the specific installation scheme is shown in Figure 5. Specifically, a glass elevator shaft with dimensions of 1.50 m × 2.10 m × 19.05 m is added 3.90 m away outside the unit entrance. The elevator shaft is connected to the building through an enclosed corridor, and the corridor is stilted (stilt height = 5.4 m).

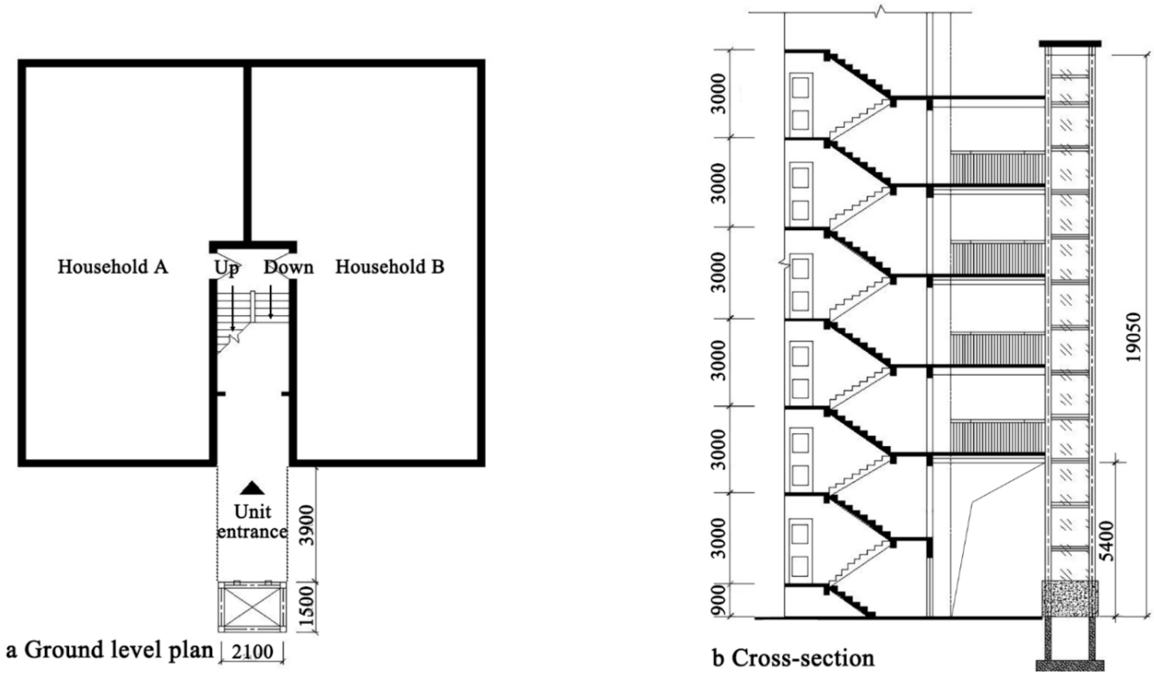

Figure 5. Installation scheme.

2.3. Scenario Settings

In this study, it is assumed that variation of three-dimensional urban morphology (adding elevators outside existed buildings) was going to influence outdoor microclimate. Due to the old age, high density, and enclosed layout of the residential area, the microclimate within the research site is relatively insensitive to environmental conditions outside. Therefore, this study only modeled the high-rise and multi-story residential buildings within the community (Figure 3b). Four scenarios were set to verify these effects in GBSware (TERA, SUN, VENT, and SEDU), including scenario A, a blank control (Figure 6a); scenario B, the current situation (Figure 6b); scenario C, the short-term plan (Figure 6c); and scenario D, the long-term plan (Figure 6d).

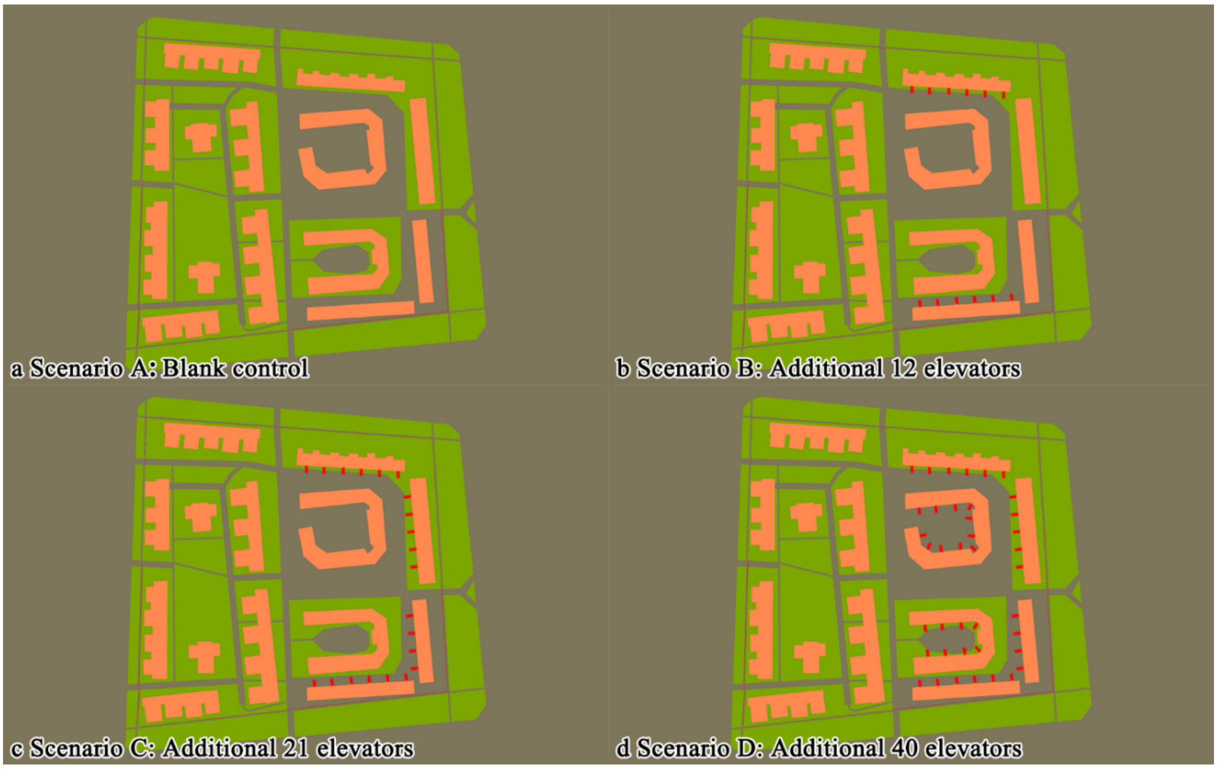

Figure 6. Scenario settings.

2.4. Simulation Equations and Parameters

2.4.1. Thermal Environment

The simulation parameters in this study were set in accordance with the requirements outlined in the Design Standard for Thermal Environment of Urban Residential Areas (JGJ 286-2013), an industry standard of China. The meteorological parameters for typical meteorological days are presented in Table 2.

Table 2. Meteorological parameters for typical meteorological days.

Hour	Dry-Bulb Temperature (°C)	*RH* (%)	Horizontal Total Irradiance (W/m²)	Horizontal Scattered Irradiance (W/m²)	V_w (m/s)	Predominant Wind Direction
0:00	24.3	91	0.00	0.00	0.9	
1:00	23.5	93	0.00	0.00	1.0	
2:00	23.3	93	0.00	0.00	1.0	
3:00	22.9	94	0.00	0.00	0.9	
4:00	22.7	94	0.00	0.00	0.9	
5:00	22.5	95	0.00	0.00	0.9	
6:00	22.4	95	0.00	0.00	0.9	
7:00	22.5	95	7.77	7.77	0.9	
8:00	22.9	93	74.37	66.60	0.9	
9:00	23.8	89	200.91	164.28	1.1	
10:00	24.8	85	348.54	241.98	1.3	
11:00	25.8	80	476.19	309.69	1.5	
12:00	26.6	77	541.68	355.20	1.7	North by northwest
13:00	27.2	75	521.70	380.73	1.8	
14:00	27.6	73	475.08	377.40	1.9	
15:00	27.9	72	399.60	334.11	2.0	
16:00	28.1	72	301.92	256.41	2.0	
17:00	27.9	73	209.79	179.82	1.9	
18:00	27.5	76	98.79	89.91	1.8	
19:00	26.8	79	15.54	14.43	1.5	
20:00	26.0	83	0.00	0.00	1.2	
21:00	25.3	87	0.00	0.00	1.1	
22:00	24.7	89	0.00	0.00	1.0	
23:00	24.7	89	0.00	0.00	1.0	
Daily average	25.1	85	152.99	115.76	1.3	

The hourly evaporation rates of permeable surfaces during summer, which are necessary for the calculations, are shown in Table 3.

Table 3. Hourly evaporation rates of permeable surfaces during summer [kg/(m²·h)].

Time	Water Surface	Greenbelt	Permeable Hard Ground	Green Roof
0:00	0.09	0.24	0.07	0.19
1:00	0.10	0.19	0.06	0.15
2:00	0.08	0.15	0.06	0.12
3:00	0.08	0.14	0.05	0.11
4:00	0.09	0.13	0.05	0.11
5:00	0.07	0.16	0.05	0.13
6:00	0.18	0.22	0.08	0.18
7:00	0.34	0.33	0.09	0.26
8:00	0.52	0.43	0.10	0.34
9:00	0.75	0.53	0.10	0.42
10:00	0.89	0.55	0.10	0.44
11:00	1.05	0.54	0.10	0.43
12:00	1.11	0.50	0.09	0.40
13:00	1.03	0.43	0.09	0.35
14:00	0.92	0.34	0.06	0.27
15:00	0.78	0.29	0.04	0.23
16:00	0.60	0.22	0.04	0.17
17:00	0.39	0.16	0.02	0.13
18:00	0.28	0.12	0.02	0.09
19:00	0.20	0.10	0.01	0.08
20:00	0.15	0.07	0.01	0.06
21:00	0.14	0.07	0.00	0.05
22:00	0.11	0.07	0.01	0.05
23:00	0.11	0.05	0.00	0.04
Daily total	10.06	6.03	1.30	4.80

2.4.2. Light Environment

The parameters for this residential area were calculated using TERA, a residential thermal environment simulation software, as shown in Table 4.

Table 4. Parameters for the research site.

Parameter	Value
Average surface solar radiation absorption coefficient	0.78
Roughness coefficient of ground	0.22
Community thermal time constant (h)	12.04
Average sky angle coefficient	0.52

2.4.3. Wind Environment

Prior to this simulation, the geographical information parameters were configured in the VENT software v. 2020. Based on the building volumes of the model, the software automatically generated the wind flow computational domain, with dimensions of 542 m in the along-wind direction, 495 m in the cross-wind direction, and 133 m in the vertical direction. Regarding mesh generation, for the regular grid (excluding the areas near the ground and buildings), no special refinement was applied [33]. However, the ground grid in the vicinity of the buildings required densification. Additionally, the boundary layer mesh was subjected to layered refinement (Table 5).

Table 5. Winter grid division information.

Total Number of Grids	Grid Type	Grid Size	
746,827	Regular grid	Arc division precision (m)	0.24
		Initial grid (m)	8.0
		Minimum subdivision level	1
		Maximum subdivision level	2
	Ground grid	Far-field subdivision level	1
		Near-field subdivision level	2
	Boundary layer	Number of ground boundary layers	2
		Number of building boundary layers	0

In this project, the inlet boundary conditions mainly include V_w and direction data under different operating conditions, among which the inlet V_w adopts the gradient wind shown in Equation (1), where v and Z are the average wind speed (m/s) and height (m) at any point, respectively; v_R is the average wind speed (m/s) at the standard height; Z_R is the standard height value (m); and a is the ground roughness index. According to the "Load Code for the Design of Building Structure" (GB 50009-2012), Z_R = 10 m. And according to the requirements of the "Technical Guidelines for Green Building Assessment" and "The Standard for Measurement and Evaluation for Efficiency of Building Ventilation" (JGJ/T 3099-2013), a ground roughness index of 0.28 is adopted for the center of a large city; the V_w is set at 1.90 m/s, with a wind direction of northeast.

$$v = v_R \left(\frac{Z}{Z_R}\right)^a \tag{1}$$

The wind speed amplification factor (v') reflects the amplification effect of high-rise buildings on wind speed, usually referring to the ratio of the maximum V_w at a height of 1.5 m above the ground around the building to the V_w at the same height in open areas. In Equations (2) and (3), $v_{1.5B}$ is the maximum V_w around the building at a height of 1.5 m above the ground; $v_{1.5f}$ is the wind speed at a height of 1.5 m from the ground in an open area away from buildings; and v_{10f} is the wind speed at a height of 10 m from the ground in an open area away from buildings, which is taken as the boundary V_w at the entrance of the outdoor wind field.

$$v' = \frac{v_{1.5B}}{v_{1.5f}} \tag{2}$$

$$v_{1.5f} = v_{10f} \left(\frac{1.5}{10}\right)^a \tag{3}$$

2.4.3. Acoustic Environment

According to the Chinese national Environmental Quality Standard for Noise (GB 3096-2008), the ambient noise level in areas requiring quiet, such as residential areas, is set at 55 dB during daytime (06:00–22:00) and 45 dB during nighttime (22:00–06:00). In this work, SEDU, a software used for noise calculation, assessment, and prediction, was employed to simulate and calculate the noise levels during both daytime and nighttime. This includes the distribution of sound pressure levels at a height of 1.5 m above the ground and in the vicinity of buildings. The establishment of the model primarily considers horizontal road noise sources, vertical noise sources from stairwells, and the noise barrier effect of greenery surrounding the residential area. The noise sources involved in the calculations for this project are presented in Table 6.

Table 6. Noise sources.

Road Noise Sources								
			Small-Sized Vehicle		Middle-Sized Vehicle		Large-Sized Vehicle	
Road Material	**Design Speed**	**Period**	**Hourly Flowrate**	**A-Weighted Sound Level at 7.5 m**	**Hourly Flowrate**	**A-Weighted Sound Level at 7.5 m**	**Hourly Flowrate**	**A-Weighted Sound Level at 7.5 m**
Asphalt concrete	20 km/h	Daytime	500	54 dB	50	53 dB	0	62 dB
		Nighttime	100	55 dB	20	52 dB	0	61 dB
Vertical plane sound sources (elevator)								
Height		A-weighted sound level when operated						
19.05 m		50 dB						

3. Results

3.1. Heat Island Effect

According to JGJ 286, the simulation of heat island intensity was conducted from 9:00 to 19:00 on a typical summer meteorological day. Specifically, the results indicate that the average heat island intensities for scenarios A to D are −0.38, −0.47, −0.54, and −0.67 °C, respectively. The residential area experiences cooler summers compared to the core areas of large cities like Chengdu, primarily due to its relatively low building heights (6 and 11 stories) and good ground greening. More importantly, the addition of elevator shafts has further contributed to reducing urban heat island intensity by providing additional shaded environments, without encroaching upon existing public green spaces. This combination of factors has led to a significant reduction in the urban heat island effect within the area. With the number of elevators installed increases, this phenomenon of reducing the heat island effect becomes even more pronounced. Additionally, by comparing specific data, it is evident that scenario D, with 40 additional elevators, experiences lower solar radiation-induced temperature rises and smaller long-wave radiation cooling amplitudes, while the evaporative heat transfer cooling remains unchanged. Combined, these effects result in a slightly greater reduction in residential area temperatures compared to typical meteorological temperatures (Figure 7).

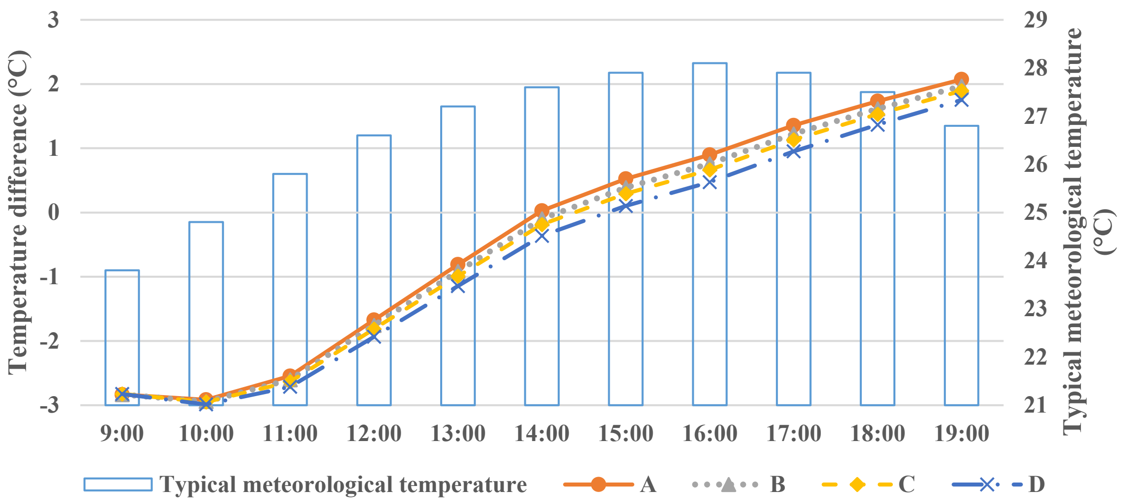

Figure 7. Differences between residential area temperatures in different scenarios and the typical meteorological temperature (°C).

3.2. Horizontal Irradiation

Adopting SUN v. 2020, an architectural solar analysis software, simulations were conducted for the four scenarios. The results indicate that the unobstructed horizontal irradiance on the ground in the research site is 13,319.52 KJ/(m^2·d) during summer (1 June to 31 August) and 4612.10 KJ/(m^2·d) during winter (1 December to 28 February). Comparing the most contrasting scenarios, A and D (Figure 8), the following results are obtained. During summer, first, the installation of elevators not only negatively impacts the sunlight exposure of the multi-story buildings where they are located but also reduces the horizontal irradiance of nearby building clusters (in this case, the high-rise cluster) by approximately 10% (Point ① in Figure 8b). Second, for the individual buildings with an elevator installed, the impact is almost confined to the facade where the elevator is located, although in fewer cases, it still affects other facades (Point ② in Figure 8b). Third, compared to installing an elevator on the south facade of a building, installing it on the north facade has a greater impact on sunlight exposure, significantly reducing the irradiance coefficient of north-facing rooms that already have poor lighting (by approximately 20%, Point ③ in Figure 8b). Fourth, installing elevators on the east or west facades has a relatively smaller negative impact on building sunlight exposure (Point ④s in Figure 8b). While, during winter, the installation of elevators on any facade has minimal impact on building sunlight exposure.

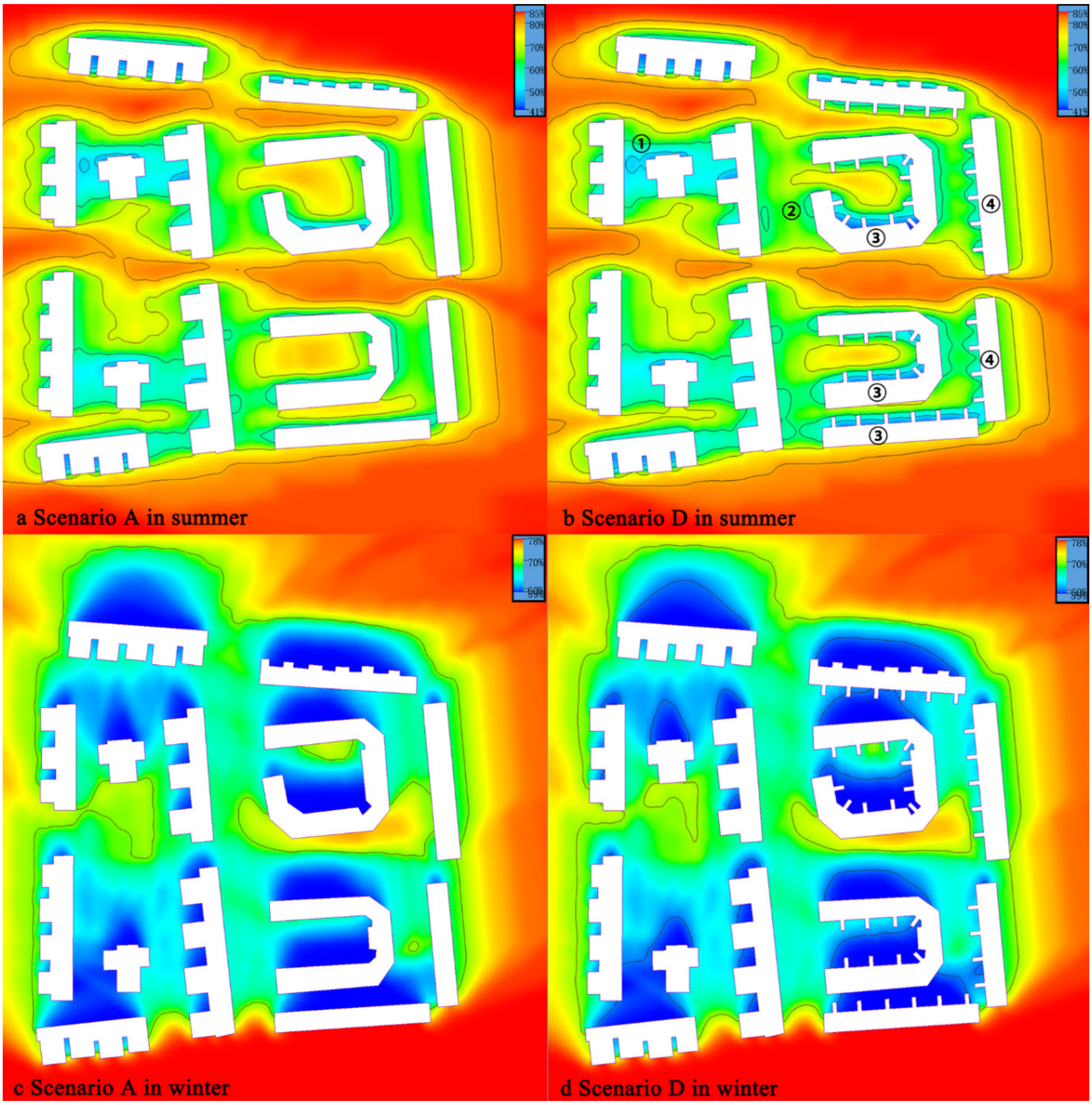

Figure 8. Horizontal irradiation under senarios A and D in summer and winter.

3.3. Outdoor Wind Field

According to the Assessment Standard for Green Building (GB/T 50378-2019), the outdoor wind environment should support comfortable pedestrian activities and natural building ventilation, with stricter wintertime requirements. To systematically evaluate the impact of elevator shaft installation on the residential area's winter wind field, this study employs VENT v. 2020, a CFD software, to simulate scenarios A and D, focusing on three interrelated indicators: V_w, wind pressure distribution, and v'. Key findings from the outdoor wind field simulation are listed as follows.

First, V_w performance. Simulation for the residential area shows that the maximum V_w at a height of 1.5 m above the ground in winter under scenarios A and D is 2.38 m/s and 2.33 m/s, respectively. These values are both complies with the requirement in GB/T 50378 that the V_w in pedestrian areas around buildings should be less than 5 m/s (Figure 9). Furthermore, it is evident that the installation of the elevator shafts has little impact on the overall winter V_w in the residential area and may even have a certain enhancing effect.

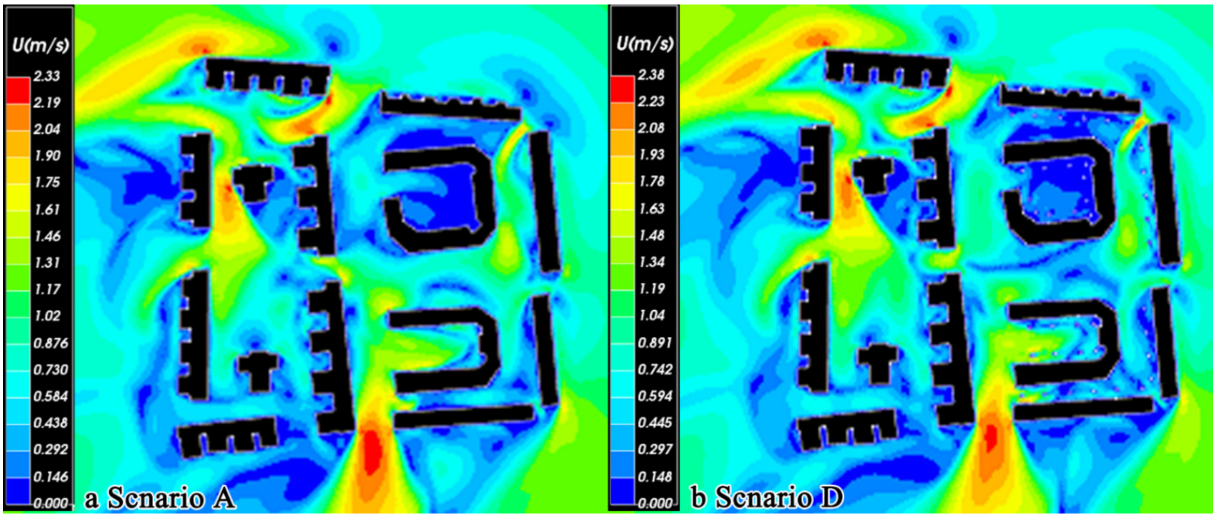

Figure 9. Maximum V_w at a height of 1.5 m in winter under senarios A and D.

Second, wind pressure distribution. The simulation of wind pressure on the windward and leeward sides of buildings in the residential area (Figure 10) shows that, under Scenarios A and D, the average wind pressure difference is 0.85 Pa and 0.14 Pa between the windward and leeward sides, which both complies with GB/T 50378 that the wind pressure difference between the windward and leeward surfaces of a building should not exceed 5.00 Pa. Furthermore, it is apparent that the installation of elevator shafts may exert a positive influence on the wind pressure difference.

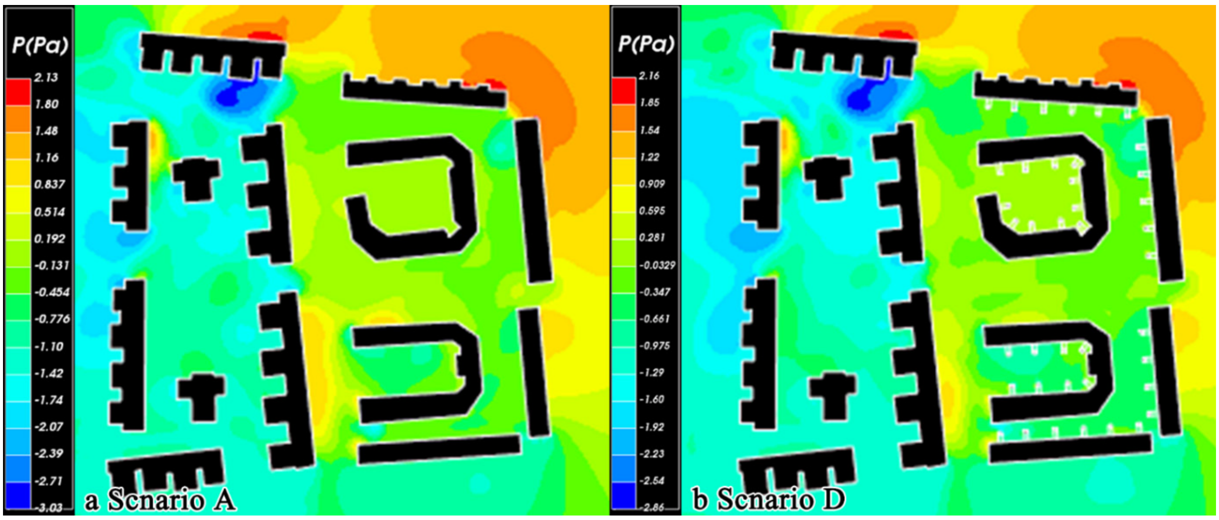

Figure 10. Wind pressure on the windward and leeward sides of buildings in winter under senarios A and D.

Third, v'. The simulation of the v' in the residential area reveals that, under scenarios A, there are localized areas in the central part of the southern side of the residential area where the v' at a height of 1.5 m reaches 2.13 (red areas in Figure 11), which does not meet the requirement in GB/T 50378 that the outdoor v' should be less than 2. However, this factor decreases to 2.09 in scenario D. Although this factor still does not meet the requirements of the current standard for an old residential area, it represents a certain degree of improvement.

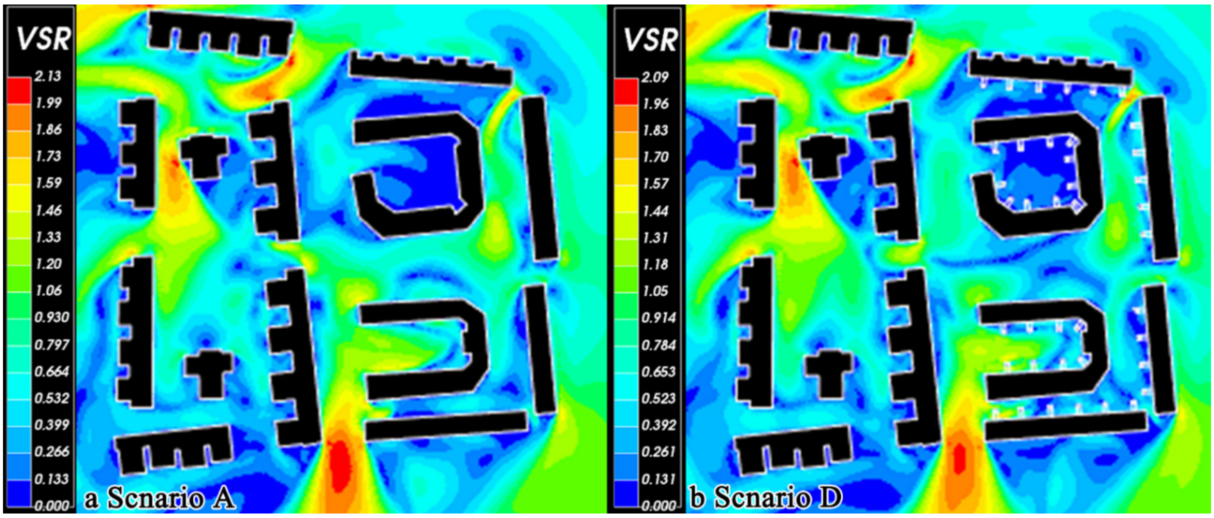

Figure 11. at a height of 1.5 m in winter under senarios A and D.

According to the simulation, the installation of elevator shafts presents a dual effect: while maintaining acceptable V_w and improving pressure distribution, localized wind amplification remains a concern. These findings suggest elevator design should prioritize aerodynamic configurations to minimize speed amplification in critical zones, particularly in residential areas with pedestrian activity requirements.

3.4. Outdoor Noise

A comparison of the simulated results of sound pressure level distributions at 1.50 m for scenarios A and D reveals several key points (Figure 12). First, the introduction of elevators significantly impacts the outdoor acoustic environment during their operation, with an increase of 10–25 dB in A-weighted sound levels. Second, the noise distribution is not uniform around each elevator; instead, there is a general trend of more pronounced noise increase along the roadway, while the interior of the residential area experiences a relatively smaller increase. Third, the areas affected by elevator noise are largely confined to the façades where elevators have been installed, with minimal impact on the opposite rear façades and surrounding areas (such as the high-rise zone). Fourth, these trends persist during both daytime and nighttime, with the effects being more pronounced at night.

Simulations of sound pressure level distributions in the vicinity of buildings also indicate that elevators have a significant impact on the sound pressure levels almost exclusively on the façade where they are located, particularly affecting residents on the first and second floors (Figure 13). This impact is present during both daytime and nighttime when the elevators are in operation, with no significant difference in the degree of impact between the two periods.

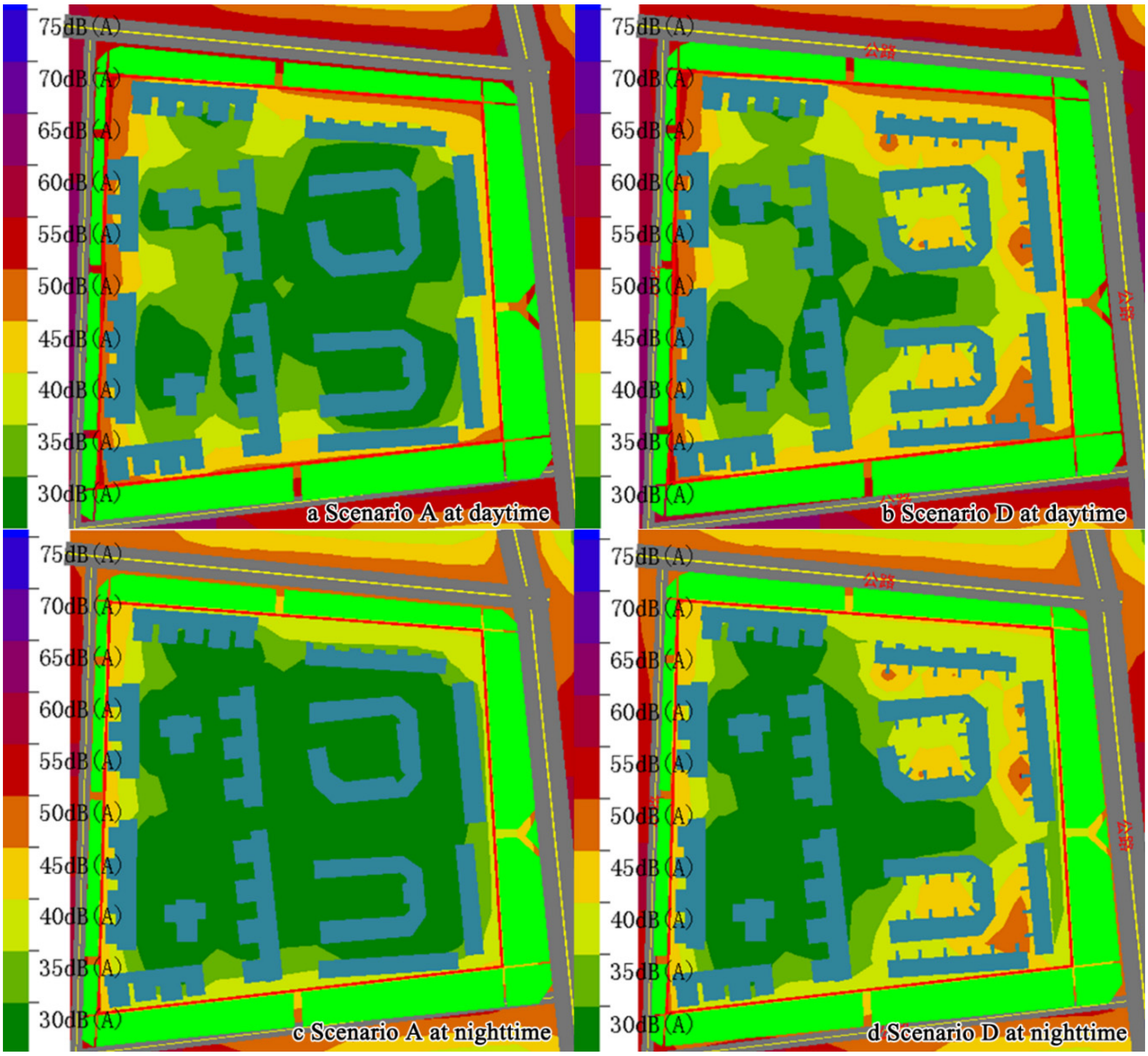

Figure 12. Sound pressure level distributions at 1.50 m under senarios A and D.

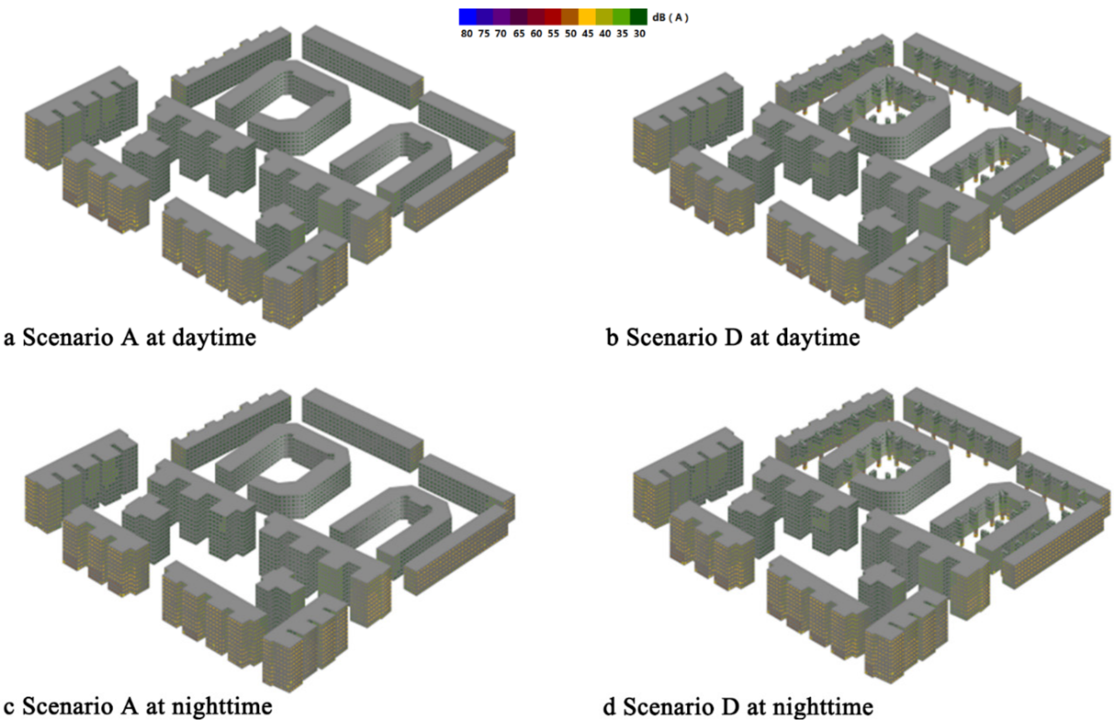

Figure 13. Sound pressure level distributions in the vicinity of buildings under senarios A and D.

4. Discussion

4.1. Discussion on the Simulation Results

Taking a residential area in China as the case study, this study investigated the hidden impacts of elevator addition on community microclimate. By simulating various scenarios of elevator installation using GBSware software v. 2020, this work analyzed the changes in key microclimate indicators such as heat island effect, horizontal irradiation, outdoor wind field, and outdoor noise. The findings provide valuable insights into the sustainable planning and design of aging-friendly urban environments.

First, regarding the heat island effect, simulations revealed that the addition of elevators led to a reduction in the urban heat island intensity. This was particularly evident in scenario D, where 40 elevators were installed, which experienced the lowest heat island intensity among all scenarios. This result contradicts the initial hypothesis that elevator addition exacerbates the heat island effect. Instead, the installation of elevators reduced urban heat island intensity through shading effects and preserving green spaces (without encroachment on existing vegetation).

Second, with respect to solar energy utilization, the results indicated that the installation of elevators significantly reduced the sunlight exposure of the buildings where they were located. This negative impact was confined primarily to the facades where the elevators were installed, with a greater reduction observed for elevators on north-facing facades. While this confirms our hypothesis that elevator addition has a negative impact on solar energy utilization, the magnitude of this impact was localized and did not extend to surrounding buildings or facades.

Third, concerning the outdoor wind field, the simulations showed that the installation of elevator shafts had little impact on the overall V_w within the residential area. In fact, there was a slight enhancing effect on V_w, as indicated by the reduced v' in scenario D compared to scenario A. This finding contradicts the hypothesis that elevator addition has a negative impact on the outdoor wind environment. The open spaces at the base of the connecting corridors between the elevator shafts and the main building did not significantly alter the existing natural ventilation conditions.

Last, with regard to the outdoor sound environment, simulation results confirmed the hypothesis that elevator addition has a negative impact on acoustic comfort. The operation of elevators significantly increased sound pressure levels in the vicinity of the buildings where they were installed, with an increase of 10–25 dB in A-weighted sound levels. This impact was more pronounced at night and primarily affected the first and second floors of the buildings. The noise distribution was not uniform around each elevator, with higher noise levels observed along roadways.

4.2. Discussion on the Installation Location of Elevators

Although this study primarily focuses on the impact of the number of installed elevators on the microclimate, it also reveals that the installation location influences indoor and outdoor environmental factors such as heat, wind, and light (Table 7).

Table 7. Comparison of the impact of different installation modes.

Bridge Form	Thermal Impact	Ventilation Impact	Lighting Impact	Typical Applicable Scenarios
Enclosed bridge	High (due to heat accumulation in summer)	Horizontal corridors hinder airflow at the ground level	Significant shading at lower floors	Cold regions requiring winter insulation
Open bridge	Low (when combined with greenery design)	Forms a vertical air shaft, promoting stack ventilation	Significant shading at lower floors	Warmer regions requiring dehumidification

In terms of the thermal environment, enclosed elevator bridges are prone to forming heat accumulation cavities. For instance, in Tianjin, the internal temperature of a certain corridor under summer solar radiation was found to be 5–8 °C higher than the external temperature [34]. Glass curtain wall elevator shafts are even more susceptible to heat accumulation due to the greenhouse effect, with shaft temperatures potentially exceeding 50 °C in summer, far surpassing the safety threshold for equipment [35]. To mitigate the risk of exacerbating local thermal conditions, several strategies can be adopted. Applying high-reflectivity exterior wall coatings, such as light-colored aluminum panels, can effectively reduce surface temperatures [36]. Installing openable vents at the top of elevator shafts, combined with mechanical exhaust systems, can facilitate efficient heat dissipation [37].

Additionally, planting climbing plants (e.g., ivy) around the elevator base can help lower the surrounding air temperature [38–40].

As newly added vertical structures, elevator shafts can potentially alter the wind field distribution of existing building clusters, and the type of elevator shaft arrangement significantly impacts wind loads and displacement responses. For example, when an elevator is located on the windward side of a building and connected to the main structure via an enclosed corridor, it may create localized wind resistance, reducing V_w in lower-level areas and thereby decreasing ventilation efficiency [41]. Conversely, if the elevator is connected to the main structure via an open corridor, the gap between the shaft and the building can form a wind passage, promoting air circulation [42]. Furthermore, existing research on the correlation between building density and V_w indicates that when building density ranges from 0.35 to 0.50, the cooling effect of vegetation and the ventilation of elevator shafts can work synergistically [43].

The installation of elevators often leads to the obstruction of windows for lower-floor residents, particularly in the case of east-west oriented corridor-style elevators, which may cause all-day shadow coverage. Subjective surveys reveal that 75% of respondents believe that elevators significantly reduce indoor daylighting, with lower-floor residents being the most severely affected [44]. Objective practices in Nanjing have also demonstrated that due to some elevator shafts being only 1.5 m away from the original buildings, daylighting hours at the ground level were reduced by up to 40% [45]. To address this issue, parametric design can be employed to optimize the positioning of elevator shafts, thereby improving daylighting parameters such as the daylight uniformity index [46]. Moreover, the use of translucent materials or the installation of light tube systems [47] can minimize the obstruction caused by elevator shafts to the building without altering its structure, or improve the lighting conditions in shaded areas.

5. Conclusions

In conclusion, this study provides a comprehensive analysis of the hidden impacts of elevator addition on the community microclimate. While some of our initial hypotheses were supported, such as the negative impact on solar energy utilization and acoustic comfort, others were contradicted by the simulation results. Notably, the addition of elevators had a cooling effect on the urban heat island intensity and had minimal negative impacts on the outdoor wind environment. These findings underscore the importance of conducting thorough assessments when planning urban modifications, particularly in the context of aging-friendly urban environments. The insights gained from this study can inform future sustainable urban planning and design efforts.

This study acknowledges several limitations inherent to the methodology and computational framework. First, the independence of simulations across different GBSware modules may introduce uncertainties when modeling multi-physics interactions, as the software inherently treats thermal, radiative, wind, and acoustic fields as decoupled processes without explicit cross-domain feedback mechanisms. While GBSware demonstrates robust performance in standalone analyses, its current architecture does not fully support coupled simulations of concurrent physical phenomena, such as thermal-structural interactions in elevator shafts or dynamic wind-sound propagation effects, which may influence microclimate outcomes. Second, the software's computational constraints, particularly in handling high-density urban morphology modifications, align with documented limitations in CFD grid resolution thresholds when addressing complex geometries like multi-story elevator attachments. Third, parameterization assumptions in GBSware's material databases and meteorological input processing—while compliant with Chinese industry standards—may oversimplify transient thermal behaviors of glass-enclosed elevator shafts and localized turbulence patterns. Finally, the validation scope was restricted to module-specific performance metrics rather than holistic system verification, a common challenge in parametric urban microclimate studies using segmented simulation workflow. These limitations highlight the need for future integration of coupled physics modeling frameworks and high-resolution urban datasets to enhance simulation fidelity.

Additionally, although this study has elucidated, through multi-scenario simulations, the single-factor impact patterns of elevator retrofitting on microclimates, it has not yet delved deeply into the synergistic mechanisms among multiple influencing factors. Future research can build upon the simulation dataset from this study and further undertake the following tasks: First, construct multivariate statistical models to quantify the relationships between the number of elevators and key microclimatic factors such as heat island intensity, horizontal irradiance, wind speed, and noise levels. Second, employ a spatially stratified sampling design to compare the heterogeneities in the comprehensive impacts of elevator installation at different locations on the microclimate. Third, introduce sensitivity analysis methods to identify the most effective installation density thresholds for improving the microclimate. Finally, develop structural equation models to unveil the direct and indirect interaction pathways among these multiple factors. By supplementing the research with the statistical methodologies, future work may comprehensively evaluate the environmental benefit boundaries of elevator retrofitting as a means of urban micro-renewal, thereby providing a scientific basis for refined and informed design strategies.

Author Contributions

Conceptualization, D.D.; methodology, D.D.; software, D.D.; validation, D.D.; formal analysis, D.D. and M.X.; investigation, H.W., M.X., and D.D.; resources, H.W.; data curation, D.D.; writing—original draft preparation, D.D.; writing—review and editing, D.D., and M.X.; visualization, D.D.; supervision, D.D. and H.W.; project administration, H.W. and D. D.; funding acquisition, D.D. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

The data that support the findings of this study are available from the corresponding author, Ding Ding, upon reasonable request.

Conflicts of Interest

The authors declare no competing interests.

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