

Article

Enhancing Urban Landscapes through Underground Space Utilization: Public Perceptions

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Abstract: Landscape occupation and green space reduction have decreased livability and hindered the sustainable development of cities. The urban landscape affects the quality of life and physical and mental state of the public, and urban underground space utilization is important for improving the urban landscape. Therefore, underground space utilization must be explored from a public perspective. Referring to typical underground municipal, transportation, and public space projects, an online questionnaire survey of 377 Nanjing residents was performed to construct a structural equation model investigating their perceptions and preferences regarding underground space usage to improve the landscape, focusing on the links between their preferences and opinions. Underground works that provide diverse open spaces were considered to have the most positive impact on the landscape (82.8%). The aesthetic value of the surface landscape (83.5%) and the vitality of historical sites (82.1%) were the most significantly affected, whereas stock underground space had no significant effect on landscape protection. In terms of age, profession, and place of work, the respondents demonstrated heterogeneous preferences. These findings indicate that targeted publicity and public participation are important to strengthen the cooperative utilization of space and realize the potential of the underground space, helping address actual requirements and develop sustainable cities.

Keywords: underground space; urban landscape; public view; structural equation model



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1. Introduction

With the acceleration of urbanization and the growth of the urban population, cities are increasingly facing the problems of limited land resources and tight development spaces. Simultaneously, the public is becoming increasingly aware of the negative impacts of the demand for urban development space on the landscape, such as the reduction in green space, the destruction of cultural heritage, and changes in urban appearance [1]. These trends have significantly affected the urban ecological environment and the overall sustainable development of cities. Consequently, the need for a new development path is becoming urgent [2–4]. Urban landscapes face unique issues such as discontinuity, diminishing local characteristics, space limitations, and a lack of modern facilities [5,6]. Urban renewal enhances the value, attractiveness, and landscape environment of city areas targeted for replanning and redevelopment [7,8]. During the urban renewal process, a balance must be struck among historical preservation, urban development, and environmental protection to retain cultural heritage and natural beauty [9–11]. The space limitations in urban renewal districts represent particularly critical aspects of sustainable development [12–15]. Consequently, researchers, urban planners, and policymakers are increasingly realizing that the development and utilization of underground space is essential to expand the available urban space effectively while promoting the sustainable development of cities. People have long utilized the underground environment to enhance human health (e.g., through sewage and wastewater removal), deliver vital services (e.g.,

water and utilities), provide climate or security isolation and containment, reduce construction and energy costs, improve transportation and traffic efficiency, and achieve various aesthetic benefits. The subsurface has functions that contribute to healthy, adaptive, and livable areas. By placing our research within a global framework, we found that underground space use is linked to the Sustainable Development Goals (SDGs) [16] of reducing urban problems, promoting sustainable urban development, and protecting and restoring ecosystems, demonstrating its importance to global sustainable development. The New Urban Agenda and the Sustainable Development Goal 11 of the United Nations signify that sustainable development should be involved in urban renewal initiatives. The criteria and application of urban development strategies are key factors in ensuring sustainable urban development. This involves developing and implementing a range of policies and programs to promote rational development within cities, including but not limited to land use, transportation planning, environmental protection, social equity, and economic growth. In China, the Report of the Party's 20th National Congress pointed out that the construction of regional economic zones and territorial spatial planning, including the use of urban underground space as the "fourth land resource", come with complementary advantages and high-quality development. The Ministry of Natural Resources proposed to effectively promote "multi-planning integration" including underground space, which will promote the synchronous development of underground space and the city and alleviate the tension of urban land resources. The Ministry of Housing and Urban-Rural Development issued a number of national standards such as "Urban Underground Space Planning Standards" to guide the scientific, rational, and sustainable development of underground space. Furthermore, transport-oriented development (TOD), as a strategic urban planning approach [17], emphasizes the creation of compact, multifunctional, and sustainable urban communities around transportation hubs. The application of this strategy requires the consideration of numerous factors, including criteria such as the layouts of public transport facilities [18], mixed land use [19], accessibility [20], and walkability [21]. With proper planning and design, TOD can effectively reduce car dependence, improve the utilization of public transportation, reduce carbon emissions, and create a livable urban environment. The latest research results [22,23] further emphasize the importance and application prospects of TOD in sustainable urban development.

The development of underground spaces has the advantage of minimizing the destruction of the natural environment on the surface and can contribute to solving the problems caused by the overcrowding of urban areas. Facilities located entirely in urban underground space (UUS) do not influence the surface landscape and can provide natural surfaces and flora that maintain the natural ecological exchanges of thermal radiation, convection, and moisture. The transfer of the urban road network to the underground space enables the natural environment, with pleasant open green spaces, to penetrate into the city. Further, a fully or partially underground structure has less visual impact than an equivalent surface structure. Thus, the rational use of underground space can improve the quality of the urban landscape, increase the areas of urban green space and public leisure space, etc., while enhancing the living comfort and happiness of urban residents [24–28]. Underground space inherently offers advantages for urban renewal, and employing it to such ends has become a valuable method of restoring urban vitality and enhancing spatial quality [29–32].

As the public is the direct beneficiary of and participates in the city, understanding the attitudes and views of the public on the use of underground space to improve the urban landscape is essential to realizing democratic and sustainable urban planning and can inform plans and policies that are responsive to the needs of the public. Studying the views of the public on the utilization of underground space can provide reference information and guidance for urban renewal and improvement projects, promote innovation and the upgrading of the urban landscape [33,34], and facilitate the diversification [35] and optimization of urban functions [36]. Underground space development in China has made notable achievements, as numerous projects using underground space to improve the

landscape have emerged in large cities. The perceptions of individuals of these benefits are influenced by their socioeconomic backgrounds and the degrees to which they are aware of underground space development, especially in countries such as China [37–39].

Numerous scholars have investigated the impacts of underground space utilization on landscape environments. Several researchers have emphasized the critical role of underground space in maintaining open space and protecting the natural environment and ecosystem [26,40,41]. Other scholars have noted the significance of underground space utilization for the protection of historical and cultural heritage sites on the surface [25,42] and discussed the multi-faceted impacts of underground space on urban renewal [24]. However, no comprehensive and systematic examination of the use of underground space to improve the landscape exists. The view of these impacts by the public and how residents understand their participation in related planning and management is still being studied. To address this research gap, we investigated the views of residents of Nanjing, China on the use of underground space to improve the urban landscape. The primary objectives were to improve the understanding of the views of residents on the use of underground space and their preferences for improving the urban landscape and to reveal the path of influence and mechanism by which public views on urban landscape improvement and urban renewal are developed and expressed. In this manner, we attempted to gain a deeper understanding of the impact of public attitudes toward the use of underground space and to ascertain practical recommendations for urban planners and decision-makers seeking to promote urban renewal and development for the creation of more livable urban environments. Three questions were asked in pursuit of this objective:

1. How aware is the public of the use of underground space to improve the urban landscape?
2. What factors affect the cognition level of the public of underground space utilization and their access to information?
3. How do people perceive the impacts of landscape enhancement on urban renewal under the above-ground and subsurface collaborative development model?

The remainder of this paper is organized as follows. Section 2 presents our conceptual framework and introduces the theoretical framework and conceptual model adopted in detail. Section 3 describes the study area and methods, proposes hypotheses, and introduces the structural models. Section 4 presents our research results in detail, along with an interpretation and analysis of the results to test the research hypothesis. Section 5 provides a detailed discussion and interpretation of the findings, as well as the implications of the findings for existing theory and practice and for urban planning and development. Finally, Section 6 outlines the main conclusions and planning strategies ascertained from our study.

2. Conceptual Framework

Landscapes provide not only aesthetic value but also ecosystem services such as climate regulation, air cleaning, and biodiversity protection. The provision of these ecosystem services is essential for urban renewal and sustainable development. Sustainable development theory emphasizes the balance between economy, society, and environment. A well-designed urban landscape can promote sustainable urban development and provide more options and possibilities for urban renewal. The theory of three-dimensional urban development proposes the downward expansion of limited urban land to realize the reasonable redistribution of urban space and functions and to improve the operational efficiency of urban space. This approach is conducive to the efficient development and utilization of urban space, giving full play to the advantages of urban agglomeration and ensuring sustainable and healthy urban development. Thus, underground space utilization, the urban landscape, and urban renewal are connected by a complex relationship. Environmental psychology research demonstrates that the behaviors and emotions of people are influenced by their surroundings. The design and layout of urban landscapes can influence the moods, behaviors, and social interactions of residents, thereby affecting urban

renewal. The cognition and evaluation of the public regarding urban planning will directly affect its acceptance of the urban environment. Thus, we performed our investigation from the perspective of public perception. Our research concept map [43] is illustrated in Figure 1. Part 1 proposes three driving factors for designing this framework based on previous research and related theories. Part 2 presents our hypotheses regarding the interrelationship between the three factors, as specified in Section 3.4. Part 3 describes the structural equation model (SEM) and measurement model (see Section 3.2). Part 4 uses survey data to validate our previous hypothesis (see Section 3.3).

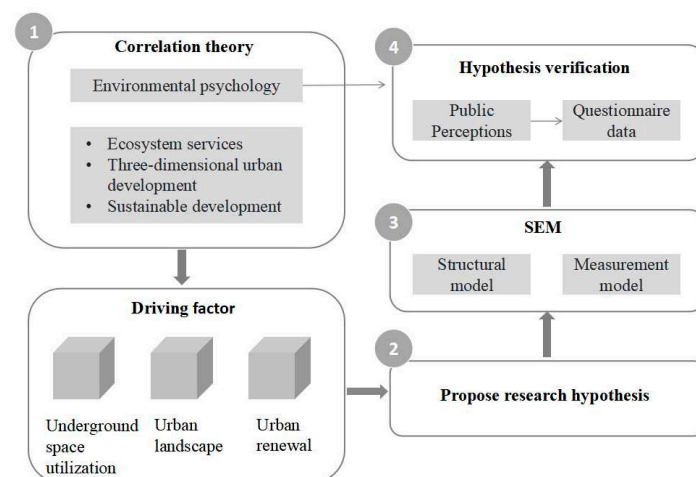


Figure 1. Research concept map.

By studying the development of underground space in urban areas, we determined that underground space can be divided into stock underground space (SUS), which refers to existing subterranean resources that suffer from inefficient utilization or abandonment; incremental underground space (IUS), which refers to previously non-existent subterranean resources generated by the construction or expansion of underground structures, facilities, and equipment; and mixed underground space (MUS), which refers to subterranean resources that are expanded by the renovation of SUS.

Strategies that use underground space to influence the landscape can be classified according to their deployment for conservation or renovation. A conservation strategy entails protecting existing parks, green spaces, and historical sites from destruction to preserve the specific character of a city; such an area is known as a protected landscape (PL). An example of a PL is the underground stratified Helsinki Katri Vala Park, wherein four separate underground developments are stacked on top of one another [44]. Conversely, renovation strategies include upgrading existing low-quality landscapes (e.g., a noisy and chaotic street) and thoughtfully improving the quality of protected landscapes; such a space is known as an improved landscape (IL). Examples of ILs include the Ewha Women's University campus center in South Korea and the "Big Dig" project in Boston [45]. Examples of underground space utilization are classified according to these various categories in Table 1. In practice, several challenges may exist in executing these strategies, especially in densely populated urban areas. First, the use of underground space may affect surrounding communities, including through construction noise, traffic congestion, and environmental changes that may be caused by the updated underground space. Second, the public perception of the use of underground space, as well as the expectations and concerns of the public about how underground space development will improve the landscape, is critical. In addition, the use of underground space needs to be aligned with the sustainable development goals of the city. Thus, when using underground space, considering how to reduce energy consumption, reduce carbon emissions, and improve the overall ecological efficiency of the city is necessary.

Table 1. Review of typical cases using underground space to improve the landscape environment.

Construct	Item	Typical Project	Effect
SUS	SUS1	The abandoned civil air defense transform project under the green belt in Shanghai	Prevention of damage to the green space, the “road zipper” has been closed through transformed comprehensive pipe corridor
	SUS2	Underground parking under the green belt	Prevention of ground space occupation, enabling the ground-level green spaces to continue purifying the air and beautifying the environment
	SUS3	InterContinental Shanghai Alice, an ecological hotel constructed by utilizing a deep quarry pit	Ecological restoration of the site, enabling people to enjoy the natural scenery of the cliffs
	SUS4	Cheonggyecheon in South Korea [46], underground culverts restored and transformed into urban streams	Revival of the historical and cultural ambiance of Seoul and reshaping of its urban public open spaces
IUS	IUS1	Caisson parking garage in the city center	Freeing up ground space for green spaces and plazas by using the corner plots in the city center
	IUS2	Underground stratified development in Katri Vala Park [47]	Feature four completely independent underground venues dedicated to various underground facilities keeping the park’s beautiful scenery intact
	IUS3	Underground extension of Adeje Religious Museum of Spain	Expansion to two and a half times its original size, and a permanent stage and event space have been established
	IUS4	“Big Dig” project in Boston, the original ground was excavated to bury an expressway underground	Integration and enhancement with the urban walking systems, creating comfortable and convenient urban walking spaces
MUS	MUS1	Les Halles, situated in the center of Paris, dismantled its food market to create a leisure pedestrian plaza.	Arrangement of various traffic functions in the underground space beneath the square, construction of a large urban center with interconnected upper and lower levels
	MUS2	The Shanghai World Expo Cultural Park [48]	Creation of a scenic landscape with the interior hollowed out to accommodate a design for 1500 parking spaces
	MUS3	Tokyo Station transformation, expanding its underground space	Creation of metropolitan square and a north–south traffic square on the ground
	MUS4	Renovation of Jiaxing Railway Station, the primary traffic and supporting commercial functions were relocated underground	Allowing for the complete release of the ground area, which was then transformed into a public green space, giving it the appearance of a “railway station in the forest”
PL	PL1	Helsinki underground tunnels	Prevention of the disruption of the existing forest, safeguarding of the natural landscape and vegetation on the surface, and preservation of ecological equilibrium and biodiversity
	PL2	Shanghai Jing’an Sculpture Park underground substation	Full preservation of the original urban green space, enabling people to enjoy its ecological benefits
	PL3	REGULAR Yuanye in Chengdu	Creation of a park-like commercial area dividing the above- and below-ground worlds, with the original natural landscape above ground and a fashionable urban cultural landscape below
	PL4	China Imperial Examination Museum, the only underground museum	Preservation of the historical monuments and streets on the surface to help protect the traditional urban structure and cultural landscape
	PL5	Shanghai Yangshupu Power Plant Heritage Park	Utilizing underground space for the renewal of the cities without disrupting the existing natural and cultural landscapes helps preserve the economic value of the landscape

Table 1. Cont.

Construct	Item	Typical Project	Effect
IL	IL1	Shenzhen Buji underground sewage treatment plant	Freeing up of ground space for the creation of parks and other natural landscapes, providing leisure and entertainment spaces for people to enjoy the beauty of nature and relieve stress
	IL2	Bahçeşehir transfer center in Istanbul	Construction of underground parking lots and transformation of vacant ground spaces into parks, increasing the amount of urban greenery
	IL3	Quzhou Sports Park, the largest soil-covering complex in the world	Creation of high-quality public spaces such as parks and squares on the surface
	IL4	Louvre underground space renovation [49]	Creation of new uses for the underground space while safeguarding the rich heritage of the city
	IL5	Longhuahui in Shanghai, underground street in the historic district	Invigoration of the city, drawing of more tourists, boosting of the value of the surrounding land, and significant contribution to the urban economy
UL	UL1	Integrated landscape planning above ground and below ground can create compact and high-quality public space through multifunctional composite utilization of land resources	
	UL2	Transportation and infrastructure (such as sewage treatment plants) are placed underground, and parks are built above ground, which can lessen the impact on nearby residents and the overall environment	
	UL3	Transportation and infrastructure are placed underground, and the ground floor can form an ideal landscape space that is safe, reliable, and accessible	
US	US1	Develop and utilize underground space, save land resources on the ground, build green ecology such as parks and forests, and realize ecological carbon sink	
	US2	The sunken plaza can improve the lighting and ventilation of the underground space environment and reduce energy consumption	
	US3	The large substation under the Jing'an Sculpture Park in Shanghai is safer, more reliable, high-quality, and efficient, and the expanded power supply capacity ensures the stability and safety of urban electricity consumption	

Note: SUS denotes stock underground space, IUS denotes incremental underground space, MUS denotes mixed underground space, PL denotes protected landscape, IL denotes improved landscape, UL denotes urban livability, and US denotes urban sustainability.

Various projects worldwide have demonstrated the role that urban underground spaces can play in protecting and enhancing urban landscapes. This capability has also been a topic of academic discussion, with researchers emphasizing that the development of underground space offers numerous benefits to the natural environment and social and ecological well-being. The review of practical cases presented in Table 1 reveals that in the process of urban renewal, most projects have planned underground facilities and above-ground landscapes together, as exemplified by the redevelopment of Les Halles [50]. Thus, the transfer of more urban functions underground can free up ground space and thereby create a three-dimensional urban space and landscape texture. According to the theory of three-dimensional urban development [51] within the framework of urban space intensification, our research is aimed at the comprehensive utilization of above- and below-ground space resources to propose the above–below-ground integrated landscape planning model (A-BGILPM). By integrating the urban elements and functions located above and below ground, this model considers the interrelationships and interactions between spaces to achieve cross-level planning and design. Using the A-BGILPM, urban planners can think holistically about urban development and design, thereby realizing the benefits of underground space to provide more functions and services while enhancing urban livability (UL) [45] and urban sustainability (US) [52] to promote the renewal of cities.

3. Study Area and Methods

3.1. Study Area

Given the diversity of underground space development types and the multiple development scenarios involved, covering all projects possible in a single urban area is difficult.

To ensure the sufficient richness and diversity of data, we selected typical landscape and underground space improvement cases as the research objects and conducted a questionnaire survey of Nanjing citizens to obtain extensive response data. Nanjing, which is situated in eastern China, is famous for its rich historical and cultural significance and is renowned for its vibrant urban landscape. As a famous historical and cultural city, Nanjing is among the first urban renewal pilot cities announced by the Ministry of Housing and Urban–Rural Development. Furthermore, as Nanjing has one of the highest levels of underground space construction and is among the more mature cities in China in terms of urbanization, its citizens have a high degree of acceptance and understanding of underground space development and the status quo of the urban landscape. Thus, their responses can be used as a representative sample that reflects universal applicability and ensures the generalization of the questionnaire results. The results of this study will be of general applicability and reference significance to cities with similar historical backgrounds and cultural accumulation, high degrees of underground space development, challenges to sustainable urban development, and relatively mature urbanization processes.

3.2. Data Collection

We developed the questionnaire (File S1) based on a literature review [53,54], case studies, expert interviews, public engagement, and government documents and planning policies. These sources provided us with a wealth of information and insights that helped us design a comprehensive and practical questionnaire. This questionnaire covered four topics: personal information, resident preference for different types of underground space projects to improve the landscape, resident understanding of improving the value of the landscape, and resident cognition of the A-BGILPM to promote urban renewal.

The questions in the questionnaire were based on the different forms of underground space utilization (parking lots, infrastructure, tunnels, and underground culverts) that affect the landscape, as identified in the literature and case studies, and were classified as SUS, IUS, or MUS. Landscape value was primarily considered in terms of ecological [24,45,55], social [30,56,57], and economic [58] factors. Urban renewal outcomes were classified as UL [45,59] or US [60] (Table 1). In the case selection process, we adhered to the principles of relevance, authority, diversity, timeliness, and novelty to ensure that the cases used in the study were credible and comprehensive. The case sources included academic databases (such as Web of Science and Scopus), professional publications (including academic journals and conference papers), government planning reports, and professional websites (such as industry association websites and research institute websites). We selected these cases after sufficient literature research and expert consultation, and they can be used as typical projects in the current study of underground space development. They were utilized to capture complete perspectives, enabling the respondents to complete the surveys quickly and accurately. All parameters were measured on a seven-point Likert scale of agreement/disagreement ranging from “strongly disagree” (1) to “strongly agree” (7) [53,54].

We conducted the web-based questionnaire survey of Nanjing residents through the Questionnaire Star platform in May 2023. Furthermore, we sent several organizations (e.g., universities, research institutions, communities, and government agencies) interview invitations to conduct a preliminary evaluation prior to the survey involving 143 interviewees, which yielded 139 responses. All respondents were screened in advance to ensure that they were proportionally balanced in terms of gender, place of residence, place of work, etc. All subjects gave their informed consent for inclusion before they participated in the study. The Kaiser–Meyer–Olkin (KMO) and Bartlett’s spherical tests were performed on the results, which indicated that the pre-survey questionnaire exhibited suitable validity. Furthermore, the Cronbach’s alpha value confirmed the high reliability of the survey as a measurement tool [61,62]. Finally, the questionnaire was modified by rephrasing several items to improve clarity and redrawing several diagrams to enhance readability based on the preliminary evaluation results and expert review feedback. The revised version of the questionnaire was used to collect the data analyzed in this study. A total of 416 questionnaires were

distributed, of which 377 were determined to be valid. This number meets the requirements for a medium-sized sample, which is considered to comprise at least 200 responses [63].

3.3. Respondent's Personal Information

Analyzing the respondent's personal information illustrated in Table 2 helped us understand the distribution of the sample based on gender, age, occupation, residence, and workplace. Notably, planning and design professionals accounted for 26%, students majoring in planning and design constituted 27%, and non-planning and design professionals represented 47% of the 377 survey respondents. This distribution reflects the level of underground space awareness among the survey participants. Regarding place of residence, 52% of the respondents were from the old town and 48% were from the new city. In terms of the workplace location, 58% of the participants worked in the old town and 42% in the new city.

Table 2. Description of respondents (N = 377).

Statistical Variables	Category	Frequency	Percentage
Gender	Male	176	46.6
	Female	201	53.4
Age	18–25	148	39.2
	26–35	147	38.9
	36–55	72	19
	Above 55	10	2.1
Profession	Planning and design professionals	99	26.8
	Student of planning and design	101	27
	Non-planning and design professionals	177	46.9
Place of residence	Old town	218	57.8
	New city region	159	42.2
Employment region	Old town	197	52.2
	New city region	180	47.7

3.4. Proposed Model

To explore the primary characteristics of and associations among public perceptions of the use of underground space to improve the landscape, we utilized an SEM that systematically and comprehensively examined the impacts of underground space utilization on the landscape environment. As a multivariate statistical model, the SEM can reveal the direct or indirect relationships among the explored and dependent variables and visualize the causal influence path [64]. We proposed an SEM of the relationships among underground space utilization, urban landscape, and urban renewal based on the following hypotheses, as illustrated in Figure 2. The first hypothesis involves the public perception of the relationship between underground space use and the urban landscape. Based on the above discussion, we assume that the public believes that the rational use of SUS/IUS/MUS has positive impacts on landscape protection (H1–H3) and enhancement (H4–H6) and that the rational use of underground space is somewhat related to the design and layout of the urban landscape, which may affect the formation and evolution of this landscape. Underground space utilization affects the urban landscape positively not only in terms of protecting and optimizing the urban landscape but also in terms of social interaction, cultural exchange, and the sustainable development of urban communities. Further, the findings may have implications for urban planning and social development, including the redefinition of public space, the enhancement of community cohesion, and the promotion of urban sustainability. The second hypothesis involves public perceptions of the impacts of urban landscapes on urban renewal. In the case of the comprehensive utilization of above-ground space resources, the design and layout of the urban landscape are related

to urban renewal to a certain extent, which may affect the feasibility and effectiveness of urban renewal. We assume that the public believes that PLs have positive impacts on urban sustainability (H7) and livability (H8) and that ILs have positive impacts on urban livability (H9) and sustainability (H10). This hypothesis emphasizes the importance of integrated planning for urban renewal, not only in terms of underground space and surface landscape integration but also in terms of the inheritance of urban historical and cultural heritage, the diversified development of urban functions, and the reconstruction of community vitality. Further, the findings may have implications for urban renewal and traditional cultural preservation, including holistic thinking related to urban renewal, the balance between historical and cultural preservation and modern functional needs, and the importance of community participation.

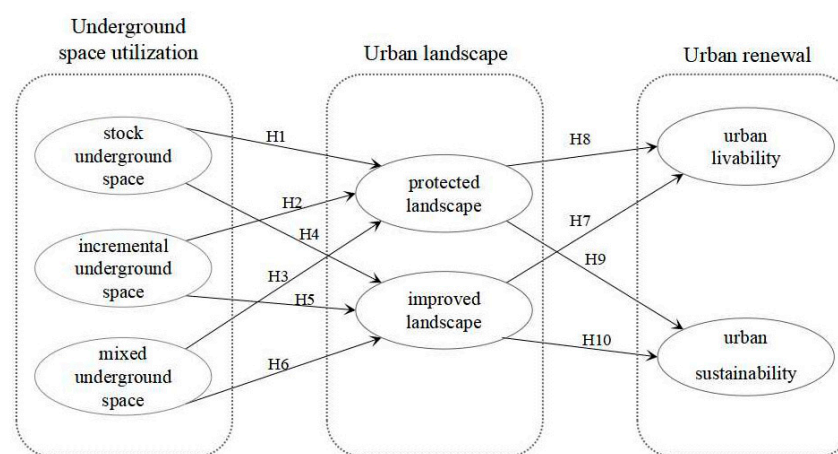


Figure 2. Structural equation model of underground space–urban landscape–urban renewal relationships.

4. Results

4.1. Preference for Using Underground Space to Influence Landscape Value

We counted the projects in the questionnaire with which the respondents strongly agreed and agreed, and the results are presented in Figure 3. Regarding the use of SUS, the respondents felt that the restoration of underground culverts, such as the Cheonggyecheon in Seoul, had the most positive impact on the landscape (SUS4, 83.2%). The restored Cheonggyecheon was transformed into an urban stream that blends the city with nature, restoring the historical and cultural atmosphere of Seoul while reshaping the public open space in the city [65]. Furthermore, regarding the use of IUS, the respondents felt that building a new road underground, such as the Big Dig in Boston, would have the most positive impact on the landscape (IUS4, 81.3%). When the Big Dig was completed, the original ground occupied by the highway formed a continuous belt of parks that integrated public green space with an improved urban walking system to create a comfortable and convenient urban space [45]. Finally, regarding the use of MUS, the public felt that projects such as the renovation of Jiaxing Railway Station had the most positive impacts on the landscape (MUS4, 84%). Following this renovation, the primary traffic and supporting commercial functions of the railway station were moved underground, enabling the complete release of the ground surface, which was transformed into a public green space that gave the appearance of a “train station in the forest.” The aforementioned research results not only have important reference value and guiding significance in the field of urban planning and underground space utilization but also provide useful experience and insights for public participation, urban sustainable development, and global urban planning and construction. Through the UUS survey, we learned about public attitudes and perceptions of urban landscape space transformation, which will help planners better understand public needs and design urban spaces that better meet community expectations. This approach of public participation introduces more democratic and open elements into urban planning and regeneration, helping create a more inclusive and shared urban space.

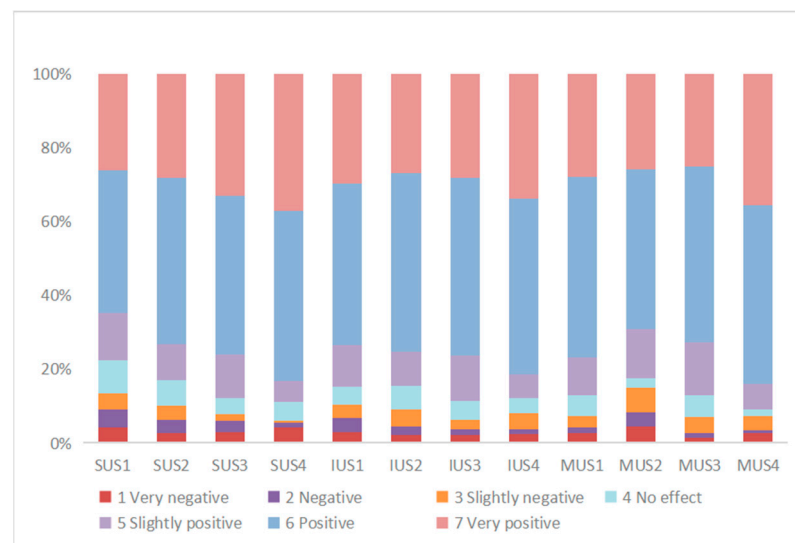


Figure 3. Respondent preferences for different underground projects.

In terms of the benefits of PL (Figure 4a), the respondents believed that sunken park squares, such as REGULAR Yuanye in Chengdu, have the most positive protective effect on the aesthetic value of the surface landscape (PL3, 83.5%). In this project, a park-like commercial area divides the above- and below-ground worlds, with the original natural landscape above ground and a fashionable urban cultural landscape below. This was followed by the perceived positive impacts on ecosystems (PL1, 81.3%) and historic sites (PL4, 78.4%) accompanying the use of underground space to build transportation facilities, prevent the destruction of existing forests, protect the natural landscape and vegetation on the surface, and maintain ecological balance and biodiversity. In terms of IL (Figure 4b), the use of underground spaces was considered to have the most positive effect on the vitality of historic sites (IL4, 82.1%), as exemplified by the Louvre expansion, followed by increasing urban green spaces (IL2, 79.7%) and creating high-quality public spaces (IL3, 77.9%). For example, historic buildings and squares in urban centers can utilize underground spaces to preserve and enhance the historical and cultural landscape above ground [24]; this approach involves creating new uses for underground spaces while preserving the rich heritage of the city.

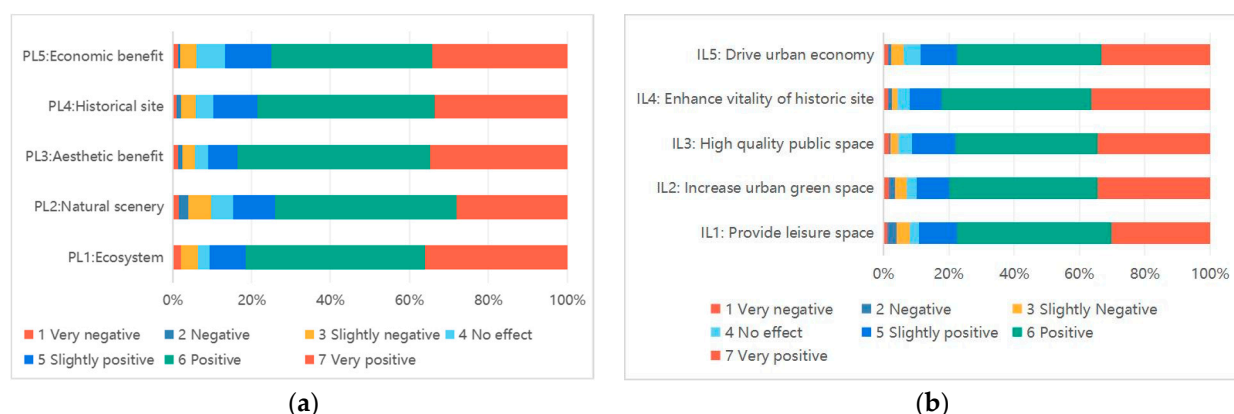


Figure 4. Respondent preferences for using underground space to influence landscape value in terms of (a) PL and (b) IL.

When asked to consider the A-BGILPM (Figure 5), the respondents believed that underground space development could have the most positive impact on the efficient composite use of land resources (UL1, 79.7%) and the realization of an ecological carbon sink (US1, 75.2%). This finding indicates a preference for the multifunctional utilization of

land resources to create a compact and high-quality public space and for the development of underground space to save surface land resources, promote green ecology such as parks and forests, and realize ecological carbon sinks.

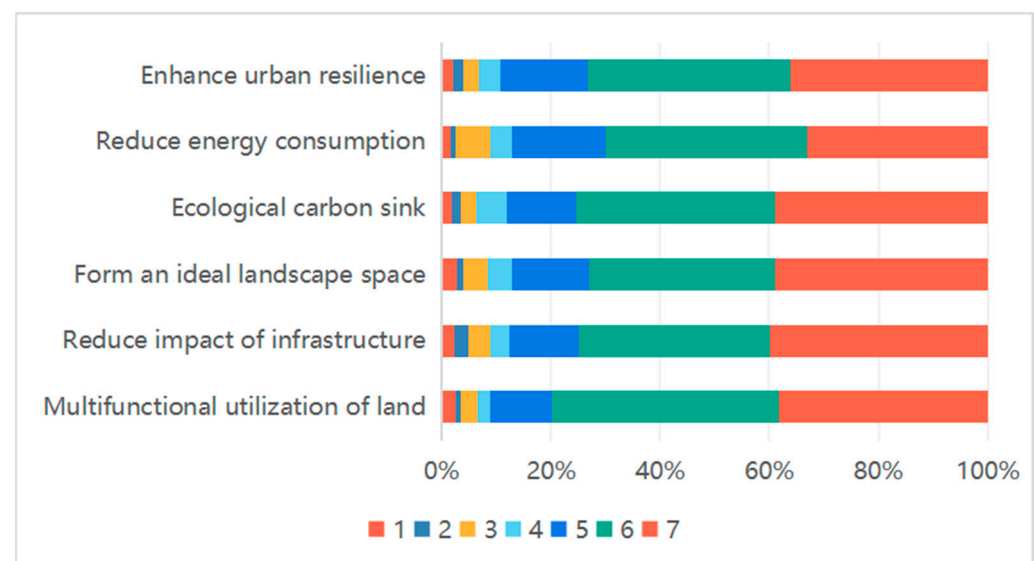


Figure 5. Respondent preferences for using underground space to influence A-BGILPM.

4.2. Social Factors and Respondent Perception

A statistical analysis of the sample population structure according to the positive and relatively positive responses in the questionnaire was conducted to explore the effects of social factors on respondent preferences (Figure 6). The results indicate that gender and place of residence have limited impacts on the perceptions of residents regarding the use of underground space to improve the landscape. That is, regardless of gender or place of residence, no significant difference exists in the perceptions of the residents regarding the use of underground space in landscape improvement. In terms of age, profession, and place of work, the respondents show heterogeneous preferences. Respondents of different age groups have different views on the impacts of the restoration of underground aqueducts on the landscape (SUS4) and the effects of underground space usage on the economic value of the landscape (PL5 and IL5). Compared with young people (18–35 years old), middle-aged people (36–55 years old) may pay more attention to practicality and convenience, including that of transportation, shopping, leisure, and other functions of underground space, which can help solve the problems of urban traffic and commercial development. The use of underground facilities such as Cheonggyecheon (SUS4) and the Big Dig project (IUS4) to provide residents with public open spaces to be close to nature or showcase urban culture has the most significant impact on the landscape according to the respondents working in the old city but not those working in the new city. This difference may originate from the urgent need to improve the lack of public space faced by the old city. Planning and design professionals and students differ from non-professionals in terms of the Caisson parking garage (IUS1) as well as the ecological value (PL1) and economic value (PL5) of underground facilities. This finding implies that professional background affects the perception of underground space utilization. This influence may be due to the professional knowledge, practical experience, and project participation of planning and design professionals and students. Consequently, these individuals may be more inclined to focus on the functionality, sustainability, and long-term planning of urban space from a professional perspective, whereas non-professionals may be more urban residents or users. Their opinions are more influenced by personal preferences and subjective feelings.

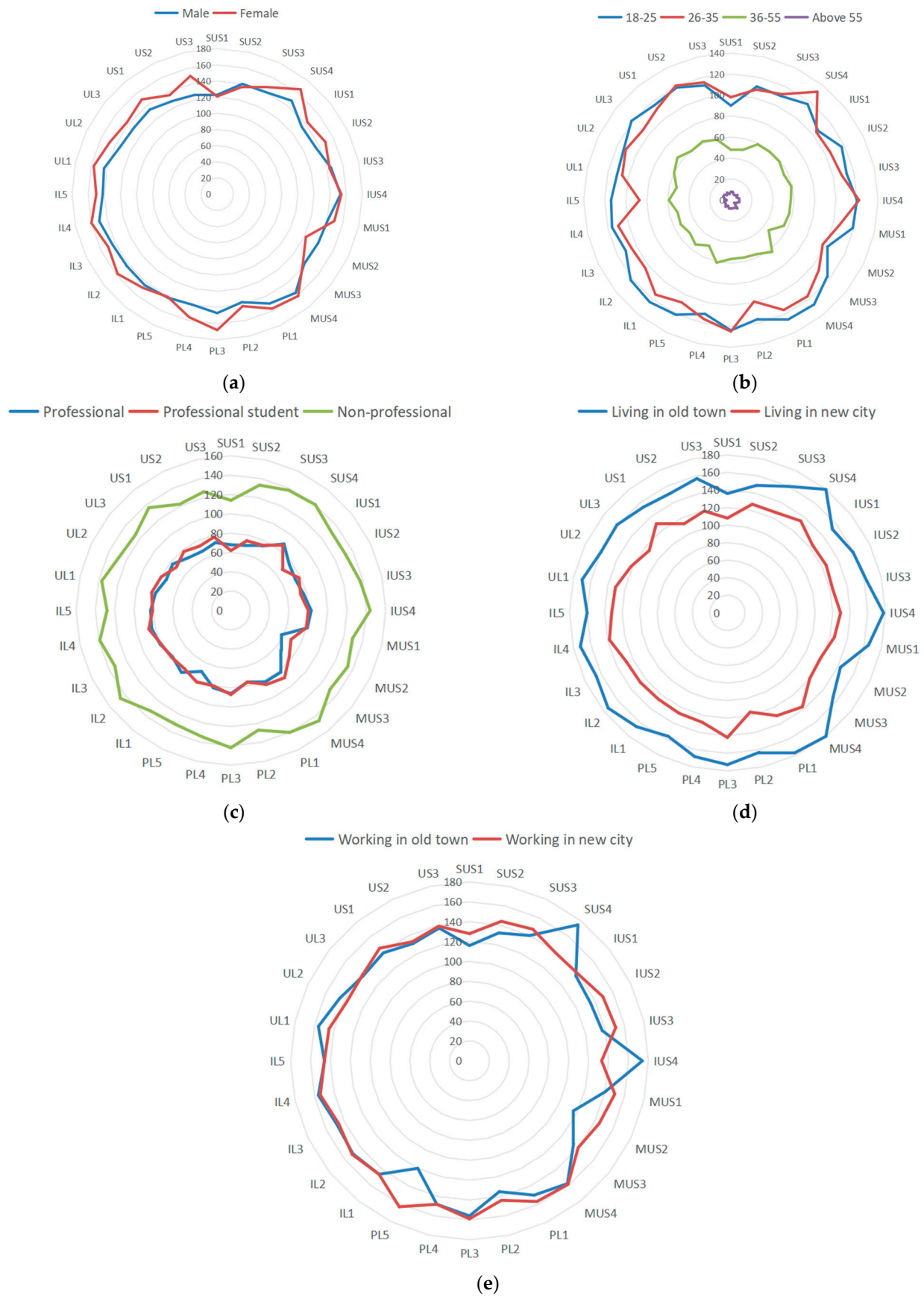


Figure 6. Statistical analysis of population structure according to responses. (a) Gender; (b) age; (c) profession; (d) place of residence; (e) place of work.

4.3. Model Results

Before testing the SEM, the reliability and validity of the data were evaluated, and the measurement model was verified. The results indicated that Cronbach's alpha coefficient was above 0.70 for all evaluated dimensions, indicating a high level of internal consistency among the data. Furthermore, all standardized factor loadings exceeded 0.4, and all KMO values were greater than 0.8 (except for that of the SUS dimension, which was 0.775), indicating that the data exhibited suitable validity. Therefore, the measurement items were considered reliable for gauging each influence factor [66–68]. Finally, a pairwise correlation analysis of the seven influencing factors was performed to verify the rationality of the factor analysis using AMOS statistical software (AMOS 25.0) [69]. Items with standardized factor load estimates in each dimension of less than 0.5 were removed, as they were not significant and therefore negligible. The psychometric properties of this revised measurement model were evaluated in terms of composite reliability and convergent validity [68,70].

An analysis of the standardized path coefficients revealed the direction and significance of the hypothesized relationships among the seven influencing factors in the model. Based on the p -values and critical ratios, all hypotheses except for H1 were confirmed (Figure 7). Table 3 presents the results of the hypothesis tests conducted on the revised model.

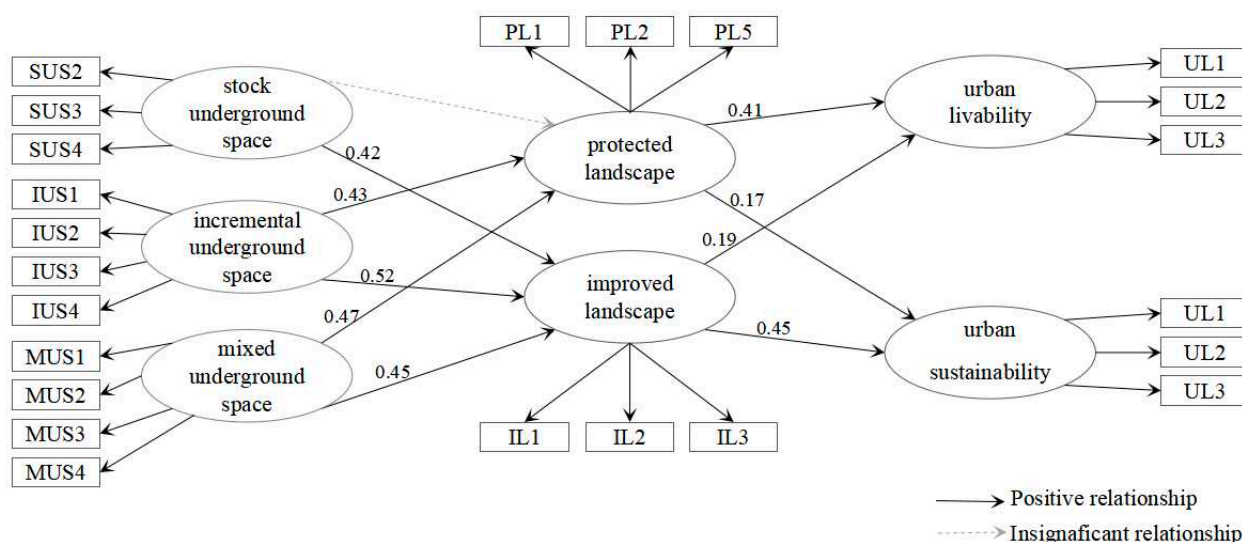


Figure 7. Research model.

Table 3. Results of the hypothesis testing of the revised model.

Hypothesis	Hypothesized Path	Estimate	S.E.	C.R.	p	Supported?
H2	IUS→PL	0.426	0.080	5.078	***	Yes
H3	MUS→PL	0.466	0.068	1.128	0.059	Yes
H4	SUS→IL	0.421	0.052	5.595	***	Yes
H5	IUS→IL	0.515	0.063	4.944	***	Yes
H6	MUS→IL	0.446	0.072	4.143	***	Yes
H7	PL→UL	0.408	0.076	0.125	0.009	Yes
H8	PL→US	0.191	0.110	2.921	0.003	Yes
H9	IL→UL	0.171	0.072	2.783	0.005	Yes
H10	IL→US	0.450	0.117	6.164	***	Yes

Note: S.E. indicates standard error; C.R. indicates critical ratio. *** $p < 0.001$.

An analysis of the model fitting test results indicated that the model had a “good” degree of fit with the collected data for most indicators, including CMIN/DF, RMR, GFI, AGFI, NFI, IFI, TLI, CFI, and RMSEA [71], as listed in Table 4.

Table 4. Test results of model fit degree after modification.

Model Fit Indicator	Optimal Standard Value	Calculated Value	Fit Condition
CMIN	—	889.238	—
DF	—	266	—
CMIN/DF	<3	3.343	Good
RMR	<0.8	0.071	Fine
GFI	>0.8	0.831	Fine
AGFI	>0.8	0.884	Good
NFI	>0.9	0.879	Good
IFI	>0.9	0.884	Good
TLI	>0.9	0.911	Fine
CFI	>0.9	0.892	Good
RMSEA	<0.08	0.058	Fine

5. Discussion

5.1. Respondent Preference and Cognition of Underground Space

Several critical conclusions can be drawn from the results of this study. By comparing the underground projects that respondents believed had the most positive impacts on the landscape, we identified several common characteristics. From this, we can gain an in-depth understanding of the public's perception of using underground space to improve the landscape (corresponding to question 1). First, these projects all increased the open green space in the city, as Golany and Ojima [41] phrased it, and transferred the urban road network to the underground space, enabling the natural environment to penetrate into the city. Notably, the natural environment contributes to the health and well-being of the urban environment and its residents; multiple studies have shown that residents most enjoy visiting green open spaces to be close to nature, walk, and exercise [33]. Second, these projects enable the dual use of above- and below-ground space to form a diverse and high-ecological-quality public natural space that provides various services to meet the needs of different social groups. The various preferences of different social groups lead to diverse views on the ecological services provided by open green spaces and the necessary improvements to such spaces. Looking at the preferences of the respondents regarding how underground space use affects landscape value demonstrates that the views of the respondents on services reflect their concerns regarding different aspects of urban development. The old town faces problems such as insufficient and scattered green space, the need to protect and develop cultural heritage, and traffic congestion. According to the survey results, respondents residing in the old town believe that the most positive impact of underground projects is protection of the original natural landscape on the surface and maintenance of its ecological benefits to the city. Services that are closely related to daily life and enjoyment, such as open space, fresh air, urban heat island mitigation, and urban noise mitigation, attract resident recognition more than other indirectly related factors and enhance urban personal happiness [72]. In Nanjing, a “furnace city” with extremely high temperatures in particular seasons, the heat island mitigation function is considered especially vital [73].

In addition, the respondents reported a high level of concern for the protection of cultural heritage. The need for public participation in the protection of cultural heritage has been confirmed in numerous studies [74]. The characteristics of underground space development and utilization often make it the only available resource for the protection and development of cultural heritage. The surge in visitor traffic after the renovation of the Louvre shows that this strategy is gaining increasing public approval. Notably, the China Imperial Examination Museum, located in the Nanjing Fuzi Temple historical district, is the only underground museum in China, and its underground space is fully utilized to improve the space quality of the museum and visitor experience. Nanjing has rich historical, cultural, and landscape resources and a high utilization level of underground space. Under different cultural, economic, and social backgrounds, the public may have different views

regarding the use of underground space to improve the landscape. These differences may be related to the practical experience and cognitive level of the public.

5.2. Effects of Social Factors on Respondent Cognition

To evaluate the views of the respondents on the use of underground space to affect the landscape, their preferences regarding the use of underground space and the improvement of the urban landscape must be considered. The results show that age, occupations, and places of work are important factors affecting the public cognition of underground space utilization (corresponding to question 2). Numerous studies have investigated the attitudes of the public toward working in underground space [75,76], using underground transportation facilities [77], and constructing underground infrastructure [78], reporting that the public acceptance of and participation in underground spaces are gradually increasing. The results of this study indicated that people of different ages have dissimilar views on using SUS to improve and protect the original landscape. Not only did the age of the respondents affect their perception of the underground environment and acceptance of underground engineering, but also the actual demand for green space differed among the age groups. The superposition of these differences shapes the cognitive preferences of the public. Indeed, the results of this study are closely related to the demand for green open space in urban planning and social dynamics. Therefore, special attention should be paid to the social structure of nearby communities when organizing above–below-ground integration planning to meet the demand of the public for urban landscape improvement and promote the sustainability and social inclusion of urban development.

To a certain extent, the places of residence of the respondents reflect the social structures of their communities, whereas their places of work affect their perception of the city from another perspective [79]. These perceptions include the culture, social interaction, planning and development, land use situation, and image of the city. Simultaneously, employees in the old city and the new district may have different living and working needs. Therefore, the shortage of public open space in the old town and the need of people to be close to nature and leisure have led respondents living and working in the old town to show a stronger identification with the use of underground space to improve the landscape than those in the new town. Interestingly, studies have shown that streetscaping can increase life satisfaction in residential areas but decrease life satisfaction in workplace areas. Thus, a better mix of land use can mitigate the negative impacts of greening on the life satisfaction of workers [80]. Predominant occupations determine the level of knowledge of the public and their access to information. In turn, this level of knowledge directly affects attitudes toward urban landscape improvement and urban renewal. People with more relevant knowledge may be more likely to understand the meaning, impacts, and long-term effects of urban planning and renewal projects as well as to support such efforts as a result. Access to information also influences public attitudes toward urban landscape improvement and renewal. Different information sources may convey different information and perspectives that will affect public cognition and attitudes toward urban renewal projects. A deeper understanding and consideration of these regional differences can provide a more nuanced picture of public views and attitudes toward cities. Indeed, such public perceptions must be considered when advancing landscape improvement projects using underground space to obtain effective support and participation. Therefore, in addition to considering the social structure of the community, attention must be paid to the social structure of non-residential areas during the bottom-up planning process to ensure that all perspectives are considered when evaluating the effects of underground space development on life satisfaction.

5.3. Relationship between Respondent Preferences for Underground Space and Cognition

As illustrated in Figure 7, the AMOS data analysis results indicate that the hypothesis describing the impact of SUS on PL was not valid but that SUS had a positive impact on IL (standardized path coefficient = 0.42). It can be seen that respondents do not believe that the use of underground space has a significant effect on landscape protection, which

is a major finding of the public's perception of above-ground collaborative development. This result could be attributed to several factors. First, the utilization of SUS principally updates and transforms its functions, environmental quality, and other elements in pursuit of qualitative improvement (e.g., New York City's Lowline Park [81]). This approach does not involve quantitative changes and has a limited ability to protect the original landscape on the surface. Furthermore, we found that air raid shelters, underground transportation facilities, and industrial sites are the typical objects of SUS reuse. The limited public perception of these underground projects also affects their perception of the role these projects play in protecting the landscape. In this study, the development of IUS had the most significant positive impacts on PL and IL, with standardized path coefficients of 0.43 and 0.52, respectively. Cases of IUS development are the most abundant and have the highest social visibility, with most cases distributed in large cities with high levels of underground space development, rich landscape resources, or long histories (e.g., Helsinki, Shanghai, and Paris). This increases the public awareness and acceptance of IUS as effectively protecting the natural scenery, open spaces, and historical sites on the surface [82,83].

We also determined the impacts of using underground spaces on different PL and IL values. The results show that the public recognizes the positive impact of the use of underground space on landscape value and the important role of urban landscape in urban renewal under the A-BGILPM model (corresponding to question 3). Residents pay more attention to practical benefits than to ecological benefits, as the former are directly related to their quality of life [33]. Humans not only require public open spaces in urban centers for equal and frequent rest activities and social interactions [55,84,85], but also seek identity and cultural heritage through historical sites [42,86]. The impact of underground space utilization on the economic value of landscapes is primarily reflected in the stimulation of space vitality, as confirmed by the survey results. The experience in Hong Kong has shown that to maintain street vitality, developing underground pedestrian networks that provide access to shopping malls associated with subway stations is more effective than directly connecting streets [86]. The results of this study respond to the three questions raised above (Figure 8), provide an example for cities like Nanjing which are in the stage of rapid growth and maturity, and provide useful experience and enlightenment for urban sustainable development.

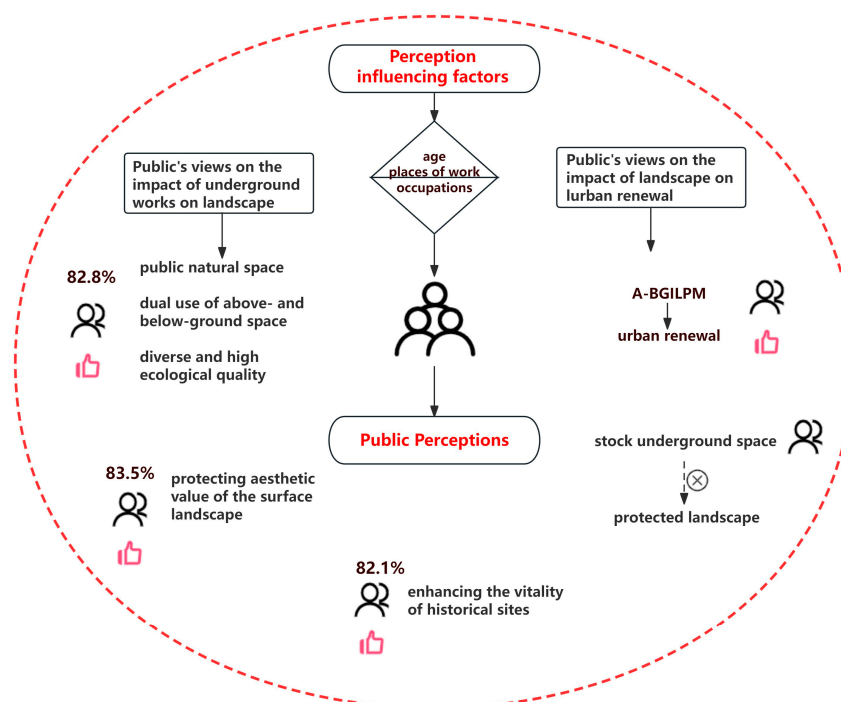


Figure 8. Recapitulatory chart of answers to the three questions.

6. Conclusions

In this study, we investigated the views of 377 Nanjing residents on the use of underground space to improve the landscape and established a comprehensive research model of the relationships among underground space, urban landscape, and urban renewal in cities to study them using an SEM. We found that although the public is concerned about different aspects of urban development, most people (82.8%) prefer public natural space that provides the dual use of above- and below-ground space to achieve diversity and high ecological quality. Examples include Cheonggyecheon in Seoul, the Big Dig in Boston, and the renovation of the forest railway station in Jiaxing. From the perspective of landscape value, the respondents believed that underground works had the most positive impacts on protecting the aesthetic value of the surface landscape (83.5%) and enhancing the vitality of historical sites (82.1%). In terms of social factors, respondents of different age groups, occupations, and places of work showed heterogeneity in their preferences for using underground space to improve the landscape. Finally, the model constructed based on the survey results indicated that the public believes that SUS has no significant impact on PL; however, it demonstrates a positive attitude toward the impacts of underground space utilization on landscape ecology, social and economic value, and urban renewal through the above–below-ground integrated development model. Therefore, strengthening the collaborative utilization of both above- and below-ground space resources is preferable; in particular, this approach will help fully explore the potential impacts of SUS on urban renewal, which will facilitate the development of sustainable cities. Policymakers should conduct targeted information dissemination and educational activities and develop an understanding of the actual needs of the public to build livable and sustainable human settlements that improve the life satisfaction of the growing urban population.

The findings of this study support the results of previous literature from a social perspective. The results emphasize the contribution of environmental experiential knowledge to public perception and the impacts of the use of space by residents on that perception. However, as the data summarized and interpreted in this study were derived from a case-based investigation of existing underground spaces and their perceived influences on the landscape, a notable limitation of this study lies in the potential sampling bias. Therefore, the survey sample should be expanded in future studies, including a broader underground space research scope and additional territorial contexts, as well as a more statistically representative sample of the population, to improve the generalizability of the research results.

7. Possible Directions for Future Studies

By pursuing the potential future research directions listed below, scholars can further refine the concepts and methods developed in this study, expanding their applicability to diverse contexts and contributing to the advancement of sustainable urban development practices:

- (1) **Comparative Analysis:** Future researchers could conduct comparative analyses across different cities or regions to assess the generalizability of the findings. This process would involve examining how public perceptions of underground space utilization for urban renewal and landscape improvement vary across diverse cultural, geographical, and economic contexts.
- (2) **Longitudinal Studies:** Longitudinal studies tracking changes in public perceptions over time could provide valuable insights into evolving attitudes towards underground space utilization. Understanding how these perceptions shift in response to urban development initiatives and environmental changes is crucial for effective urban planning and policy formulation.
- (3) **Stakeholder Engagement:** Exploring the role of stakeholder engagement and participatory approaches in urban development projects involving underground space could be another topic for future investigation. Understanding how involving residents

and various stakeholders in the planning and implementation processes impacts the success and sustainability of such projects would be valuable.

- (4) Interdisciplinary Approaches: Given the multifaceted nature of urban development, future scholars could adopt interdisciplinary approaches, integrating fields such as urban planning, environmental psychology, and sociology to gain a comprehensive understanding of the complex dynamics at play in underground space utilization and its impact on urban landscapes.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/su16114501/s1>, File S1: Questionnaire.

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