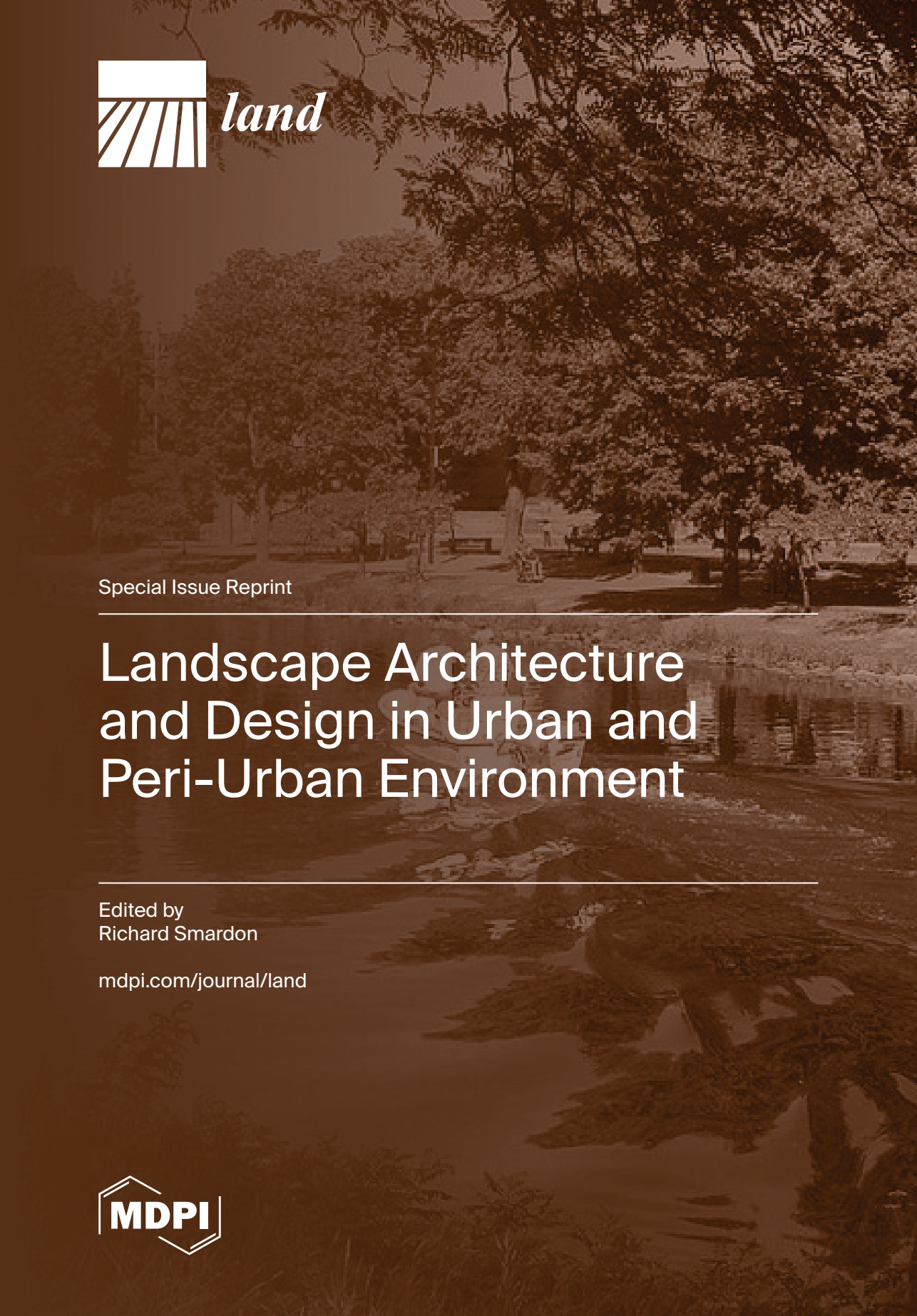

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Special Issue Reprint

Landscape Architecture and Design in Urban and Peri-Urban Environment

Edited by
Richard Smardon

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Landscape Architecture and Design in Urban and Peri-Urban Environment

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Cover image courtesy of Richard Smardon

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About the Editor

Richard Smardon

Richard "Rick" Smardon has worked in academic, government, and private-practice positions before his current one at the SUNY College of Environmental Science and Forestry where he is a SUNY Distinguished Service Professor Emeritus. He has a Ph.D. in Environmental Planning from the University of California, Berkeley, and a Masters in Landscape Architecture and Bachelors from the University of Massachusetts, Amherst. He has edited/written nine books, the most recent being *The Renewable Energy Landscape* (2017), *Revitalizing Urban Waterway Communities: Streams of Environmental Justice* (2018), *Education for Sustainable Human and Environmental Systems* (2019), and *Selected Papers from the 6th Fabos Conference on Landscape and Greenway Planning*. His new peer-reviewed Special Issue entitled "Celebrating 25 Years of World Wetlands Day" builds on his 2009 *book Sustaining the Worlds Wetlands: Setting Policy and Resolving Conflicts*. He also co-produced the 2019 and 2021 Visual Resource Stewardship conferences and co-edited the 2017 Visual Resource Stewardship conference proceedings.

Preface

This *Land* Special Issue entitled "Landscape Architecture Research and Design for Urban and Periurban Environments" is meant to bring together a wide range of environmental design researchers to address this theme. This Special Issue includes multi-authored articles from Australia, Chile, China, Italy, Malaysia, Spain, and the United States. Its articles cover a range of subjects including landscape conservation; residential architectural heritage; urban landscape perception; urban park access, use, and perception; public art design; suburban expansion and mobility; and visual urban landscape quality. This Special Issue complements a limited number of publications that address the state of the art in urban landscape architecture research (Bishop & Corkery 2022, Prominski & Von Seggern 2019). The Special Issue Guest Editor wishes to thank all the contributing authors for this Special Issue as well as the editors of the journal *Land* who have addressed the myriad publication issues involved in the production of this Special Issue.

Richard Smardon, Ph.D., SUNY Distinguished Service Professor Emeritus

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Richard Smardon
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Editorial

Overview of "Landscape Architecture Research and Design for Urban and Peri-Urban Environments"

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1. Introduction

Landscape architecture and design research is becoming increasingly relevant due to rapid urbanization and its impact on urban and peri-urban environments.

The constant proliferation and sprawl of urban areas is an imperative challenge. Society requires knowledge about which natural and manmade landscape innovations or patterns are most suitable and sustainable for urban architecture and design. Such knowledge is crucial to achieving sustainable urbanization while maintaining and improving urban and peri-urban areas as well as providing a healthy environment for urban residents.

There have been few recent overviews of urban landscape architecture research [1–3], as landscape architecture is a very broad and multidisciplinary mix of physical and social science, plus the arts and humanities. This Special Issue of the *Land* journal contains 12 original articles addressing urban landscape conservation, suburbanization growth, urban park access and use, public facility and art perception, and urban landscape aesthetics.

2. Key Findings and Insights

As noted above, the articles in this Special Issue fall into the five following major categories: (1) urban landscape conservation, (2) suburbanization growth, (3) urban park access and use, (4) public facility and art perception, and (5) urban landscape aesthetics.

Lin et al.'s (List of Contributions) article documents that the urban residents in older communities in Beijing, China have a higher perception of well-being as opposed to those in newer block housing. Wang et al. (List of Contributions) analyze the attributes of traditional rural residential architecture that could be continued with newer peri-urban architectural design. Delponte et al. (List of Contributions) report on the "Savingscapes" project in Girona and Geneva, Italy, where social mobilization is used to achieve landscape conservation aims. All three articles contain research approaches providing means for discovering landscape heritage values as well as for landscape conservation.

A major contribution to addressing suburban expansion and mobility issues is Zhu et al.'s (List of Contributions) article, where the authors use scenario-based parametric modeling to generate and optimize suburban land use patterns in the United States. The findings are significant, indicating that substantial enhancement to neighborhood environmental performance and overall accessibility can be achieved by modifying existing suburban land use patterns and individual block configuration without increasing density.

Three articles address urban park access, use, and perception. Zhang et al. (List of Contributions) study 100 urban parks in Chengdu, China using multi-dimension indicators. The results reveal spatial distribution issues and differences in park quality which can be used to guide future park planning and design. Mercadé-Aloy and Cervera-Alonso-de-Medina (List of Contributions) assessed the Montjuc Trail Master Plan and 360 Route design in Barcelona, Spain. In this study, the authors documented future connectivity to the surrounding urban fabric, as well as the local residents' quality of life. Payder et al. (List of Contributions) assessed urban park design, visual quality and walking behavior within a large regional park in the Araucanian region of Chile. Specific findings revealed

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key park design attributes which allowed for walking accessibility, user behavior, user group differences, and visual quality perception. In all three studies, the authors support the importance of urban green open space accessibility, equitable urban park design, and improving urban residents' quality of life.

In two articles, the authors specifically address the quality of urban public places. Liu et al. (List of Contributions) utilized eye tracking methods to assess the aesthetic attributes of public spaces. The key findings revealed the color and material preferences of different public space users. Chang et al. (List of Contributions) assessed the neural perceptions of public art by both professionals and non-experts. Results from both studies provide guidance for public open space facility design.

The fifth group of articles addresses urban and peri-urban landscape aesthetics. Gao et al.'s (List of Contributions) article is a systematic review of what is perceived as visual pollution and so can serve as guidance for measures to reduce negative impact and preserve urban visual quality. Another article by Gao et al. (List of Contributions) assessed rural road landscape character in Sabak Bernan, Malaysia. The results indicated a higher level of preference for open agricultural roadside views. Finally, Ignatieva et al. (List of Contributions) present empirical research on public preferences for urban lawns and greenspace alternatives in Perth, Australia. The results indicated that maintained grass lawns are valued for aesthetics, cooling, and recreation. Alternative lawn treatments were assessed as well. All three studies illustrate solid methodological approaches for gauging public perceptions of urban landscapes, plus possible alternative management options.

3. Conclusions

The wide range and depth of urban landscape research illustrates the development of useful methods as well as the connection to design alternatives and outcomes. This Special Issue is intended to complement existing guides for landscape architecture research applicable to urban and peri-urban landscapes [1,2].

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Conflicts of Interest: The author declares no conflicts of interest.

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1. Lin, Y.; Fu, H.; Zhong Q, Zou, Z.; Chen, S.; He, Z.; Zhang, H. The Influencing Mechanism of the Communities' Built Environment on Residents' Subjective Well-Being: A Case Study of Beijing. *Land* **2024**, *13*, 793. https://doi.org/10.3390/land13060793.
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Article

The Influencing Mechanism of the Communities' Built Environment on Residents' Subjective Well-Being: A Case Study of Beijing

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Abstract: There is a consensus toward quantitative environmental design in the information age, but the content and specific practices of its quantification have yet to be systematically studied. To enhance residents' subjective well-being through environmental design, this study includes 847 valid questionnaires across four types of communities and identifies different types of resident groups using correspondence analysis. Then, this study compares the differences in the built environment and subjective well-being using one-way ANOVA and analyzes their impact via regression analysis. The results indicate that residents in old communities have the highest subjective well-being (3.93/5) and built environment assessments, and residents in policy housing communities have the lowest subjective well-being (3.37/5) and built environment assessments. A resident's subjective well-being is more influenced by two types of built environment factors: architecture and landscape and the human–land relationship. Age, education level, public place usage, and the community's overall evaluation also significantly affect residents' subjective well-being. In the information age, quantitative design is the inevitable direction of future design. Through quantitative research, targeted design strategies can be proposed to serve community residents better in their communities and provide references for communities in other developing countries.

Keywords: built environment; subjective well-being; population differences; environmental design; quality of life

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1. Introduction

As global urbanization progresses, cities have significantly improved living standards, economic opportunities, and access to services. However, rapid expansion has also led to issues such as pollution, which pose a significant threat to residents' well-being. The rapid urbanization process, particularly in developing countries, has led to the severe deterioration of the built environment [1,2], which poses a significant challenge to improving residents' well-being [3,4]. Approximately one billion people live in communities that often lack essential services such as clean water, sanitation, and adequate housing, further exacerbating the residents' well-being crisis. Compounding these challenges [5], the COVID-19 pandemic has underscored the fragility of urban ecosystems [6]. Particularly, China has been experiencing rapid economic growth and urbanization since 2020, with urbanization surpassing 60% [7]. The densely populated and high-density built environments in large cities have posed significant challenges to the quality of life for residents. Within the global vision directed toward the Sustainable Development Goals (SDGs), enhancing people's well-being has emerged as one of the critical objectives pursued by countries worldwide.

According to the United Nations report, the enhancement of well-being reflects improvements in quality of life and is a vital indicator of social progress and development [7]. This calls for a comprehensive and multidimensional approach to analyze the built environment and enhance residents' well-being.

Well-being is the comprehensive judgment result of people's multidimensional quality of life [8,9]. Specifically, well-being can be measured from objective and subjective perspectives [10]. Researchers assess objective well-being based on indicators such as income, literacy rates, and life expectancy, along with subjective well-being, encompassing how individuals perceive and experience their well-being [10,11]. Although objective well-being is easily measurable and comparable [11], researchers have pointed out that socio-economic indicators struggle to reflect true happiness levels, especially as residents are heterogeneous and have different improvement needs [12–14]. To address the limitations of measuring objective well-being, researchers have increasingly turned to surveys or interviews to assess residents' life satisfaction or hedonic levels from a psychological perspective [12,15]. Life satisfaction refers to an individual's overall contentment with various aspects of their life, while hedonic levels are related to residents' negative and positive emotions [16]. Studies have found that self-reported subjective well-being data exhibit high internal consistency, reliability, and stability [17,18], capturing individuals' subjective assessments, which are difficult to capture using objective indicators. However, the psychological measures of subjective well-being often rely on personal experiences and fail to consider an individual's physical state [19]. Individual needs and responses vary in both physiological and psychological aspects [20]. Recent studies suggest that subjective well-being depends on reactions from both physiological and psychological perspectives [20,21]. Understanding the influence of physiological factors on subjective well-being can help design more effective health interventions. Physiological indicators, such as heart rate, blood pressure, immune function, and hormone levels, offer objective and quantifiable data that complement the psychological assessment of subjective well-being, leading to more reliable and comprehensive evaluation results [19,21]. However, limited studies assess subjective well-being from physiological and psychological perspectives in urban planning and design.

The environmental design of the built environment is an essential way to enhance residents' subjective well-being. Some researchers have explored the effect of a collective built environment on subjective well-being from one or more aspects [3]. For example, immersing people in scenery to temporarily escape mundane life can alleviate mental fatigue and enhance subjective well-being [22]. Moreover, a well-built environment can attract user participation, create positive activity experiences, and strengthen users' physiques [23–26]. Urban greening could also contribute to well-being by emitting substances that disinfect and inhibit bacteria, improving air quality and boosting residents' immunity [22]. Other studies have focused on the multiple aspects of built environments. For example, Pfeiffer and Cloutier (2016) outlined the key drivers of subjective well-being, including public spaces, natural spaces, social interactions, and safety [27]. Mouratidis (2018) provided a conceptual indicator framework in which the built environment influences subjective well-being through social relationships, leisure, health, and emotional experiences [28]. Shekhar et al. (2019) argue that subjective well-being is determined by four factors, including engagement, access, identity, and safety [29]. Dang et al. (2023) analyzed the relationship between the built environment and subjective well-being from the perspectives of personal, housing, and neighborhood factors [30]. Finally, the factors affecting residents' subjective well-being differ at various scales. According to previous studies, research has confirmed factors influencing subjective well-being at different scales, such as regional climate factors and air quality at the regional scale [31,32], the degree of democracy and employment rate at the national scale [33,34], and urbanization levels and city size at the urban scale [35,36]. However, limited studies focus on the collective built environment in communities and its impact on subjective well-being.

Except for collective built environment factors, individual background also plays a vital role in shaping residents' subjective well-being. Existing research has identified that demographic backgrounds, such as cultural backgrounds, professions, and income, can lead to varying demands for the built environment, affecting residents' satisfaction with the built environment and subjective well-being [37,38]. Considering the various needs and preferences of user groups in the built environment, some studies have explored the variability in subjective well-being by considering different demographic characteristics. For instance, Kang et al. found that subjective well-being is higher among women and older adults than among middle-aged individuals, with subjective well-being and income showing an inverted U-shaped distribution, where families with annual salaries between CNY 300,000 and 490,000 have the highest subjective well-being [39]. Gu et al. also discovered that women's subjective well-being is higher, with age and subjective well-being presenting a positive U-shaped distribution [40]. The effects of both the collective built environment and individual background factors in subjective well-being still need to be comprehensively studied to inform a more targeted environmental design.

There is not yet a consensus on how to design communities' built environments at the smallest homogenized spatial unit in order to measure and improve residents' subjective well-being or to meet residents' needs and enhance their subjective well-being. Previous designs of existing community-built environments, which are based on an intensive treatment of land and high-density land use development, lead to a more diverse population inhabiting these spaces during urbanization [41]. Research on the factors affecting residents' subjective well-being at the community level mainly includes neighborhood relations [42], building quality [43], human–environment relations, landscape quality [44–46], infrastructure elements [47], convenient production, and consumption elements [48,49]. Some researchers have begun to further consider the types of communities. For example, Gu found that urban residents care more about community types [40]. However, these studies did not specifically analyze the impact of community types on residents' subjective well-being. Although Zhan considered community types [50], they did not analyze the differences in subjective well-being among residents of different community types, focusing only on the subjective well-being of the elderly. However, the consistency and difference of the factors affecting residents' subjective well-being in different communities still need further exploration.

Therefore, to address these deficiencies, based on four types of communities, this paper first identifies different resident groups, considering subjective well-being, community types, and demographical characteristics via correspondence analysis. Then, this study compares the differences in the built environment and subjective well-being using one-way ANOVA. Finally, we comparatively analyze the impact mechanism of subjective well-being in different types of communities via regression analysis. This study aims to answer the following research questions: (1) What are the characteristics of subjective well-being and the corresponding residents in different communities? (2) What is consistent and different for subjective well-being and the built environment assessment among the residents? (3) What factors influence residents' subjective well-being in different communities? This study provides empirical evidence and a nuanced understanding of the complex interplay between the physical environment and the quality of life among different community resident groups. It prompts a reevaluation of existing community design, urging it to be more inclusive and to reflect diverse resident needs and preferences. By identifying and understanding the factors within the built environment that affect subjective well-being, urban planners and policymakers can adopt more human-centric approaches to environmental designs. Focused on designing communities to enhance subjective well-being, this study provides actionable insights that could guide national and local policies toward achieving Sustainable Development Goals.

2. Methods and Materials

2.1. Study Area

This study selected Beijing as its study area. Firstly, as the capital city, encompassing 16 districts, Beijing has experienced rapid urbanization since 2000, reaching an urbanization rate of over 90% by 2020, with an urban population reaching 20 million. Urbanization has been achieved within the Fifth Ring Road, with a high degree of homogeneity in the built environment and population density. Secondly, there has been a new phenomenon in Beijing's development of the built environment. In 2017, the population of Beijing showed a decline in the population of the central six districts for the first time in over twenty years, with a decrease in the proportion of the floating population, and continuous negative growth in the subsequent five years. By 2021, the population of permanent residents in Beijing decreased by 4000 from the previous year. Compared to a work-dominated preference in the past, the pursuit of subjective well-being has become the primary factor in the choice of residence. In the post-urbanization phase, the pursuit of subjective well-being in life determines the future development path of the city. Therefore, this study focuses on Beijing to explore environmental research and design to enhance residents' subjective well-being post-urbanization.

This paper selected the Haidian District, Chaoyang District, Dongcheng District, Xicheng District, and Fengtai District as study areas, which have a high degree of homogeneity in the built environment. In terms of community selection, combining previous studies and the original intentions of Beijing community construction [40,42–49], Beijing communities are divided into old communities, company housing communities, policy housing communities, and new commercial housing communities, as shown in Table 1. This study randomly selects four types of communities from each administrative district. The distribution of communities is shown in Figure 1

Table 1. Community Types and Corresponding Characteristics.

Community Type	Community Characteristics
Old Communities	The old urban streets and districts are often located in the city center areas (Dongcheng, Xicheng), with relatively small community activity spaces but strong neighborhood interactions (Figure 2).
Company Housing Communities	They are usually built with funding from institutions, self-built service facilities, and integration of community and institutional interactions (Figure 3).
Policy Housing Communities	These were constructed by city governments, real estate developers, or collective housing units with a social security nature, including affordable, limited-price, and low-rent housing communities (Figure 4).
New Commercial Housing Communities	These were developed by real estate developers as commercial housing communities characterized by a high architectural quality (Figure 5).

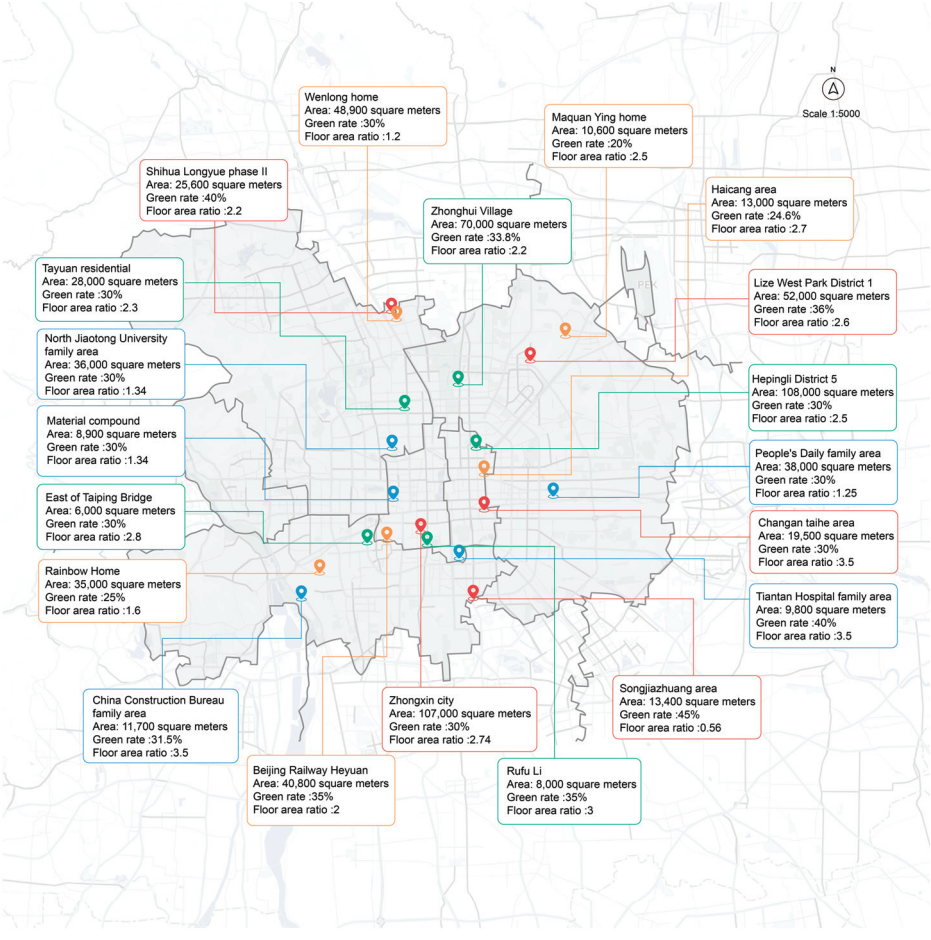

Figure 1. Community selection and basic information.

Figure 2. Tayuan Community.

Figure 3. Beijing Jiaotong University Residential Community.

Figure 4. Rainbow Garden Community.

Figure 5. China World City Community.

2.2. Questionnaire Design and Data Collection

This study employed a questionnaire to measure residents' subjective well-being and its influencing factors. The questionnaire primarily covers three aspects: demographic information, including gender, age, education, and income; subjective well-being measurement, including four physiological and four psychological items [51–54]; and built environment factors (Supplementary Materials). Based on previous studies (Table 2), this study integrates built environment dimensions and builds an indicator framework for the built environment assessments using five aspects, including neighborhood relationship elements, architecture and landscape elements, human–environment relation elements, infrastructure elements, and production and consumption elements. This study uses a Likert 5-level scale, where 1 represents strong dissatisfaction or strong disagreement, and 5 represents strong satisfaction or strong agreement.

Table 2. Indicator framework of the built environment.

Built Environment Dimensions	Indicators	References
Architecture and Landscape	E1 Green Coverage Rate E2 Environmental Cleanliness E3 Openness of View E4 Landscape Harmony E5 Sound Environment Quality E6 Crowdedness of Community E7 Community Crowdedness E8 Air Quality	[55–57]
Neighborhood Relations	S1 Knowing Many Neighbors S2 Good Community Security S3 Trust in Neighbors S4 Willingness to Help Each Other S5 Neighbors Activities S6 Sense of Identification with Community Culture S7 Social Interactions with Community Members	[30,42,55,56,58]
Infrastructure	F1 Facility Accessibility F2 Facility Safety F3 Diversity of Facilities F4 Concentration of Facilities F5 Road Connectivity F6 Nighttime Illumination	[42,56,58,59]
Human–environment relations	Sm2 Conditions for Cooling off Sm3 Building Crowdedness Sm4 Aesthetic Quality of Surfaces Sm5 Architectural Layout Sm6 Landscape Distribution Sm7 Security Environment Sm9 Biodiversity of Flora and Fauna Sm10 Ground Water Drainage and Retention Conditions Sm11 Exercise Activities	[30,60,61]
Production and Consumption	Sm8 Vehicle Traffic Environment Sm12 Convenience of Commerce Sm13 Diversity of Commerce	[58,59]

In each selected community, an interview was conducted with a community committee worker to understand the community conditions and assist with questionnaire distribution. Then, this study randomly selected 30–50 households per community and surveyed the adults of the households. This study distributed 1005 questionnaires and received 997 valid responses, according to completeness (all questions answered). The response rate was 99.2%, indicating high participant engagement and data reliability. However, 150 questionnaires were excluded due to failure to pass the pre-set screening questions, resulting in 847 questionnaires being included in the analysis for this study.

It was found that the Kaiser–Meyer–Olkin (KMO) measure exceeded 0.8, indicating the suitability of the dataset for factor analysis. However, the explained variance of the variables did not surpass 80%. Consequently, dimension reduction was deemed unnecessary. Stepwise regression was employed for collinearity diagnostics and regression analysis. Results indicated a Durbin–Watson value of around two and VIF values all less than 10, suggesting weak collinearity, negating the need for collinearity diagnostics.

The population characteristics are relatively consistent across the different communities. The gender ratio is close to 1:1 (Table 3). The age distribution is concentrated above 25 years, with the largest proportion being over 45 years. The ratio of the population with higher education (bachelor's degree and above) is almost equal to those without higher education, with residents in new commercial housing and company housing communities having higher education levels. Residents' income is concentrated between CNY 100,000 to 300,000, with lower incomes in old communities. Only 30% of the respondents are currently

employed. The frequency and duration of public space usage are similar among residents of different communities. As for frequency, most residents visit the community public space 1–2 times a day or less. As for the duration, most residents visit and stay in the community public space for less than 2 h.

Table 3. Demographic information of residents in each type of community.

Category		New Commercial Housing Communities	Old Communities	Company Housing Communities	Policy Housing Communities
Gender	Male	130	105	93	104
	Female	105	100	100	110
Age	≤25	40	30	11	14
	25–45	93	79	74	86
	>45	102	96	108	114
Education	Middle school and below	17	37	12	15
	High school, vocational	87	102	58	98
	Bachelor's	94	56	74	87
	Graduate and above	37	10	49	14
	Retired	51	49	73	67
Frequency of Public Space Usage	<1 time/day	108	91	77	97
	1–2 times/day	112	93	92	92
	≥3 times/day	15	21	24	25
Duration of Public Space Usage	<1 h	108	93	98	90
	1–2 h	91	72	50	71
	2–3 h	32	29	41	39
	>3 h	4	11	4	14
Annual Income	≤50,000	10	46	6	11
	50,000–100,000	30	66	12	47
	100,000–200,000	63	54	72	77
	200,000–300,000	93	28	83	61
	>300,000	39	11	20	18
Occupation	Government and public institutions	44	29	37	34
	Enterprise	36	26	20	24
	Freelancer	59	69	42	58
	Unemployed	23	13	7	18

2.3. Statistical Analysis

This study utilized correspondence analysis to portray the basic characteristics of subjective well-being among residents using the SPSS 22.0. A first round of correspondence analysis was initially applied to explore the basic relationships between variables, including residents' basic information and subjective well-being [62]. Subsequently, difference analysis was employed to compare differences in subjective well-being in population attributes. According to the results in the first round of correspondence analysis and difference analysis, this study conducted the final round of correspondence analysis to portray the characteristics of subjective well-being among different resident groups. Since the first round of differentiation measurements indicated that gender did not significantly distinguish between groups, the second round of correspondence analysis did not consider the gender characteristics of the population.

For variables that follow a normal distribution, one-way ANOVA was used to analyze differences in subjective well-being and built environment assessment among different groups using the SPSS 22.0 [63,64]. Non-parametric tests analyzed differences for variables that did not follow a normal distribution. To address the mechanisms influencing residents'

subjective well-being, this study conducted collinearity tests and general linear regression to identify factors that affect their subjective well-being using the SPSS 22.0.

3. Results

3.1. Resident Depiction According to Different Subjective Well-Being Levels

According to the correspondence analysis results, there are three types of residents, depending on the type of community, level of subjective well-being, and demographic characteristics (Figure 6). Type A consists of residents with a higher level of subjective well-being, mainly living in old communities, with lower incomes, younger in age, and lower educational levels. Type B represents the residents with a moderate level of subjective well-being, primarily residing in unit or policy housing communities. They are generally of middle-range income, older, mostly freelancers or retired individuals, holding at least a bachelor's degree, and managing to maintain high-frequency visits to the community's public space. Type C includes residents with a lower level of subjective well-being, predominantly residing in new commercial housing communities. They are generally aged between 25 and 45 years with higher education levels, working mainly in government agencies, public institutions, or companies, with higher family annual incomes. However, these residents, significantly, seldom utilize the community-built environment in terms of frequency and duration of public space usage.

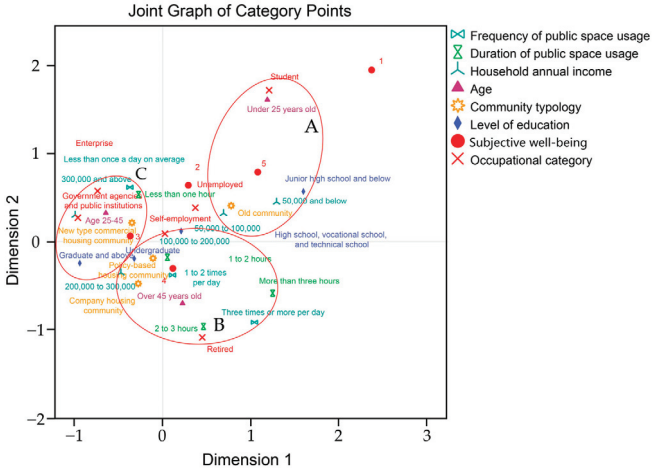

Figure 6. Depiction of residents. Note: the A, B, C represent the residents of Type A, Type B and Type C, and the number 1–5 represent the levels of subjective well-being.

3.2. Differences in Subjective Well-Being and Built Environment Assessment among Communities

Overall, residents have relatively high levels of subjective well-being. Residents in the old community have the highest subjective well-being (3.93/5), while residents in policy housing communities have the lowest (3.37/5).

Residents in different communities have different satisfaction levels but a consistent rating order for the built environment components (Figure 7). As for the built environment assessment, residents in the old community have the highest satisfaction levels in all aspects of the built environment, while residents in policy housing communities have the lowest. Specifically, residents in the old community rate the built environment as 3.5/5. As for the built environment components, residents of all types of communities are most satisfied with neighborhood relations and least with architecture and landscape, as well as production and consumption.

Age influences levels of subjective well-being and partially affects the evaluation of the built environment (Figure 8). According to the ANOVA test and corresponding multiple comparison test results, residents under 25 exhibit significantly higher levels of subjective

well-being and built environment assessments than the other two age groups. While there is a significant difference in subjective well-being between the other two age groups, there is no significant difference in satisfaction with the built environment components. This may be partly due to the relatively broad categorization of age groups and, on the other hand, to the more mature and stable perceptions of middle-aged and older populations.

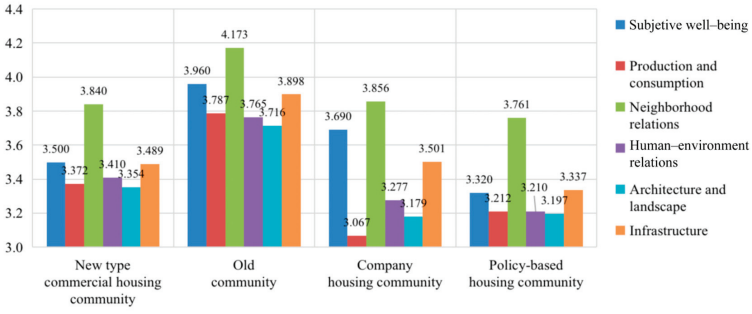

Figure 7. Subjective well-being and built environment assessments among residents of four types of communities.

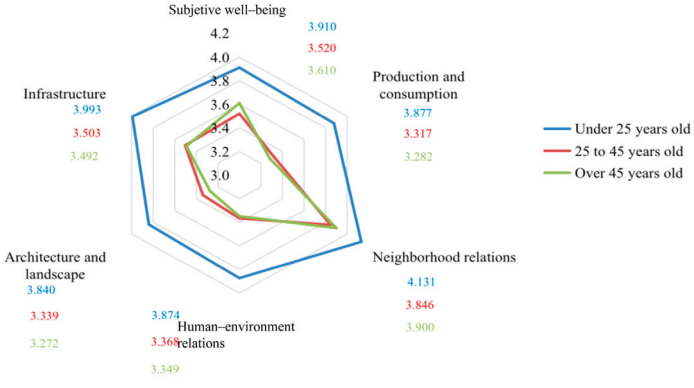

Figure 8. Subjective well-being and built environment assessments among residents of different age groups.

Education partially influences subjective well-being levels and the built environment's evaluation (Figure 9). According to the ANOVA test and corresponding multiple comparison test results, residents with a below junior high school education show a significantly higher subjective well-being and built environment assessment than other educational groups. Residents with a high school education or higher have relatively consistent and lower levels of subjective well-being and built environment assessments. Specifically, residents of all educational levels express the highest satisfaction with neighborhood relations, while they show the least satisfaction with production and consumption, as well as architecture and landscape.

Occupation also influences subjective well-being levels and the built environment's evaluation, except for neighborhood relations (Figure 10). Based on the population characterization results, residents are divided into three categories: those without employment (including freelancers, unemployed individuals, and retirees), corporate and public enterprise employees, and students. According to the ANOVA test and corresponding multiple comparison test results, the three occupation groups have significant differences in subjective well-being and built environment assessments, except for neighborhood relations. The student demographic exhibits the highest level for subjective well-being and the built

environment, whereas freelancers report the lowest levels for subjective well-being and the built environment. All three groups demonstrate the greatest satisfaction with neighborhood relations and the least satisfaction with architecture and landscape elements and aspects related to production and consumption.

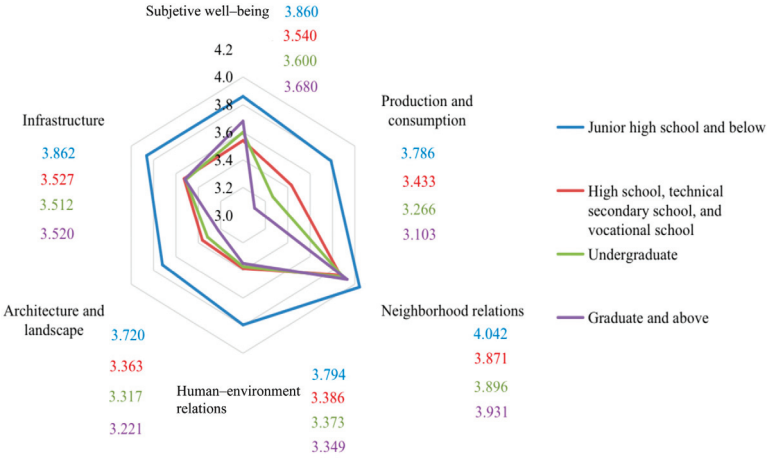

Figure 9. Average subjective well-being and built environment assessments among residents of different educational levels.

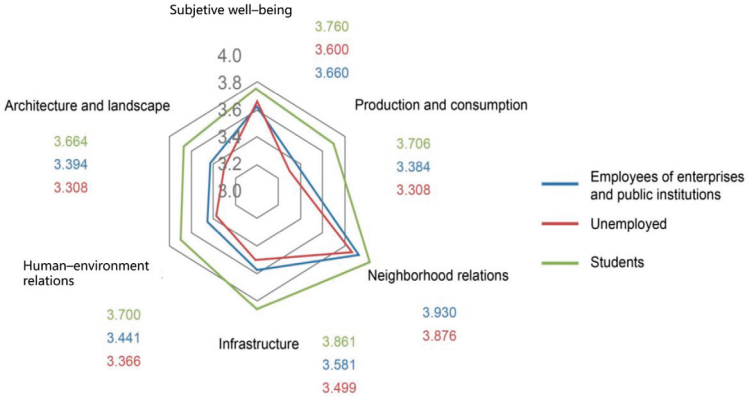

Figure 10. Average subjective well-being and built environment assessments among residents of different occupations.

3.3. Influencing Mechanisms of Residents' Subjective Well-Being

For overall residents, education level, overall built environment evaluations, and the four aspects of the built environment positively enhance residents' subjective well-being (Table 4). Regarding the built environment, seven indicators in the four categories of the built environment factors significantly affect residents' subjective well-being. Specifically, the green coverage rate (0.190), the overall natural environment of the community (0.163), and the overall functional layout of the community (0.134) have the highest effects on residents' subjective well-being. Duration of public space usage (0.068), education level (0.066), and groundwater drainage (0.061) have the highest effects on residents' subjective well-being. Most built environment factors positively impact subjective well-being, except for architectural density, where a higher density correlates with lower subjective well-being levels. The indicators of production and consumption do not significantly impact residents' subjective well-being.

Table 4. Influencing mechanisms of residents' subjective well-being.

Category	Indicators	Overall	New Commercial Housing Communities	Old Communities	Company Housing Communities	Policy-Based Housing Community
Basic Information	Age		−0.108 ** (0.031)	0.139 *** (0.001)		
	Education Level	0.066 *** (0.008)	0.118 *** (0.007)			
	Occupation					
	Frequency of Public Space Usage	0.074 *** (0.008)	0.120 ** (0.049)			
	Duration of Public Space Usage	0.068 ** (0.028)		0.109 *** (0.005)		
Overall assessment	A1 Overall Natural Environment of Community	0.163 *** (0.000)			0.206 ** (0.013)	
	A2 Overall Functional Layout of Community	0.134 *** (0.001)		0.253 *** (0.000)		
Architecture and Landscape	E1 Green Coverage Rate	0.190 *** (0.000)		0.097 ** (0.044)	0.253 *** (0.007)	0.236 *** (0.003)
	E2 Environmental Cleanliness					
	E3 Openness of View					
	E4 Landscape Harmony	0.078 ** (0.018)	0.207 *** (0.003)		0.152 ** (0.024)	
	E5 Sound Environment Quality					
	E6 Crowdedness of Community					
	E7 Community Crowdedness					
	E8 Air Quality	0.090 *** (0.005)		0.208 ** (0.014)		
Neighborhood Relations	S1 Knowing Many Neighbors					
	S2 Good Community Security					
	S3 Trust in Neighbors					
	S4 Willingness to Help Each Other			−0.270 *** (0.006)		
	S5 Neighbors Activities					
	S6 Sense of Identification with Community Culture					
	S7 Social Interactions with Community Members	0.131 *** (0.001)				
Infrastructure	F1 Facility Accessibility					
	F2 Facility Safety	0.080 ** (0.038)				
	F3 Diversity of Facilities					
	F4 Concentration of Facilities					
	F5 Road Connectivity					
	F6 Nighttime Illumination					
Human-environment relations	Sm2 Conditions for Cooling off					
	Sm3 Building Crowdedness	−0.085 ** (0.043)				
	Sm4 Aesthetic Quality of Surfaces					
	Sm5 Architectural Layout					
	Sm6 Landscape Distribution			−0.082 *** (0.001)		
	Sm7 Security Environment	0.075 *** (0.009)				
	Sm9 Biodiversity of Flora and Fauna					
	Sm10 Ground Water Drainage and Retention Conditions	0.061 ** (0.013)			0.174 *** (0.002)	
	Sm11 Exercise Activities			−0.013 *** (0.006)		
Production and Consumption	Sm8 Vehicle Traffic Environment					
	Sm12 Convenience of Commerce			0.016 *** (0.008)		
	Sm13 Diversity of Commerce					

Note: *** $p < 0.01$, ** $p < 0.05$.

The factors influencing residents' subjective well-being vary significantly across different types of communities. In new commercial housing communities, population character-

istics, such as age and education level, are the factors that mainly influence the residents' subjective well-being. For the old communities, there are more indicators in four aspects of the built environment that play an essential role in influencing subjective well-being than in other communities. For company housing communities, architecture and landscape and human–environment relations are the main factors that influence the residents' subjective well-being. However, only the green coverage rate impacts subjective well-being in policy housing communities.

For the residents in new commercial housing communities, age, education level, overall built environment evaluations, and architecture and landscape affect residents' subjective well-being. Specifically, older age correlates with lower subjective well-being (−0.108), whereas higher education levels (0.118) and more frequent use of public spaces (0.120) are associated with higher subjective well-being. Among specific elements, only the harmony of the landscape (0.207) affects residents' subjective well-being, but it is the most important factor that influences the residents' subjective well-being.

For residents of old communities, age, duration of public space usage, overall built environment evaluations, and six indicators in four aspects of the built environment affect residents' subjective well-being. Residents of older age are associated with a higher level of subjective well-being (0.139), possibly due to stronger human—environment relations. Furthermore, longer usage of public spaces indicates a higher level of subjective well-being (0.109), reflecting a deeper interaction between elderly residents and their community environment. As for architecture and landscape, the green coverage rate (0.097) and air quality (0.208) positively influence the residents' subjective well-being. Regarding neighborhood relations, more mutual help correlates with dissatisfaction (−0.270). As for factors related to human–environment relations, higher satisfaction with exercise activities correlates with lower subjective well-being (−0.013), suggesting that subjective well-being and its influencing factors should not be simplistically viewed as unidimensional. The convenience of commercial services effectively enhances subjective well-being in old communities (0.016).

4. Discussions

4.1. The Subjective Well-Being and Built Environment Conditions in Different Communities

The results indicate that subjective well-being and the built environment assessment is the highest in old communities, but the lowest in policy housing communities. The high level of subjective well-being and built environment assessments in old communities might be attributed to the renovation of old communities, which has also been proven in studies of Spain, Australia, and the USA [65–67]. Recently, the Beijing government issued the "Beijing Old Communities Renovation Work Reform Plan" to address the deteriorated and poor conditions of community environments that had been neglected over the years. Moreover, the plan involved soliciting public opinion extensively, ensuring that the renovations met the residents' needs. For instance, in Taipingqiao Dongli, multiple open spaces within the community were renovated to improve the condition of public spaces, while in Tayuan Community, illegal constructions were demolished, and the green spaces were uniformly refurbished. The environments of the five selected communities were improved to some extent as a result. In contrast, policy housing communities generally scored lower in all aspects, possibly because affordable housing is often located further from the city center. These locations' spatial and social isolation significantly contribute to less hospitable living conditions, making it challenging to meet the actual needs of low-income residents.

The distinct satisfaction levels across different community types underscore the critical role of urban policy and governance in influencing residents' subjective well-being. The superior satisfaction levels reported by old community residents across various dimensions can be attributed to the social cohesion and established networks often found in such environments. This observation emphasizes the positive impact of community bonds on individual subjective well-being [68,69]. This finding aligns with previous studies highlighting the significance of social connections and community engagement in enhancing subjective well-being. For instance, Helliwell et al. (2018) found that social participation

significantly boosts life satisfaction [70]. In Japan, research indicates that neighborhood social capital positively influences mental health [71]. In contrast, the lower satisfaction levels in company housing communities, particularly regarding production and consumption and architecture and landscapes, highlight the need for a holistic approach to urban planning that integrates economic opportunities with aesthetic and functional considerations [72]. Studies in various countries also emphasize this need. For example, research in the United States suggests that mixed-use developments can enhance both economic vibrancy and community well-being [73]. Similarly, European urban planning models advocate for integrating green spaces and aesthetic elements to improve life quality in urban settings [74].

4.2. The Demographic Difference in Subjective Well-Being and Built Environment Assessments

This study categorized residents into three types: higher subjective well-being levels mainly residing in old communities, moderate subjective well-being levels living in unit and policy housing communities, and lower subjective well-being levels mainly in new commercial housing communities. The higher subjective well-being in old communities might be related to their lower life expectations and a stronger sense of community belonging. Life satisfaction often correlates with how personal expectations are met, with lower expectations making it easier for residents to feel satisfied [75,76]. Additionally, residents of old communities might have developed stronger neighborly relations due to long-term residence, an important factor in enhancing subjective well-being [77]. For other communities, despite their higher economic status and educational levels, their subjective well-being levels were not as high as those of old communities. This observation aligns with the theory of relative deprivation, which suggests that an individual's subjective well-being may decrease if their achievements seem less compared to their reference group, even if their absolute conditions have improved [78]. Studies have supported this theory, showing that individuals' well-being is influenced more by relative than absolute income [79]. Particularly for new commercial housing communities, despite higher household incomes, the underutilization of community public spaces indicates a lack of sufficient community belonging and social interactions, another key factor affecting subjective well-being [80].

Our findings reveal that younger residents exhibit significantly higher levels of subjective well-being and built environment assessments. This indicates a potential alignment with the aspirations and values of younger generations, who may prioritize different aspects of the built environment than their older groups. This aligns with the observations that younger individuals tend to have more adaptable perceptions of their living spaces, influenced by contemporary societal values and trends [81,82]. Additionally, the higher subjective well-being and satisfaction levels in built environments among younger residents might suggest that recent advancements in urban design are more aligned with the preferences and needs of younger populations. This resonance could be due to younger individuals' openness and adaptability to new concepts in living environments that prioritize sustainability, technology integration, and flexible spaces—features that are increasingly emphasized in modern urban planning. This inclination towards new urban designs might also be bolstered by younger individuals' greater propensity for embracing change, allowing them to more readily appreciate and find satisfaction in innovative urban landscapes that differ from traditional setups [83,84].

Educational levels play a complex role in shaping residents' subjective well-being and satisfaction with the built environment, with those possessing lower educational qualifications reporting higher levels of satisfaction. This could reflect a discrepancy between expectations and reality, where higher education levels may correlate with higher expectations [85]. The universal appreciation for neighborhood relations across educational levels underscores the fundamental human need for social connection, highlighting the intrinsic value of community ties [86,87]. As for occupation, the contrasting levels of satisfaction observed among students, freelancers, and corporate or public enterprise employees suggest that one's occupation influences how one interacts with and perceives

the built environment. Students reported the highest satisfaction. On the other hand, freelancers displayed the lowest levels of satisfaction, which could be attributed to the precarious nature of their work and the need for a supportive environment that fosters creativity and productivity [88].

4.3. The Influencing Mechanism of Subjective Well-Being Considering Different Types of Communities

The influencing mechanism of subjective well-being should consider the needs of different age groups in various community types. For residents of new commercial housing communities, older residents are associated with lower subjective well-being levels, possibly related to younger people's higher adaptability and openness, compared to older individuals' lower adaptability and openness. Young people may find it easier to integrate into new environments and derive satisfaction from them. Conversely, for residents of old communities, age and subjective well-being are positively correlated, possibly reflecting older individuals' attachment to the community and the value of established community networks. This aligns with research on the relationship between age and subjective well-being, demonstrating different perceptions and experiences of subjective well-being across age groups [89].

Residents' subjective well-being under different community types is influenced by different built environment factors. Residents of company housing communities are more concerned with the overall natural layout of the community. Neighborhood relations, infrastructure, and production and consumption conditions do not significantly impact subjective well-being. Company housing communities, usually designed for employees of specific units or institutions and their families, might have considered overall environmental harmony and natural beauty from the beginning. Residents' focus on the natural layout might reflect expectations for a high-quality living environment, especially in urban settings where natural elements enhance life quality. This echoes theories in environmental psychology which emphasize the restorative effects of natural environments on psychological well-being [22,46]. For example, a study in the Netherlands found that access to green spaces significantly improves mental health and overall life satisfaction. Similarly, research conducted in South Korea shows that urban parks and green spaces play a critical role in reducing stress and enhancing the quality of life [90]. Residents of company housing communities might have tighter community connections due to shared work backgrounds and social networks, which could make the direct impact of neighborly relationships on subjective well-being less significant than other factors [91]. Meanwhile, these communities might already possess infrastructure and services meeting basic living needs, so further improvements in these areas might not significantly increase subjective well-being. Policy housing aims to provide economically suitable living conditions, emphasizing cost-effectiveness, and might lack in some aspects (e.g., design, facilities) compared to commercial housing. In this context, the green coverage rate becomes a key factor for enhancing residents' subjective well-being because green spaces not only serve an aesthetic function but also contribute to improving air quality, reducing noise pollution, and providing leisure and recreation spaces directly related to residents' daily life quality [91–94]. Research shows that green spaces positively impact mental health and well-being [37,95].

An interesting finding is that, in old communities, the more help is provided among residents, the less satisfied they are. This might reflect internal social pressures or excessive demands on individuals' time and resources. In close-knit community relationships, too many social demands can lead to stress, especially when such help becomes expected or obligatory. This phenomenon is widely discussed in social psychology, where excessive social support is sometimes seen as a burden, affecting individual psychological health and subjective well-being [96]. For example, a study in Sweden found that excessive social demands in tight-knit communities can lead to increased stress and lower overall satisfaction among residents [97]. Similarly, in the United States, a study by Thoits (2011) demonstrated that while social support generally benefits mental health, too much support

can become burdensome and negatively impact individual well-being [98]. Additionally, while mutual help reflects community cohesion in dense community networks, it can limit individual autonomy. Too many community duties and expectations might conflict with individual needs and desires. This conflict can lead to dissatisfaction, especially in cultures that highly value individual autonomy. This highlights the complex impact of community participation on individual subjective well-being, noting that while community involvement can enhance social capital and individual satisfaction, excessive community demands might conflict with individual autonomy, leading to dissatisfaction [99].

In older communities, the negative correlation between the reasonableness of landscape distribution and residents' subjective well-being might be more complex. Firstly, residents of older communities might be conservative toward any form of change, even if those changes are intended to improve their living conditions. This conservative attitude partly stems from people's sense of belonging and security in familiar environments, providing psychological comfort and stability. Environmental psychology offers a framework to understand this phenomenon, emphasizing the importance of harmonious relationships between people and their environments on individual psychological health [100]. Residents' emotional attachment to their living places, especially in older communities, significantly affects their acceptance of environmental changes [101]. Thus, measures aimed at improvement might be seen as threats to this harmonious relationship, eliciting residents' maladaptation or dissatisfaction. This finding relates to the dual impact on social cohesion and individual satisfaction. Moreover, the physical environment of a community profoundly affects residents' social behaviors and interactions. Residents of older communities might have established stable social networks and daily behavior patterns based on the current environmental layout. Changing these environments, even to improve life quality, might disrupt these established patterns, causing residents to feel uneasy and dissatisfied. Residents' reactions are not only averse to the changes themselves but also fear losing the community belonging and identity established over a long period of living.

4.4. Policy Recommendations

Comprehensive strategies to enhance overall well-being should cater to the distinct characteristics of different community types. New commercial housing communities should focus on improving landscape harmony and the quality of public spaces to meet residents' demands for aesthetic and harmonious living environments. It is advised to enhance community appeal by increasing green coverage, improving the aesthetic design of public facilities, and optimizing landscape layouts. Simultaneously, encouraging activities in communal places within the community can foster interactions among residents and a sense of belonging. The renovation of older communities should pay closer attention to the actual needs of residents and their sense of human–environment relations, avoiding dissatisfaction due to excessive commercialization or over-regulation. Renovation efforts could focus on improving infrastructure quality and the usability of public spaces while preserving the community's cultural characteristics and historical memory. For residents of older communities, strengthening community services and support systems, especially social support for elderly residents, can effectively enhance their well-being. Company housing communities and policy housing should emphasize increasing green coverage and environmental quality while improving neighborly relations and community participation. This includes creating more public gathering points and organizing community activities to enhance interactions and cooperation among neighbors. For policy housing, considering its unique community location and resident composition, measures to provide convenient transportation links and increase employment opportunities are needed to reduce residents' feelings of social isolation.

Personalized strategies for enhancing well-being based on population characteristics are also necessary. For the young, highly educated population living in new commercial housing communities, it is suggested to develop more career development platforms and social activity spaces, such as co-working spaces, community learning centers, and creative

workshops. This not only satisfies their pursuit of a high-quality living environment but also promotes their professional and personal growth. Additionally, increasing resources related to education and technology and encouraging residents to participate in community innovation projects can improve their sense of community belonging and subjective well-being. For middle-aged and older residents of older communities, the focus should be on improving and providing more age-friendly health and leisure facilities, such as building walking paths, fitness areas, and easily accessible community health points to meet their health and lifestyle needs. Considering the social pressure issues that may arise from close neighborhood relations within the community, it is recommended to set up dedicated community support services, such as regularly holding mental health workshops and providing conflict resolution and community counseling services, to maintain a harmonious community environment and alleviate residents' psychological burdens. Furthermore, for residents of company housing communities and policy housing, policies should focus on improving the quality of public spaces and green environments, for instance, by optimizing green coverage and enhancing the diversity and accessibility of public facilities, to enhance the attractiveness of these communities as places to live. Especially for policy housing communities, enhancing the completeness and diversity of community services to address potential spatial and social isolation issues can improve their quality of life and well-being.

5. Conclusions

Taking four typical community types in Beijing as examples, this article explores the differences in subjective well-being among residents and their influencing mechanisms, revealing several key findings: (1) Residents can be categorized into three distinct types, based on community type, subjective well-being, and demographic characteristics. Type A comprises residents with higher levels of subjective well-being, predominantly living in older communities. These individuals typically have lower incomes, younger ages, and lower educational levels. Type B exhibits moderate subjective well-being and primarily resides in unit or policy housing communities. Type C includes residents with lower levels of subjective well-being, mainly living in new commercial housing communities. (2) Overall, residents exhibit relatively high levels of subjective well-being. Residents in old communities report the highest subjective well-being scores (3.93/5), while those in policy housing communities report the lowest (3.37/5). Across all residents, the green coverage rate (0.190), the overall natural environment of the community (0.163), and the functional layout of the community (0.134) are the most influential factors. (3) The factors affecting residents' subjective well-being differ substantially across community types. In new commercial housing communities, demographic characteristics such as age and education level are the primary influencers of subjective well-being. In old communities, multiple indicators related to the built environment play a critical role. For residents in company housing communities, architectural and landscape features, along with human–environment relations, are the main determinants of subjective well-being. In contrast, in policy housing communities only the green coverage rate significantly impacts subjective well-being. However, it is noteworthy that some counterintuitive phenomena emerged among the influencing factors, such as more mutual help among neighbors correlating with less satisfaction, and higher satisfaction with exercise activities correlating with less subjective well-being. This might be due to the concentrated age distribution of the surveyed population, leading to biased results, or it could indicate that from the residents' perspective, these counterintuitive phenomena represent their true demands, similar to the reverse qualities in the Kano model. Future research by the authors will further investigate these counterintuitive phenomena.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land13060793/s1, Survey Questionnaire on the Impact of the Built Environment on Residents' Subjective Well-being.

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Review

Architectural Continuity Assessment of Rural Settlement Houses: A Systematic Literature Review

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Abstract: As a significant component of rural settlements, residential architecture is a record of historical changes containing considerable research value. In the study of residential architectural continuity, the focus is on the inheritance and innovation of traditional residential architectural "genes" in contemporary new residential buildings. Based on a systematic review of the literature, the purpose of this study is to analyze the research trends, categories, and variables relating to architectural continuity in residential buildings, and to build a systematic and comprehensive framework for assessing the architectural continuity of residential buildings in rural settlements based on prior research. This study provides guidance and references for evaluating the design of new residential buildings in rural settlements and for formulating regional planning principles. Using the PRISMA guidelines as the basis for the review method, we filtered the literature from three databases: Web of Science (WoS), Scopus, and EI, and studied the 40 articles selected at the end. As can be seen from the results, the literature on architectural continuity in rural settlements has focused more on functional and typological levels and less on the archetypal level of architectural continuity (user behavior). Still, the archetypal level is the most important, because the behavior of housing users directly influences the degree to which housing is continuous in terms of its function and type. The most important finding of this review is that the resident behavior of housing users has a significant influence on the assessment of the continuity of housing architecture, and thus, the continuity of housing architecture in rural settlements must be assessed in conjunction with user behavior.

Keywords: rural settlement; residential architecture; continuity; systematic literature review

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1. Introduction

Vernacular architecture represents cultural patterns and lifestyles. It is closely related to space, time, and materiality [1]. In the course of its development, the user makes the necessary changes according to social and environmental constraints in order to adapt them to the actual needs of each place [2]. Residential architecture is a major component of vernacular architecture [3]. An analysis of 127 studies over the past 30 years shows that the number of studies on vernacular architecture has increased dramatically since 2007 [4], demonstrating the significant potential of research on the continuity of residential architecture. But continuing the traditional architectural features in the new houses isn't easy [5]. In 1999, the International Council on Monuments and Sites (ICOMOS) adopted the Charter for the Heritage of Vernacular Architecture, which explicitly stated the need to maintain architectural coherence through the continuity of architecture [2]. Therefore, it is essential to investigate the continuity of residential architecture.

The Oxford Dictionary defines the word "continuity" as "the persistence or operation of something over time and space" that has two layers of connotation. On one

hand, "continuity" can be described as the preservation, maintenance, or protection of an object, emphasizing that the original object is preserved in the objective spatial environment as time changes. On the other hand, continuity can be more focused on persistence, specifically on the objective level of objects, especially residential buildings, which are affected by changes in time, space, and human activities, and will eventually disappear one day. The word "continuity" can then be understood as the ongoing existence or functioning of content, the inheritance and continuation of the architectural characteristics of residential buildings, which is similar to the concept of "morphogenetic", which originated in the field of biology. It is also important to note the following: in this paper, we propose traditional residential architecture that refers to architecture with regional features, constructed using local materials and traditional craftsmanship in the context of conventional production and life, reflecting residents' social habits and cultural values [6]. In general, continuity in residential architecture is no longer seen as simply preserving what remains of the past, but rather as concentrating on inheriting and developing the unique features of traditional residential buildings in contemporary new residential buildings [7].

Architectural continuity has been extensively studied. The famous architect Bruno Zevi discussed the study of the spatial continuity of Gothic architecture in his book "Architecture as space" as early as 1993. He argued that the spatial continuity of Gothic architecture is the result of the dynamic development of society, and that the degree of continuity represents the vitality of the architecture [8]. Although residential architecture represents local culture and tradition, it does not necessarily mean it is 'timeless' or 'unchanging' [7]. Influenced by socio-economic patterns and lifestyles, "change" is accepted as part of the continuity of residential architecture [9]. Rural settlements maintain their continuity in the process of constant change, and they pass this on to the next generation through social production, adoption, and transmission [10–12]. The continuity of residential architecture in rural settlements is a dynamic concept closely related to social change and development. The discussion on the continuity of residential architecture is more about the recreation of the dynamic evolution of residential architecture; it is also the process through which there is a continuance of its unique identity.

However, in recent years, the residential architecture of rural settlements has been influenced by the interregional spread of culture and global socioeconomic transformation [10]. Both new residential architectures in the same region and traditional residential architectures face the problem of style discontinuity. Scholars have approached this question from two perspectives. Researchers have focused on assessing the continuity of architectural forms. Several studies point out that new residential houses in villages entirely mimic the forms of urban architectural design, neglecting regional characteristics and causing the problem of formal discontinuity between new and traditional residential homes in rural settlements [13–17]. In terms of this level of research, researchers primarily use quantitative analysis to compare the similarity and consistency of the objective forms of traditional and new housing, and then assess the degree of housing continuity. On the other hand, many researchers focus on assessing the continuity of architectural culture in residential buildings [18–21]. Various regional, ethnic, and religious cultures influence the creation and continuity of the residential architecture. Qualitative analysis is used to analyze the cultural aspects that influence residential architecture, with the researcher making subjective judgments about the degree of continuity of the residential architecture, and offers corresponding suggestions for improvement.

The above two aspects of research allow us to learn that in the process of continuity of residential architecture and because of the different focuses of research, the resulting assessment of continuity of residential architecture is often limited to one level in the absence of a comprehensive evaluation of continuity of residential architecture. There are differences in research methods and variable selection, which hamper the assessment of the continuity of residential architecture to some degree. Thus, this study aims to construct a systematic and comprehensive framework for assessing the architectural continuity of rural settlements based on previous studies, which is of practical importance for the development

of planning principles and maintenance of the architectural features of rural settlements. To this end, this study asks the following questions: (1) What are the trends in studying the architectural continuity of rural settlement housing?, (2) Which category is the most important for studying architectural continuity in rural villages? What is the reason?, and (3) What variables are involved in the study of architectural continuity in rural villages? A systematic review of the literature on the subject of architectural continuity of rural settlements would allow us to quantify the importance of the methods and variables used in the assessment of architectural continuity in residential buildings. It would also enable us to construct a systematic and comprehensive framework for assessing the architectural continuity of rural settlements from both architectural character and resident behavior perspectives, based on the points of view of previous studies, which may help the country or region inherit regional features and maintain diversity in architectural culture.

2. Materials and Methods

This study followed a systematic literature review process adapted from that of Boland et al. (2017) [22]. A protocol for searching and screening articles to minimize bias and ensure the accuracy and comprehensiveness of the data was developed [23]. A systematic literature review enables a comparison of inconsistencies in the literature on a particular research area to guide decision-making [24] and to identify future research directions as well as research frameworks [25–27]. Following the preferred reporting items for systematic reviews and meta-analyses guidelines, keywords relevant to this study were identified. Next, the process of literature selection and collection is described; that is, searching the literature through databases and performing initial refinements and exclusions within the databases. Finally, by developing an inclusion and exclusion criteria, the literature derived from the database was rescreened using Rayyan (a web and mobile app for systematic reviews) to determine the final number of studies to be included [28]. Rayyan helps to rapidly screen the literature; it is a semi-automated way of handling documentation and allows multiple individuals to work together through networks, which is an obvious advantage compared to the literature screening tools used in the systematic literature review. The Scopus, Web of Science, and EI databases were selected because they contain a wide range of data [29] and are peer-reviewed with high authority, ensuring the quality of the literature.

2.1. Keyword Selection

Firstly, we entered the keywords “residential”, “continuity”, and “village” into the three databases for the initial search. We found one, six, and five articles related to the keywords, respectively, but they were considered invalid because these numbers of articles returned were rather insignificant. To expand the results, we added search terms related to this study by referring to keywords in the systematic literature review related to residential architecture to ensure that more literature could be obtained [30,31]. Next, to address the issue of selecting keywords for the search, we conducted a discussion with experts in the field of residential architecture research within the group and, in the process, added keywords related to the study of the continuity of residential architecture, such as vernacular architecture, similarity, and inheriting. Finally, we used synonyms for “residential architecture”, “continuity”, and “rural” and used the wildcard “*” to construct our search formula for a comprehensive literature search (Table 1).

Table 1. Keyword selection.

Residential Architecture	Continuity	Countryside
Vernacular architecture	Continuity	Village
Traditional courtyard	Consistency	Countryside
Residential	Similarity	Rural
Dwellings	Inheritance	
House	Cultural sustainability	

2.2. Literature Search

We searched three databases, beginning in April 2023, to identify the literature required for a residential architecture continuity review. The literature search formula (Table 2) was constructed using keywords from Part One, and a literature search was conducted through 2022 to ensure the reproducibility of the study [32]; the language of the literature was limited to English to ensure that the expression of ideas in the literature could be accurately judged in the next stage, namely reading the literature to avoid misunderstandings. We searched the Web of Science database by selecting the citation indices SCI, SSCI, and AHCI from the core collection, which resulted in 563 articles. Since the search process involved keyword matching only, a large number of papers outside the scope of the present study were obtained, which had to be initially screened using the filter bar on the left-hand side of the database for articles unrelated to this study. A total of 117 articles remained after this screening process. This search form was imported into the Scopus database, which yielded 1151 articles, and after excluding the categories of topics unrelated to this study, 359 articles remained. The same search form was entered into the EI core database, yielding 1050 articles, and after excluding the articles unrelated to our search domain by "controlled vocabulary", 407 articles remained. Our initial screening yielded 883 studies. The acquired literature was exported to the database as the basis for the second literature screening.

Table 2. Database search build.

Database	Search Type	Result
WoS	(TS = ("Vernacular architecture" OR "residential" OR "Traditional-Courtyard" OR "dwellings*" OR "house*")) AND (TS = ("Cultural sustainability" OR "continuity*" OR "consistency*" OR "Similarity*" OR "inheriting")) AND (TS = ("Village*" OR "countryside* OR "rural"))	117
Scopus	(TITLE-ABS-KEY ({vernacular architecture} OR {traditional courtyard} OR residential* OR dwellings* OR house*) AND TITLE-ABS-KEY (continuity* OR consistency* OR similarity* OR {cultural sustainability} OR inheriting) AND TITLE-ABS-KEY (village* OR countryside* OR rural*))	359
EI	(((((Vernacular architecture or Traditional Courtyard or residential or dwellings or house) WN KY) AND ((Cultural sustainability or continuity or consistency or Similarity or inheriting) WN KY)) AND ((countryside or village or rural) WN KY)))	407

2.3. Literature Screening

Given that the 883 articles screened in the database were only obtained by keyword matching and that there were different research topics within them, we had to obtain more literature that corresponded to the purview of the current study by importing it into Rayyan, a web and mobile app for systematic reviews, for a second screening (based on title and abstract) [28]. First, to save time in the screening process, it was necessary to check for duplicates of these 883 articles before the secondary screening. Because different databases duplicate the same articles, the literature with high similarity was listed by the duplicate filter command of the Rayyan application, after which 64 duplicate articles were deleted, leaving 819 articles. Second, we performed a second screening of the literature based on the developed inclusion and exclusion criteria (Table 3), combined with the literature titles and abstracts. Rayyan provided a visualization of titles and abstract content so that we could read it more easily, and we obtained 66 articles after the second literature screening. We then had to conduct a third screening (full-text reading) to ascertain whether the 66 articles we had screened were closely linked to the concept of residential continuity that our current study was exploring. For the full-text reading process, the exclusion and inclusion criteria were based on whether the articles addressed continuity in residential

architecture. In the end, after the third literature filtering, we obtained 29 papers directly related to the continuity of residential architecture in rural settlements. To ensure the completeness of the study, we also included 11 additional articles through the snowball literature screening approach, and 40 articles were ultimately identified as the sample for the present study. The flow diagram of the literature search and screening is depicted in Figure 1. The remaining authors participated in a third full-text screening of the 66 articles to increase the validity of the study. Sixty-six articles were assigned to the "included", "excluded", or "unsure" category. The reasons for uncertainty were recorded in writing, and the final decision on inclusion was reached through a group discussion to address the areas of controversy. Furthermore, to ensure rigor in the included literature and to invite experts (This research group) to sample the quality of the third literature search from the final 40 screened articles, experts within the subject pool selected one piece out of five for full-text reading to determine the accuracy of the list included in the literature.

Table 3. Inclusion and exclusion criteria.

Inclusion Criteria	Exclusion Criteria
Residence	Non-residence
Related to continuity	Nothing to do with continuity
Rural area	Non-rural areas

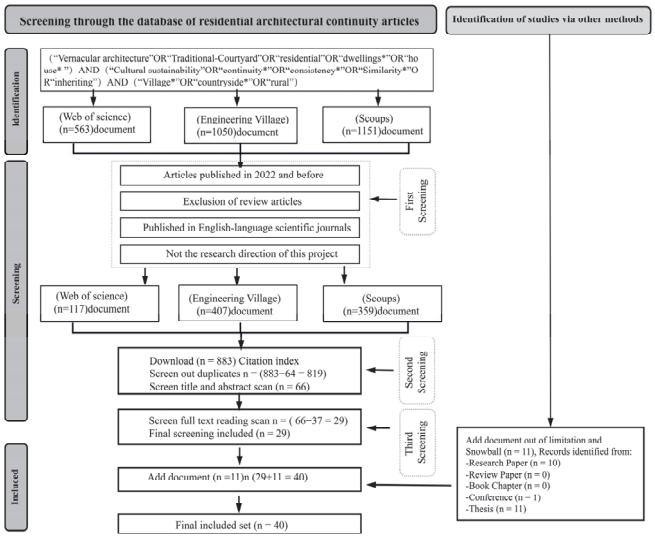

Figure 1. PRISMA flow diagram for the article selection process.

3. Results

3.1. Tendencies in the Study of the Continuity of Residential Architecture

Table 4 shows that most studies of architectural continuity in rural settlements were conducted in developing countries in the eastern hemisphere, with the highest number of studies being conducted in China. This is because villages are gradually being incorporated into urban areas with the expansion of cities in developing countries. In that process, traditional housing faces the problem of conservation and development [33], which also demonstrates that research on the continuity of housing architecture needs to pay greater attention to the developing world.

Table 4. Article of the included studies based on PRISMA statements.

Study ID	Title/ Author	Region	Continuity Classification	Constant	Model/Theory/ Methodology	Nature of Research
01	[14]	/	continuity of type	culture	Recog-Net	quantitative and qualitative combination
02	[34]	Indonesia	continuity of archetypal	custom culture values belief	Mimesis-semiotics method	qualitative analysis
03	[35]	Algeria	continuity of type	culture values custom lifestyle	Typological analysis Spatial syntax gamma analysis	quantitative analysis
04	[36]	Iran	continuity of type	culture	Mathematical relations Python	quantitative and qualitative combination
05	[33]	Poland	continuity of archetypal	culture lifestyle custom	Variance clustering	quantitative and qualitative combination
06	[37]	China	continuity of type	culture custom memory belief	SPSS Matlab	quantitative analysis
07	[38]	Palestine	continuity of function	culture	EDSL	quantitative analysis
08	[39]	China and Poland	continuity of function	culture custom concept	/	qualitative analysis
09	[40]	Marshall	continuity of archetypal	culture value belief	/	qualitative analysis
10	[21]	India	continuity of type	social culture	Justified Floor Plan Spatial syntax	quantitative and qualitative combination
11	[41]	/	continuity of type	culture concept	/	qualitative analysis
12	[42]	Turkey	continuity of archetypal	culture memory	Plot comparison data comparison	qualitative analysis
13	[17]	Italy	continuity of type	values culture lifestyle	Clustering principal component analysis	quantitative analysis
14	[43]	Indonesia	continuity of function	philosophy culture values	life-cycle analysis	quantitative analysis
15	[44]	Cyprus	continuity of function	philosophy	Mahoney table method	quantitative and qualitative combination
16	[45]	China	continuity of function	cognitive	/	qualitative analysis
17	[46]	Turkish	continuity of type	culture social values	Shape syntax	quantitative analysis
18	[47]	China	continuity of function	culture	SI	qualitative analysis
19	[48]	Turkey	continuity of archetypal	culture values custom memory	/	qualitative analysis
20	[49]	/	continuity of type	culture lifestyle	/	qualitative analysis
21	[50]	Bulgaria	continuity of function	/	/	qualitative analysis

Table 4. *Cont.*

Study ID	Title/ Author	Region	Continuity Classification	Constant	Model/Theory/ Methodology	Nature of Research
22	[51]	China	continuity of function	culture rules habit values	/	quantitative analysis
23	[5]	Thailand	continuity of function	/	Analytic Hierarchy Process\Multiple criteria Decision Making \Similarity to Ideal	quantitative and qualitative combination
24	[52]	China	continuity of function	philosophy custom culture	/	qualitative analysis
25	[53]	Egypt	continuity of type	culture values	/	qualitative analysis
26	[54]	China	continuity of type	custom culture	/	qualitative analysis
27	[55]	China	continuity of type	culture custom	/	qualitative analysis
28	[56]	China	continuity of function	custom belief values habit behavior	/	qualitative analysis
29	[57]	Cyprus	continuity of archetypal	environment culture value lifestyle	/	qualitative analysis
30	[58]	Turkey	continuity of type	culture belief values environment memory	/	qualitative analysis
31	[12]	Indonesia	continuity of archetypal	Rules values culture belief lifestyle	/	qualitative analysis
32	[11]	Indonesia	continuity of archetypal	environment	naturalistic paradigm	qualitative analysis
33	[59]	Indonesia	continuity of type	values lifestyle	/	qualitative analysis
34	[60]	Algeria	continuity of type	culture	Spatial syntax gamma analysis	quantitative and qualitative combination
35	[61]	Turkey	continuity of type	environment culture memory emotion	/	qualitative analysis
36	[1]	/	continuity of function	motion culture values memory	/	qualitative analysis
37	[62]	China	continuity of type	memory emotion culture	/	qualitative analysis
38	[21]	Marshall	continuity of archetypal	culture values memory belief lifestyle	Spatial syntax	quantitative and qualitative combination
39	[63]	Itcaly	continuity of type	culture social	Variance clustering	quantitative and qualitative combination
40	[64]	Sri Lanka	continuity of function	philosophy values	/	qualitative analysis

In terms of the trends in research methods on the continuity of residential architecture, a visual analysis was conducted on the techniques, models, and theories used in the continuity of residential architecture in the included literature. As shown in Table 4, the most prominent feature of the methods used in exploring the continuity of residential buildings was cross-use. A few studies have been conducted in one way, and the cross-use of methods can explain and analyze the research objects more clearly. Space syntax, gamma analysis, cluster analysis, and variance are the methods used to study the continuity of residential buildings. Space syntax is the most frequently used because it mainly analyzes the spatial organization of the study, which is also the most commonly used content in research on the continuity of residential buildings. On the other hand, the spatial syntax method (a new language for describing architectural and urban spatial patterns) focuses on analyzing the spatial organization of the building (plan). However, other variables in the assessment of the continuity of residential buildings, such as material, color, and structure, should be compared using cluster analysis and the variance method. Cluster analysis and the variance approach can analyze multiple variables involved in residential building continuity and rank residential building similarities (using formulas) to compensate for the lack of research on spatial syntax [33]. As shown in Table 4, 24 out of the 40 articles were included in the qualitative analysis. In recent years, the number of qualitative and quantitative studies has increased. Thus, the framework for assessing the continuity of residential buildings constructed in this study was a combination of quantitative and qualitative studies. We did not plan to use a single method, but a combination of the spatial phrase method, gamma analysis, cluster analysis, and variance method, as needed.

3.2. Research Classification of Continuity of Rural Settlement Dwellings

The "deep beauty" framework proposed by Professor Gary J. Coates for local architecture research was used for reference in the classification of residential architecture continuity research. This framework is primarily composed of three interlinked levels: functional, typological, and archetypal. Research papers on the continuity of residential architecture can be categorized in terms of the different emphases on the three levels of the "deep beauty" framework. It also forms the basis of the framework for assessing the continuity of residential architecture in the present study, namely the continuity of function, type, and archetype (Table 4).

"The functional level includes design for all the pragmatic needs of the building's users. Truly functional buildings are also artfully integrated with their sites and respond simply and appropriately to the available sunlight, wind, and light. Such buildings, which are always no larger than they need to be, are necessarily energy efficient" [65]. Residential buildings continue to function primarily through the extraction of environmentally friendly technologies, such as ventilation, thermal insulation [52], and thermal insulation of traditional residential buildings in rural areas. By combining them with modern technologies and applying them to contemporary new residential buildings to alleviate the problem of transient energy consumption in modern construction technologies while improving the comfort of residential buildings, the continuity of the function of traditional residential buildings is realized. Many studies have proven that learning about ecological construction experience (use of renewable materials, the selection of appropriate wall thicknesses for insulation, and the selection of appropriate window and door sizes) from traditional dwelling building functions is no longer an option [5,13,14], but a must [66]. In contrast, the continuity of residential building functions should not only focus on energy savings, renewable resources, or building technology but should also consider the psychological will of residential users [67]. A unilateral focus on building sustainability tends to ignore the actual needs of users.

"The typological level involves the adaptation of bio-regional building traditions and historically situated building types in the design of contemporary buildings that are capable of evoking a sense of connection with history, community, nature, and place" [65]. By continuing the type of residential building, something, both familiar and unfamiliar,

is created by redesigning the form of the residential building to fit the characteristics of the time [37,49,53,55,62,63]. Residential architecture is an ever-changing entity with transformations in time and space [1]. In addition, the continuation of residential building types is similar to the concept of "morphogenesis". Extracting morphological features from traditional residential buildings, transforming them, and applying them to new contemporary residential buildings, can evoke user connections to the area, enhance residents' sense of identity for new contemporary residential buildings, and play a significant role in continuing residential buildings.

"The archetypal level is the deepest layer of meaning and metaphorical significance in architecture. Buildings that reach this level lead users back through layers of consciousness and time from the outer surface of the waking mind to the depths of what Carl Jung calls the collective unconscious" [65]. The study of the archetypal dimension of the continuity of residential architecture involves the collective unconscious, which Jung argues consists of archetypes and is a model of instinctive behavior [68]. In other words, the archetypal dimension of continuity in residential architecture focuses on the behavior of residential users. Residential user behavior reflects cultural values, akin to the modern Western emphasis on "persons with a sense of continuity and tradition do not need to preserve the past [69]". Therefore, research on the archetypal continuity of residential buildings must focus on the behavior of users in residential spaces.

In summary, the functional level focuses on energy conservation and energy sustainability, which can be summarized as a study of building applicability; the typological level focuses on the redesign of morphological elements in residential building types, which is a continuation of the regional characteristics of residential buildings; and the archetypal level emphasizes that the formation of residential buildings is the presentation of the collective unconscious, which is influenced by cultural values and it impacts the continuation of residential buildings through the behavior of residential users. Following the "deep beauty" framework proposed by Professor Coates, the three levels of function, type, and archetypal focus on different study aspects. The 40 included articles were categorized, revealing the following (Figure 2). It can be seen that the research literature on the continuity of residential architecture is predominantly focused on the level of type, followed by the function level, and there is a relatively low focus on the archetypal level because research on the continuity of residential architecture is mainly conducted from the perspective of architectural design, with a focus on exploring the objective elements of the architecture, and it easily ignores the influence of user behavior on residential space. In recent years, however, there has been a growing trend in research into the continuity of residential architectural archetypal, and the research approach is primarily qualitative, with a focus on residential resident behavior [17].

Figure 2. Classification of residential building continuity.

3.3. Variables of Continuity in Residential Architecture

The residential building continuity variable was divided into two levels: architectural characteristics and resident behavior. Extracting the continuity variables from the literature (Table 5) allowed us to determine their importance in the continuity study process. This laid the groundwork for selecting variables for a residential building continuity assessment framework. The architectural character variables were ranked according to the number of variables involved in the study of the continuity of residential architecture (top 10) in the order of materials [33], plan [35], technology [45], morphology [36], decoration [33], color [17], volume [17], structure [47], façade [48], and size [51]. Materials are the most commonly used construction variable because they are the most rapidly updated and are closely related to advances in construction technology. Resident behavior variables were ranked according to the number of variables involved in the study of the continuity of residential architecture (top 10) in the following order: construction [43], cooking [46], rites [56], parties [39], sleep [40], socializing [8], maintenance [56], storage [49], rest [36], and feeding [46]. Construction, cooking, and ritual behaviors are also the primary focus of behavioral research because they are related to the everyday lives and spirituality of residential consumers. Through the study of residential behavior, we can understand, to a great extent, the reasons for ecological technology at the functional continuity level of residential buildings. The study of culinary behaviors can reveal the roots of the family rituals of residential users, and ritual behaviors are related to the production of certain special elements, spaces, and forms in residential spaces. In addition, the variables of architecture and behavior involved in the continuity of residential architecture intersect in the study of functions, types, and archetypes. Moreover, they are not limited to a single level, which also shows that any variable in the residential space is influenced by many aspects, and that the evaluation of the continuity of residential architecture needs to be viewed systematically and holistically.

Table 5. Continuity of residential architecture variables.

Building Variables	Study ID	Number	Behavior Variables	Study ID	Number
material	01 04 09 10 12 15 16 21 23 26 31 32 34 37	14	construction	09 11 13 14 15 21 22 24 25 26	10
plane	03 08 12 16 24 25 31 32 37 34	10	cooking	04 09 10 12 16 20 29 31 37	9
technology	04 13 22 25 29 31 32 37	8	rite	02 09 22 31 32 36 37	7
morphology	02 04 10 16 20 22	6	party	03 08 09 10 16 25 33	7
decoration	02 09 14 31 36	5	sleep	04 09 10 12 23 29 37	7
color	09 16 29 32 34	5	socializing	03 10 25 31 32 34	6
volume	11 20 25 38	4	maintenance	09 12 13 15 22	5
structure	02 03 12 31	4	Storage	02 10 20 38	4
facade	08 10 13 33	4	rest	04 31 32 34	4
size	15 38	3	feeding	10 12 25 34	4

4. Discussion

Globally, research on architectural continuity can be traced back to the study of urban morphology in England, Italy, and France. The British Conzenian school combined urban planning with research on urban morphology and introduced the concept of morphogenesis into the field, focusing on studying the morphology of the built environment during historical change. In contrast to the British school, the study of Italian urban morphology was closely integrated into the practice of architectural design in cities from an early stage, with a focus on combining local features of buildings in the design process and an emphasis on the continuity of the inherent laws of architecture (the law of space organization) [70]. This also played a role in guiding the conservation of historic architectural heritage in this period. The French studies of urban morphology, influenced by the Italian school, share similarities with it, and it focuses on the dialectical relationship between the physical

development of cities, types of residential buildings and residential building design from the point of view of topological–geometric relationships, with a focus on "pure" morphology [71]. Therefore, the history of early urban morphology in Western countries shows that, although there is sufficient research on the analysis of architectural forms from the perspective of urban morphology, research on architectural continuity is mainly based on objective physical aspects. With this in mind, the research in this study will supplement the user behavior factors that affect the continuity of the architecture of rural settlements.

The categorization of the 40 papers in the study revealed that the number of studies addressing the archetypal level of continuity of residential architecture is lower than the functional and typological levels, but they are the most significant ones because the extraction of constants (extracted through articles) in the study of residential building continuity reveals (Table 4) that the functional, typological, or archetypal levels of residential building continuity involve factors, such as culture, values, customs, and memories, which influence the creation of residential buildings through the behaviors of users. It is thus clear from the analysis above that the behavior of residential building users, which is emphasized at the archetypal level, is an essential part of assessing the continuity of residential buildings, and the most important finding of this review is the construction of a combined architectural character and resident behavior framework for assessing the continuity of residential buildings by considering the behavior of users as a component of the continuity assessment framework of residential buildings. Here, we use both architectural character and resident behavior terms because we wish to show that the continuity of residential buildings is influenced not only by a single level of objective (architectural form aspect) but also by residential user behavior, which affects the continuity of residential buildings. Thus, the evaluation framework constructed in this study includes both levels.

Traditional residential architecture, as a continuous creation of life, is composed of three interlinked levels: function, type, and archetypal. First, from the functional level of residential buildings, although passive ecological technologies can meet the needs of contemporary space users to a certain extent compared with active cooling and heating technologies, active technologies break the limitations of the climatic environment for residential buildings, which provide obvious comfort and dynamism, and it is problematic to explore continuity only at the functional level. Second, at the type level, residential material variables account for the largest proportion of the research literature on the continuity of residential buildings. However, the continuity of residential buildings faces difficulties in providing traditional building materials (both subjective factors, such as government restrictions, and passive factors, such as the disappearance of resources or environmental damage) and the loss of knowledge of traditional construction techniques, which result in certain obstacles in the continuity of residential buildings. The emergence of new materials and technologies that are faster and cheaper, and more convenient construction methods, have consistently impacted the continuity of original building types. Finally, the continuity of the architectural archetype of residential buildings emphasizes the behavior of the residential users. In researching housing function and type, scholars have noted that the degree of continuity in the function and type of traditional housing is influenced not only by the local environment, but is also linked to resident behavior [53,72]. In other words, the evaluation of the continuity of rural settlement housing architecture must combine three levels: continuity of function, continuity of type, and continuity of the prototype.

First, based on the variables obtained from residential building continuity in Table 5, the ten most critical architectural variables were selected in the order of material, plan, technology, morphology, decoration, color, volume, structure, façade, and size, according to the coding arrangement from A-1 to A-10. In the process of field research on the continuity of residential buildings, we can use photography, mapping, and aerial photography to collect the objective aspects of the continuity of residential buildings as the primary data of the continuity of residential buildings. Furthermore, at the behavioral level of continuity of residential buildings, top ten variables were selected based on their importance in the following order: construction, cooking, rites, parties, sleep, socializing, maintenance,

storage, rest, and feeding. These variables were used as critical components of the research, and ranked in order of importance as numbers B-1 to B-10. Primary data were obtained through structured and semi-structured interviews and focus group discussions. The importance of numbers 1–10 in the ranking of the variables represents the weight of the score or comparison.

Second, through the above discussion on the trend of residential building continuity research, it is well known that evaluating the continuity of architectural features uses the spatial phrase, gamma, cluster, and variance methods. The spatial sentence method focuses on plane deconstruction. In contrast, the gamma analysis method can compare the similarity between the planes of traditional and modern houses after an investigation, using the spatial sentence method. In addition, combining the cluster analysis and variance method allows the similarity of other elements to be compared. The architectural continuity scores of residential buildings can be quantified using questionnaires and expert ratings, and scores were matched based on the importance of previously quantified behavioral variables. The questionnaire design was combined with a Likert scale, and the results were mainly composed of offline and online components to ensure comprehensive data acquisition. We analyzed the results for different age groups to select the final questionnaire, and aggregated the questionnaire scores with expert ratings. The degree of continuity between the architectural characteristics of traditional rural and contemporary residential buildings was derived by assessing the variables of both architectural features and user behavior, and quantifying specific numeric results in the preparation for the next stage of total score classification [17].

Finally, continuity scores in terms of architectural features and user behavior were summarized, and the degree of continuity of residential buildings was broken down into four ABCD grades by expert consultation, from the highest to the lowest. A level is defined as the continuity level of residential buildings with reasonable continuity, B level indicates that there are some problems in the continuity of residential buildings with room for improvement, and the residential buildings listed as C level suggest that there are serious problems. Rectification should be conducted according to the continuity variables of residential buildings. D-grade residential buildings indicate a loss of continuity. The constructed evaluation framework compares the continuity between traditional and new housing such that higher ranks imply better preservation of regional features that are important in shaping the value of architectural uniqueness and maintaining the diversity of architectural culture. In this study, a framework was constructed to assess the continuity of residential architecture and to understand the continuity of residential functions, types, and archetypes as dynamic and systematic (Figure 3). Based on this, a systematic evaluation framework combining architectural characteristics and user behavior was constructed to evaluate the design schemes of the residential buildings that have been put to use, and the new contemporary residential buildings or those that will be put into construction to ensure the continuity of traditional residential buildings in various regions (Figure 4).

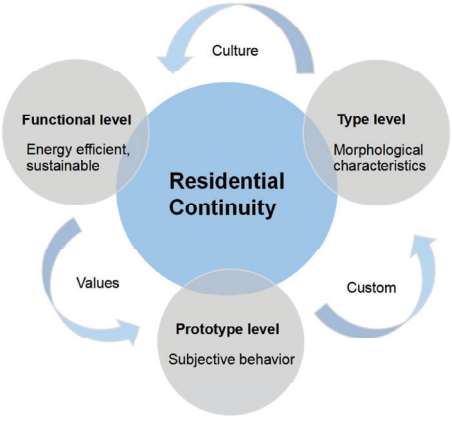

Figure 3. Continuity of residential architecture.

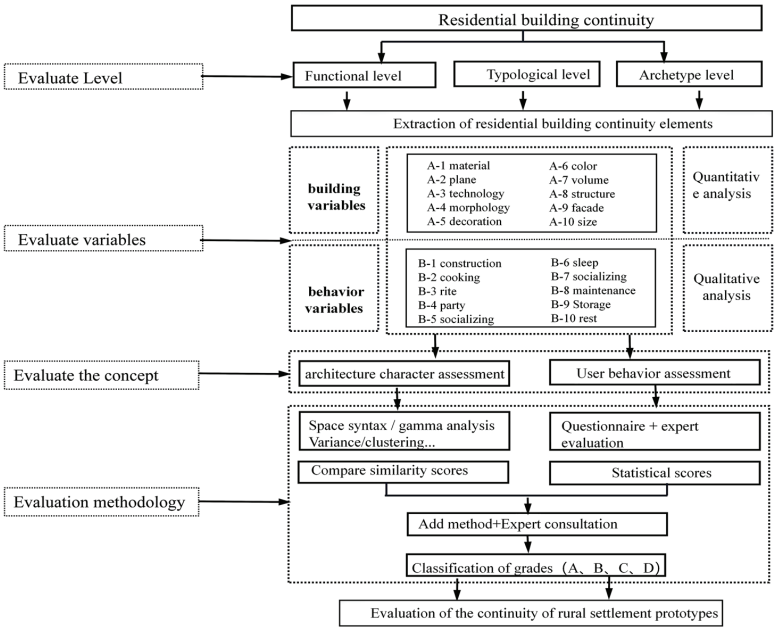

Figure 4. Continuity of the residential architecture assessment framework.

5. Conclusions

Today, traditional houses, which are an important part of the country's rural settlement heritage, are increasingly surrounded by typical urban dwellings, which are creating difficulties in the continuation of traditional houses and the transmission of culture. This study aimed to conduct a systematic literature review of the continuity of residential architecture in rural settlements and obtained 40 articles on the subject of residential architecture continuity by searching and filtering three databases (peer-reviewed and highly authoritative): WoS, Scopus, and EI. Through a review of those 40 papers, we found that the critical problem in the study of the continuity of residential architecture in rural settlements is the lack of focus on the behavior of residential users. Research on residential building continuity often begins with the objective aspect of residential building functions and the type and study of building materials, plans, technology, and other elements, although it

involves the archetypal level including the culture, values, customs, and other elements that affect the behavior of users. However, these studies focused on the objective elements of buildings and the environment. Therefore, an evaluation framework should be built using a human-centered approach that focuses on the study of user behaviors [73]. During the construction of the evaluation framework, we also quantified the research variables involved in the 40 residential building continuity articles, divided them into two levels, user behavior and architectural characteristics, and selected ten variables each from the levels of user behavior and architectural attributes according to the frequency of different variables. A range of research methods, such as the spatial sentence method, gamma analysis, cluster analysis, and the methodological method, which have been used often in previous studies, were combined to assess the characteristic building variables and user behavior variables. In addition to a framework for assessing the continuity of residential buildings in rural settlements based on function, levels of residential building types and prototypes, and the combination of architectural features and user behavior was constructed.

Inheritance of traditional homes requires an effort to establish a concept of "continuity" during the building stage [1]. Combining the features of architectural forms from traditional residential architecture and new materials reduces the damage caused by foreign architectural structures to the unique architectural style of rural settlements. This ensures harmony in rural landscapes. Furthermore, while inheriting the regional features of traditional residential architecture, more attention should be paid to the study of residents' behavior and routines. The development of an assessment framework for the continuity of residential buildings can help planners and designers to evaluate the continuity of residential buildings, develop regional planning principles, and implement design plans more efficiently.

This systematic review has some limitations. In terms of research content, the study of the continuity of rural settlement dwellings is mainly influenced by Western urban morphology. Previous studies have primarily focused on the objective architectural level, with less focus on the level of user behavior. Regarding the research methodology, we selected only three peer-reviewed, highly authoritative databases in the screening phase, and restricted the language to English, which may have resulted in missing some search results. We also included only high-quality reports with well-cited references [24], and excluded notes, webpages, and unpublished paper sources. Objective factors limited the systematic review conducted in this study.

Studying the continuity of residential buildings in rural settlements involves many theories in Western urban studies. As part of our future research, we plan to apply theories such as morphogenesis and typology to the study of rural residential architecture, which can potentially broaden the scope of theoretical inquiry to some degree. Furthermore, we plan to conduct an empirical investigation into the construction of a residential building continuity assessment framework to continue improving the hierarchical evaluation rules of the evaluation framework in the process of evaluating the continuity of residential buildings in different rural villages, in order to test the practicality of the evaluation framework for residential building continuity in rural settlements.

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Civil Society Mobilizations Shaping Landscape in Genoa and Girona Areas: Results and Lessons Learnt from the Savingscapes Project

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Abstract: This paper deals with the results of the "SavingScapes" research project, where Girona (SP) and Genoa (IT) areas were chosen as case studies to assess the role and relevance of civil society in landscape alteration and conservation. These contexts share many features which led to similar transformative pressures and consequent deeply rooted place attachment clashing in the form of social mobilizations. Nevertheless, the civil society approach and actions proved profoundly different. Hence, there is a need to define a shared methodology to make them comparable. The authors define seven categories, ranging from defeat to prefigurative politics, to assess local mobilization in terms of territorial impacts.

Keywords: environmental mobilization; sustainable planning; landscape; preservation; territorial identity

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1. Introduction

The present work investigates social mobilization theories as an instrument or context to highlight their relevance to an issue that is central to this research: the preservation of territory and landscape. The starting hypothesis is that mobilization has played a key role in the construction and visibility of territorial and environmental issues [1,2]. Finding solutions largely depends on the actions and consequences of mobilizations. The present work focuses on the results of environmental mobilizations in two province-sized areas: the Metropolitan City of Genoa in Italy and the Province of Girona (Figure 1), on the Spanish side. Although these two sub-regional territorial units have much in common, from their coastal location, to the driving forces behind their economy, and the fact that their landscape plays an important role in development, activism, and the link between their inhabitants and their natural surroundings, they host very different human settlements.

In terms of population, Genoa counts a five-fold number of Girona inhabitants. Genoa represents the capital and socio-economic hub of a linear continuous conurbation along the coast of the Liguria Region, where the port economy and industry have shaped its development for decades, while Girona is one of the several inner centers (the only place where the population exceeds 100,000) of a multi-nodal network of towns, cities, and counties throughout the region.

Despite their deeply different backgrounds, a constant transformative pressure acting in both contexts, together with a strong attachment to places, has driven people to react and mobilize.

In these mobilizations, a different cultural approach can be traced: Genoa acts as a merely urban subject, while Girona shows a strong rural identity. Nevertheless, certain parallels and similarities have been detected. An extraordinary quality landscape in both areas is the common layer on which the opportunity for local activation linked to territorial identity and the preservation of natural spaces is historically linked. For both,

the perception of destructive forces acting on the landscape identity characters is a key factor that explains the movements activation process.

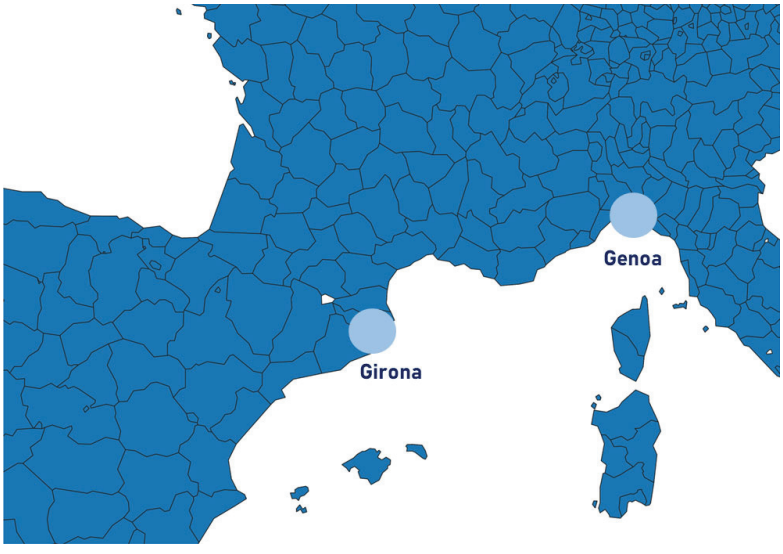

Figure 1. Location of Genoa and Girona areas.

A further focus of the research deals with the role that territory plays in forging the local identity and culture, in terms of relevance within public debate and governance tensions and conflicts, and on how civil society relates to land planning, management policies and instruments.

To this aim, the authors will introduce an outcome-based approach to analyze several case-studies from both contexts through the lens of the results achieved by local movements mobilization.

The present work is structured into four sections. Initially a theoretical framework is defined on the link between social movements and territorial identity and preservation. The chosen methodology and the analytical categories defined for the case-studies' assessment are introduced, as well.

The Section 2 deals with the description of the two study areas. The authors review the main socioeconomic and planning stages throughout the last 50–70 years, as well as the evolution of those movements and respective actions concerning territorial-environmental issues.

The Section 3 focuses on the results of the research, where the aim of the authors is to provide an original taxonomy-made up of seven impact-based categories- to assess mobilizations' outcomes from both territories. The Section 4 summarizes the structural role of mobilizations in territorial and heritage governance and preservation.

2. "Savingscapes" Project: Theoretical Framework and Methodology

2.1. Movements in the Last Decades' Theories

While the definition of a single theoretical basis from the many possible ones is not the aim, it is essential. Theories of social mobilization have been widely researched and debated in the field of political science since the last quarter of the 20th century (Figure 2). The roots of social mobilization stretch back at least a century, but it was only in the 1980s that people began to talk about the "New Social Movements" [3,4]. It was then that the ability of mobilizations to bring people together visibly and make an impact gained importance and when, from the theoretical perspective, analyses aimed to explain how social mobilization is constructed [5].

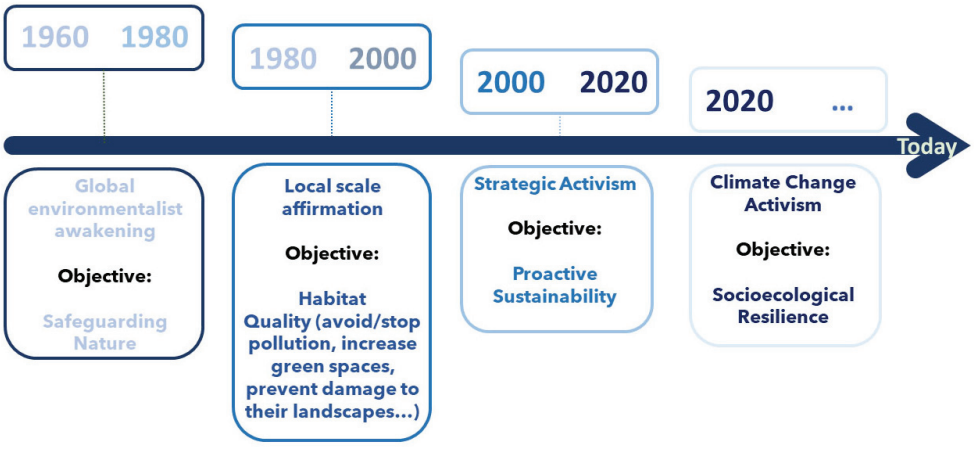

Figure 2. Environmental movements approach and evolution cycles.

Numerous authors [6,7] have discussed the concept of identity as a two-fold argument in this context: firstly, in interpreting the social foundations of movements, and secondly as the set of threatened values triggering the mobilization.

Indeed, the territory, natural environment, or landscape features may play several roles within social mobilizations: they may act as a reason for their existence; as a pretext; as a stage; as an instrument; or as an objective, being territorial and environmental impacts one of the most explicit manifestations of the consequences of economic, technological and social transformations, but landscape impacts constituting a common and useful instrument of representation of identity and social agglutination [8].

Social movements with territorial and environmental claims have been increasingly seen as a common manifestation of social discontent around the planet. Several authors such as Subra in 2016 [9] give various reasons for this, such as a loss of prestige and legitimacy of the institutions and/or experts that promote, endorse, and design large projects that modify the environment and the landscape. Other authors, such as Nel.lo in 2003 [10], note that it is another consequence of the rescaling processes [6,11] that "fracture" the relationship between the territories that undergo the transformations, and where the profits produced return to.

Territorial conflicts have become increasingly common in Italy and Spain as their industrialization, service economy, urbanization, and the rise of the middle class has expanded and become established. Further to this last aspect, global data on environmental conflicts show a certain correlation between the number of mobilizations and the level of well-being and this is one of the reasons that environmentally-damaging activities are being relocated to the global south [12]. One explanation of this dynamic is that the sense of belonging has become an essential aspect of well-being and it causes people to react and mobilize. The loss of this sense of belonging can be traumatic, and there is evidence that it can have negative impacts on health [13].

Political Opportunity theory is undoubtedly useful in interpreting when mobilization takes place, and the results it obtains [14,15]. Moreover, in two developed regions undergoing an evolution towards more responsive and power-devolutionary democracies, the political "windows of opportunity" will tend to grow [16,17]. It is a bi-directional opportunity, from movements to political parties and institutions, and vice versa. As [18] highlights, the study of social movements needs to adopt a relational approach. In addition, the NIMBY (Not In My Back Yard) concept is taken into account, as private interests are often seen as one of the main drivers of territorial defense movements [19,20].

Finally, resulting impacts are taken as a point of analysis. Both the short-term impacts on the form of social mobilization (support, public debate, visibility), and their long-term

environmental, territorial and political outcomes are considered. As a result, in face of the rich debate around the causal effect of social movements [18], the starting hypothesis agrees with the moderately optimistic perspective regarding the "conditional effect" [21] of mobilizations: concerning the considered cases, a counterfactual analysis regarding what would have happened without the social movements would show a significant loss of quality and heritage in the two areas studied. Such a perspective may be less-frequently examined and may even be relegated to the background [18], but eventually decisive. Firstly, because it is the essential "hallmark" for the social legitimation of mobilization. Secondly, because it can increase the possibility that movements and mobilizations can continue throughout decades of territorial transformation processes.

2.2. "Savingscapes" Methodology

This research is the result of knowledge acquired from previously published results [22], combined with the analysis of documentary archives (digital and printed) and specialist publications, complementary interviews of experts, and the inference of a tentative taxonomy of territorial mobilizations according to their outcome.

An original database was analyzed with 160 cases of environmental conflicts involving 155 movements in the region of Girona over a period of 50 years. Such a wide scope overcomes certain methodological limitations in the study of the impacts of social movements, including a small number of cases, a short timescale and a focus on large organizations [18]. Data sources used were common to most research in the field [18], online newspaper archive services, printed and digital archives of environmental organizations, and direct communication with activists. Among the four theoretical dimensions, impacts; outputs; outcomes; and consequences [18–22], we focused largely on the outputs and define four typologies, according to the resolution or current status of the environmental conflict. This research has employed the same approach (Figure 3). However, the absence of a similar database in Italy led the authors to identify relevant comparable cases for the study. Starting from the need to validate the taxonomy proposed for the case of Girona, the territorial context of Genoa was chosen; this parallel does not have the meaning of a "traditional" analysis of similarities and differences, but of a verification of the identified categories.

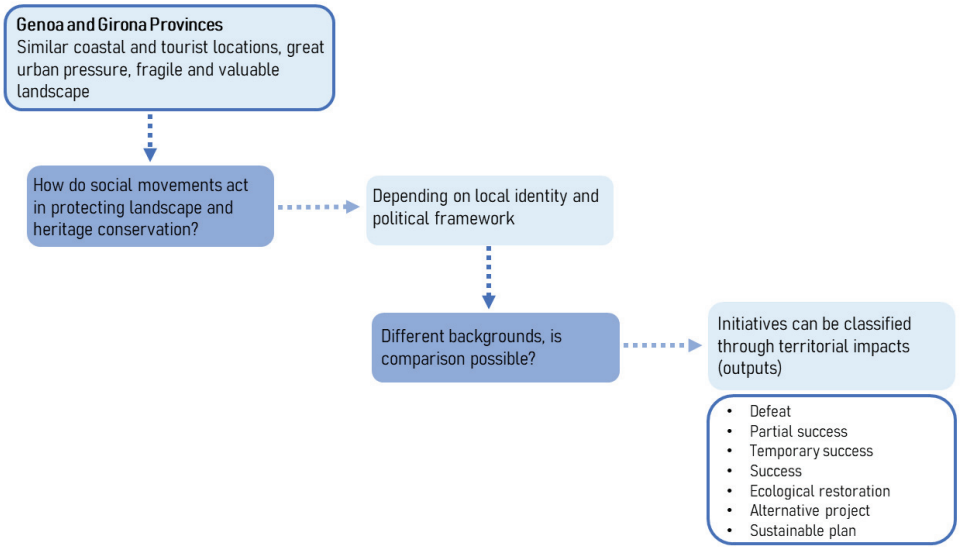

Figure 3. Case classification process flowchart (Authors).

As previously mentioned, the core aim of this research is to explore the role of civil society in shaping landscapes. This involves a deeper understanding of the impacts, in terms of territorial/environmental actions, political incidence, and societal shift. Compared to [22], a wider range of categories was inferred based on the different nature and evolving paths the conflicts took. This new, more detailed taxonomy sits on a spectrum that ranges from a worst-case scenario of the defeat of the mobilization, to the promotion of alternative projects, and even political prefiguration (Table 1). Such a wide range makes it possible to comprehend the importance of movements that arise from place attachment and/or environmental awareness in re-modelling local and regional landscapes, by generating a systematic way to integrate impacts, outputs, and outcomes. In fact, the taxonomy is rather like a Russian doll. The "Success" level states the main aim of territorial defense groups, which is to contain and impede impacts. Thenceforth, novel, more proactive notions of activism emerge that turn visions into practice, making the cultural heritage that society gains from environmentalism tangible. Hence, the impacts and consequences of territorial mobilizations are discussed from the perspective of how the social movements behind them have penetrated to the heart of territorial governance and development.

Table 1. Environmental and territorial conflicts—Impact categories. (Authors).

Defeat	Plan or project with impact on the environment, the landscape or cultural heritage, which, despite social opposition, was finally approved and carried out.
Partial Success	Project developed with significant changes due to social pressure, in order to reduce direct and indirect impact on environment and landscape.
Temporary Success	Plan or project facing social opposition that led to a tacit non-development, yet without being formally dropped. Negative public opinion, and successive delays in the approval procedure, often combined with external factors such as an upcoming election, or an economic crisis, led to the abandonment of the project.
Success	Socially rejected plan or project that did not take place due to an official mandate to halt it, from the relevant government or decision makers, or due to a court sentence. In some cases, the victory led to the establishment of a protected status for the affected feature/site/area.
Ecological Restoration	Area that, after suffering significant impacts and degradation from a previously existing activity or project, later underwent an ecological restoration initiative in response to bottom-up claims.
Alternative Project	Bottom-up and/or cross-sectoral sustainable initiatives, arising directly or indirectly from societal responses to threats against natural, cultural and environmental assets.
Sustainable Plan/Policy Prefiguration	Sustainable plan or policy resulting from the mobilization of civil society, after denouncing wide-ranging socioecological threats, unsustainable trends, and/or calls for specific policy-making or sustainable management practices.

In this sense, given the briefly introduced taxonomy, the proposed methodology needs to be implemented through the use of case studies. In particular, we therefore proceed with

the selection of territorial conflicts that have taken place in comparable contexts in order to validate the methodological approach of the research, as well as its transferability.

3. Application of Methodology: Cases Studies and Results

This section summarizes the characteristics of the two territories researched, in particular, those aspects concerning a general description of the province, detailing their local movements and planning tools (Figure 4).

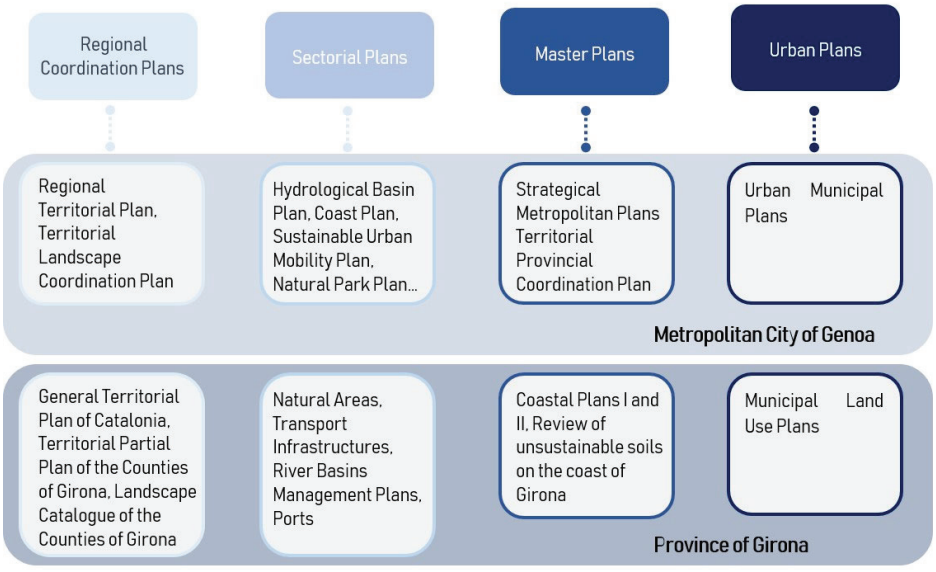

Figure 4. Case studies land planning framework.

3.1. Metropolitan City of Genoa (Italy)

Located in north-western Italy and facing the Mediterranean, the Metropolitan City of Genoa, has a population of over 812,000, across 67 municipalities, and an overall area of 1834 km^2; it is the geographical, economical and urban center of Liguria. Nearly 75% of the area's population (one third of Ligurian inhabitants) live in the capital city, and many others work or study there. It is a highly strategic logistical and infrastructural hub, Italy's biggest port (and one of the most strategic in Europe), but it is also the main cultural center with a student population of 30,000 in the university and numerous international research centers.

In order to understand Genoa, it is necessary to refer to the geographical layout of Liguria. It is a thin strip of land linking the Alps and the Mediterranean, with a maximum width that does not exceeds 40 km. Mountains cover two-thirds of the region, and, apart from the shoreline, there are no lowlands, making only a small part of the region suitable for urbanization. This becomes clearer when looking at land-use in Liguria: only 6% is classified as urban. The economic activities of Genoa and its hinterland have traditionally centered on port traffic and industry; but since heavy industry collapsed in the 1970s, the port has undergone profound transformations, making Genoa one of the most important European logistic hubs. A long period of decline led to changes in the economical assets and tourism became an increasingly important resource.

The proximity of the mountains has always been seen as a barrier to development, feeding the common mentality that the transformation of natural areas foments economic activity, and the survival of the local community and its "know-how" [23]. Thus, social movements did not generally question the construction of heavy industry, but aimed to resolve the occasional conflicts that arose when the continual damage caused by the heavy

industry reached an unacceptable level, along with an increasing awareness of the impacts of such activities.

However, a profound recession in the 1980s, along with deep demographic changes, such as an aging population, immigration from non-European countries, increasing unemployment and social degradation in the suburbs and historical center, ignited a shift in the nature of mobilizations. A number of serious industrial and natural accidents between 1985 and 1995 (the explosion of an oil storage plant, Haven oil tanker disaster and several dramatic floods), caused a change in what people valued, from quantity (income, population, volume of trade), to quality (of work, living environment, social relations). Protests spread spontaneously as a result of political problems or local environmental emergencies, focusing on general aspects related to development choices and the role of the city itself. It was the birth of the "citizens' committees", increasingly approaching local administration with demands for improvements in the environmental quality of streets and residential areas.

Committees were quite small (7–30 activists), self-organized, formed of a mix of ex-political activists, teachers, retired housewives, and supported by employees, caregivers and blue-collar workers. The average age was between 45 and 65, and members' education was middle to high. A common cultural trait, suggested by the members themselves, was "campanilismo", (a "narrow focus"). Action was short-term, and often ended once answers or promises relating to the question were received. While numerous attempts have been made to organize and therefore coordinate the activity of committees, this has never been successful, despite their territorial proximity.

In accordance with this vision, the temporary "solution" to the environmental problems proposed by the mobilized actors was to institutionalize environmental risks, thus declaring the western area of Genoa an "area at high risk of environmental crisis". This demand was rejected in March 1995 by the referring Minister. This decision had repercussions on the capacity for social and political aggregation that the local committees had developed for around a decade. Dozens of active committees were dissolved and attempts to set up a citizens' coordination of environmental committees all failed. This fostered research into the "commitism" phenomenon, which traces two driving factors to the rapid development of such forms of mobilization [24]: the notable propensity of the Genoese community towards stable housing, resulting in a strong sense of local roots and identification with the neighbourhood and low standard of local politics. Local decision makers were accused of being unable to solve the problems of inhabitants through the usual participatory channels, and of providing little information about the state of the environment and related problems. Their desire to minimize risks to their careers by justifying policies that are anything but ecological was clear through their manipulation of data [24].

The Increase in "commitism" was in parallel with a more general process of societal environmental awareness at the national level, represented by environmental associations. While, until the early 1960s, only a small group of particularly enlightened people (scientists, intellectuals, biologists, or "rich people") were aware of ecological problems, alongside historical conservation organizations such as Pro Natura and Italia Nostra, in the 1970s, ecological awareness became more widespread. Thus, a second generation of organizations arose (The World Wildlife Fund, FAI and later Legambiente, originally Lega per l'ambiente), their work merging political, technical-specialist, and educational commitments. As a result, militancy is now considered a 'job', a structured set of tasks that must be performed for results to be achieved. Simultaneously, according to authors such as Colombo in 1999 [25] there was a tangible increase in the environmental awareness of the population between the early 1980s and the end of the 1990s. However, interviews conducted in different decades [25–28] show a gap between the expectations held by citizens regarding the environment, and their ability to demonstrate real support through making specific choices.

In the last decades, despite the increasing willingness of citizens to support and listen to environmental associations, general problems (pessimism towards politics, uncertainty

about the future), and internal problems faced by the associations themselves (difficulty in replacing activists, decrease in emotional tension) hampered potential outcomes [25].

As already mentioned, the Ligurian landscape is very precious and fragile, with intensive urbanization and industrialization along the thin coastline. This local dynamic led planning legislation and tools to focus first on the protection of the natural landscape, biodiversity and historical heritage. This clashed with urban plans, which were often outdated, and only later updated and adapted to contemporary challenges.

Following a top-down and general-sectoral planning framework, land development and territorial assets are regulated by a Regional Plan (1997); a Landscape Coordination Plan (1990); Supra-local Plans (at a provincial or metropolitan scale); several sectoral plans; and urban plans for the 234 municipalities in the region. Nonetheless, actual planning first took place at the local scale after the National Law n° 1150/1942, even though many were only projects on paper for many years after the end of the Second World War. Reconstruction was rampant and unregulated, and led to high-density urbanization that had serious effects on fragile contexts, such as the coastline, where development was highly unsustainable and took no account of nature. The Ligurian landscape first formed part of planning with the 1991 LCP, the first such plan to be approved in Italy (ex-National Law n° 431/1985) and currently under review. The LCP sets specific rules to guarantee different degrees of conservation to different areas or features, according to their particular historical or natural importance.

From a sectoral perspective, one of the main fragilities of the Ligurian landscape is hydrogeological instability, due to its geographical and morphological structure, past uncontrolled coastal urbanization and, currently, climate change. Based on National Law n° 183/1989 introducing the Hydrographical Basin Plan, the Ligurian Basin Authorities produced 50 Plans. Many of these plans focused largely on hydrogeological aspects, thus ignoring the complex and systemic approach of the law to soil and water preservation, and offered only partial and temporary solutions. Regarding natural areas, while some parks have existed since the 1930s, the Parks and Reserves legislation at the national level was introduced in 1991 (National Law n° 394/1991). At present seven parks have been established.

In time, the focus on landscape protection and environment conservation in Ligurian planning, led to a freezing of the status-quo, which has resulted in the neglect of built-up areas inland where conservation did not take the form of regeneration projects [29]. Likewise, urban plans were often outdated and unable to cope with new challenges such as the aging population, sustainable development, and climate change. After a long process of regional decentralization, 1997 saw a general reform of urban planning in Liguria (Regional Law n° 36/1997). In order to adopt updated national legislation, new Municipal Urban Plans were established (PUC—Piano Urbanistico Comunale). Depending on regional peculiarities, PUCs paved the way for small greenfield intervention, thus enhancing the regeneration of brownfield areas.

3.2. Province of Girona

The province of Girona is located at the north-eastern tip of the Iberian Peninsula, within the autonomous community of Catalonia, and bordering France. With an area of 5910 km^2, and a population of 781,788 (2020), it is administratively organized into 221 municipalities. A brief summary of this territory can be based on five aspects. The first refers to an area marked by great natural and scenic diversity that combines coastal areas, the internationally famous Costa Brava, with high Pyrenean mountains and inland plains; highly fertile agricultural areas, and densely forested zones; medium-sized urban conurbations, and a multitude of small rural nuclei of medieval origin.

Two more elements are important in understanding the region. Its location is highly strategic, forming part of the main corridor between the Iberian Peninsula and the rest of Europe, and between the metropolitan area of Barcelona and the border. The diversity of landscape in Catalonia, along with its strategic location, meet in a very small geographical

area. The latter have shaped its social and cultural foundations, whether material or immaterial, whilst others, such as the presence of large logistical infrastructures and facilities, and national and international tourism have determined its economic model.

The third aspect to take into account is that the average standard of living is higher in Girona than in the rest of Catalonia, and that the region's economy has historically been both dynamic and diverse. However, recent decades have seen a growing trend towards specialization in services, public and commercial, and tourism and construction.

Although this characterization responds in many ways to a secular evolution, many contemporary dynamics were shaped in the second half of the twentieth century. An important economic aspect of the Franco dictatorship between the 1950s and 1970s was what was called "Desarrollismo" (developmentism). This was based on accelerated growth across the economy as a whole, but in particular, on the emerging importance of tourism as an economic motor. Likewise, many regional infrastructures were constructed, among them the Girona-Costa Brava airport (1967), and the motorway connecting Catalonia and France. This caused profound transformation to the landscape, whether in natural-rural environments, tourist destinations, or in urban and peri-urban areas [30]. As in many other places, what constituted an attraction for visitors was in turn a victim of its own "success".

As the dictatorship waned, the first environmental advocacy groups appeared in Girona, integrated in wider anti-Franco and pro-democracy movements. While there were few such movements in the 1970s, three had notable social and media repercussions: the "Costa Brava Debate", the campaigns for the protection of the Alt Empordà Wetlands, and the Volcanic Area of La Garrotxa. All three occurred between 1975 and 1976, and are significant and symbolic highlights of the fight against the destruction of the landscape that is mainly associated with the regime of Franco. In addition, these fights led also to the declaration of the two first regional Natural Parks in Catalonia (the Garrotxa Volcanic Area Park in 1982, and the Alt Empordà Wetlands in 1983), and were the origin of Girona's oldest environmentalist organizations. These have existed for some 30–40 years, and are the benchmark for the whole movement at a county or regional level, and include the Associació de Naturalistes i Ecologistes de la Garrotxa, 1978; IAEDEN—Salvem l'Empordà, 1980; the Associació Naturalistes de Girona, 1981; LIMNOS—Pla de l'Estany, 1987; and ADEPAR, now Emys Foundation, 1987.

The political changes of 1977–1980 led to democratic elections at national, regional, and local levels, which aroused great expectations. If speculation was a consequence of Francoism, then the disappearance of the regime should lead to the disappearance of the problem. Indeed, some leading figures of mobilizations found a new leading role in the nascent democracy, with urban planning among their most urgent priorities as an instrument to improve living conditions, social justice, and the protection of the territory. This led to an extraordinary planning effort during the 1980s and 1990s, and urban improvements were evident [31].

In the 1990s, following a boom in the construction sector (period that ended with a recession following the Olympic Games in Barcelona), it was realized that speculation was not only a mentality of the authoritarian regime, but a practice that acted on and influenced urban development under democracy as well. This triggered a new wave of environmental conflicts against housing projects and marinas, with a high impact on the territory in general and on valuable natural spaces in particular.

It was evident, then, that intense territorial transformation processes would continue in a region marked by real-estate economics, and a strategic geographical location within the Peninsula. It also became clear that awareness about the quality and value of the landscape was socially widespread.

A new growth cycle of unprecedented magnitude took place between 1998 and 2007 [32]. This gave rise, once again, to mobilizations and conflicts. Projects that had been abandoned in the previous crisis were reactivated, while new ones appeared that inspired the formation of multiple groups, often under the name "Save ... [place]". Once more, this led to a political reaction. Since 2004, coinciding with the formation in Catalo-

nia of the first progressive government in twenty-five years, new urban, environmental and landscape management legislation has been passed; these were strongly influenced by European Union Directives and specific initiatives such as the European Landscape Convention (2000), which aimed to limit very occasionally and reverse the expansion of urbanization [33,34]. Paradoxically, this change of government and policies did not reduce the pressure of movements or conflicts. On the contrary, the period until 2010 was marked by a highly developed territorial dialectic. On one hand, it was a window of political opportunity, while, on the other the actions of the new government had an impact on deeply-rooted and socialized urban speculation [17,34].

Costa Brava is probably one of the most illustrative cases. It suffered accelerated development from the 1950s with real estate and tourism as economic motors that are still decisive sixty years later. After first mobilizations took place in the 1970s, despite the constitution of democratic institutions and some relevant cases of reformist planning [35], territorial conflicts and mobilizations have become a constant [22]. Tensions represent a particular form of territorial governance, a spatial "trialectics" between tourism/real estate interests, political authorities and social movements.

Focusing on the last two decades, environmental activism around Costa Brava has also been very active, with 2002 marking a turning point in the type of demands the organizations made. After listing several plans and projects that threatened a number of natural landmarks and the landscape of the Alt and Baix Empordà counties, IAEDEN—Salvem l'Empordà deployed a county-wide campaign demanding a regional Master Plan. The Catalan Government embraced the demand with background studies starting by the end of 2002 (Anuari Territorial, 2003), and the initial approval of the Plan in May 2004 (Anuari Territorial, 2004). The Master Plan initiated extensive planning policy at the Catalan level (Table 1), and included, among others, two Coastal System Urban Master Plans (2005), a Territorial Partial Plan and Landscape Catalogue (both 2010) for the whole of the Girona region. This new regional planning policy endorsed a renewed and more comprehensive vision of the territory, aimed at tackling planning failures embedded in local plans and insufficiently integrated environmental planning.

Parallel to this new land planning culture, the construction sector collapsed following the international financial crisis of 2008 [36]. Repeating the cyclical process of previous decades, in 2018 a new wave of second residence projects encroached on some of the remaining patches of coastal land. High-end developments for the international market, fed by global capital, spurred mobilizations all along the coast under the SOS Costa Brava campaign. This movement called for an Urban Master Plan that would adapt local plans to current sustainable urban development policies and regulations. Once again, the Catalan Government reacted, and the planning procedures started in January 2019. Among its first results were two development moratoriums that impeded projects seeking to evade the new planning regulation. In January 2021, the Costa Brava Urban Master Plan was finally approved, declassifying or reducing 142 areas were to have been the site of over 15,000 housing units.

Some distinctive features of the selected case-studies for both contexts are presented in Table 2 below.

Table 2. Genoa and Girona Study Areas—Impact categories and cases' description (Authors' own).

Metropolitan City of Genoa	Province of Girona
Defeat	
Vado Ligure Gateway (Maersk Container Terminal) Port Container Platform built in Vado Ligure in 2019 **Outcome:** Environmental issues remain unsolved because of the absent local opposition.	The Very High Voltage power line (MAT) Cross-border Very High Voltage (400 kW) Power Line between Setmenat (Catalonia) and Baixàs (France), crossing several counties of Girona province. **Outcome:** The MAT case raised societal awareness of the energy system. Strategic European interests pushed for infrastructures, thus ignoring the impacts on society, the landscape and environment, as well as potential alternatives.

Table 2. *Cont.*

Metropolitan City of Genoa	Province of Girona
Partial Victory	
Genoa Gronda A new highway (about 70 km) built in the western part of the city to ease its traffic congestion, separating urban vehicular traffic from freight transport. **Outcome:** The strong opposition of local and national organizations produced progressive changes to the original project and, finally, forced the Genoa Municipality to start a public debate to discuss alternatives reducing environmental and social impacts.	Camí de Ronda de Palamós Protests and appeals against the alteration of the coastal path in Palamós led to reduced impact and corrective measures **Outcome:** No specific outcomes beyond certain changes to the project itself.
Temporary Victory/Abandoned Project	
Portofino Tunnel A new tunnel to link Rapallo, S. Margherita Ligure, and Portofino to enable easier access to the motorway (a specific route has yet to be defined) **Outcome:** Due to the impossibility to reach a compromise between stakeholders, local administrations and environmental activists, the project was postponed and traffic problems remain unsolved.	C-32 motorway prolongation New road route between Palafolls and Lloret de Mar. **Outcome:** Court of Law suspended a project due to regional climate change legislation. A new socio-political context derived from the climate crisis, also fueled by the post-pandemic concept of One Health, is questioning projects such as the C-32 or Barcelona airport's runway extension.
Victory	
ILVA Cornigliano Industry Plant One of the two main steel plants in Italy, located near the city center (in the Cornigliano neighborhood), which at one stage employed 7000 people, and produced 2 million tons of steel a year. **Outcome:** The constant pressure from workers, local inhabitants, and environmental associations, succeeded in closing the blast furnace; the industrial area was cleaned up, and jobs were protected.	Castell beach protection Residential resort project in unspoiled beach resulted in protected natural area. **Outcome:** The Castell sentences set a legal precedent regarding the absence of economic compensations for the reclassification of land with natural values as non-urbanizable. However, payments above the market price were made by the Government of Catalonia to the owners, providing the latter with a substantial profit.
Ecological Restoration	
Pra' Port Buffer Following the construction of a new port container platform in the western part of Genoa (facing the Pra' and Voltri neighborhoods), this segment of the coastline was the object of a major regeneration and ecological restoration project to compensate for the negative impact of the new infrastructure on local communities. **Outcome:** The action of environmental associations and committees succeeded in gaining compensation for the negative impacts on the quality of life caused by this large-scale strategic infrastructure. Even though the project was inevitable, a compromise was reached, leading to high quality public space for leisure and sport activities that were previously inexistent.	La Pletera coastal wetlands Unfinished residential resort project on unspoiled beach resulted in restored coastal wetlands in a Natural Park. **Outcome:** A misguided land planning model from 50 years ago was corrected, once the destruction of the coastal wetlands had started. A large natural area within a Natural Park was established, that acts as a natural solution in face of the impacts of extreme weather and climate change, as shown in the floods caused by storm Gloria in 2020.
Alternative Project	
Carmagnani-Superba Area Two large oil plants, Carmagnani and Superba, located in a residential area (the Multedo neighborhood) in western Genoa. **Outcome:** The constant action of local associations and committees for environmental and human safety forced the Genoa Municipality to strengthen the proscription of such dangerous activities, thus making it more difficult for companies to act in this area. They now make a conscious decision to move to new areas, where oil can be more easily stored.	Som Energia (We Are Energy) In 2010, the first renewable energy cooperative of Spain was established in Girona. It is now the benchmark for a change in the energy model. **Outcome:** Som Energia has become the nursery for the democratization of the energy system in Spain as thousands of people have found an alternative to the conventional utilities dominating the market, showing the potential of the cooperative economy. The cooperative also offers training to address energy-related interests and needs. Several other cooperatives have since been founded.
Sustainable Development Plan or Program Prefiguration	
Beigua Park A large nature reserve on the hills between the Genoa and Savona metropolitan areas, where titanium deposits were found. These have not yet been exploited, as ways to balance resource exploitation and sustainable development have to be agreed upon. **Outcome:** The limits imposed by nature reserves, and the opposition of environmental associations and local committees temporarily blocked the mining company's initiative. Following the consent of the Regional Administration, opposition was focused on restricting the company's action to simple scientific research, thus fighting further mining activities irreconcilable with land and nature preservation.	Costa Brava Urban Director Plan Protests from the SOS Costa Brava platform triggered the development of a new regional plan stopping the building of over 15,000 potential housing units and excluding 1200 Ha of classified land from construction. **Outcome:** The Costa Brava Urban Master Plan marked a turning point in Catalonia's regional planning. Although the Government already had such plans on its agenda, no specific timeline had been established for their implementation. In 2022, an analogous plan is under preparation for the rest of the Catalan coast (except the Barcelona metropolitan area).

4. Discussion and Conclusions

Considering outcomes and consequences of social mobilizations in Genoa and Girona, the impacts may have been diverse and spurious. Nonetheless, we can note some features common to both areas in the different forms that landscape modifications and socio-organizational systems have acquired.

These results are due to the intrinsically co-evolutionary character of the relationship between humans and the environment. In this context, social movements are the means through which society produces the resources necessary to influence the other actors in territorial governance processes, whether they are decision-makers, the media, academia, or other sectors of civil society [18].

Nowadays, outcomes of territorial mobilizations also take the form of new territorial narratives that are expressed in regulatory, policy-making, or planning initiatives. Therefore, social movements with an environmental/territorial focus become another actor in territorial development, capable of shaping landscapes in multiple dimensions: biophysical, conceptual-political and cultural-social.

As shown in the cases examined, the reality of environmental movements is increasingly complex and varied. It is a maturing process lasting several decades. We identify three periods of evolution: 1960–1980; 1980–2000; and 2000-the present, in which the demands, narrative and actions of territorial defense movements gain new layers of knowledge and vision. In the initial stages of the 1960–1970s, in parallel with a global environmental awakening (Stockholm Conference of 1972, publication of 'The Limits to Growth', etc.) it could have been thought that safeguarding nature was the main objective uniting everyone. Later on (1980–1990s), when local-scale and community engagement played a leading role in societal development (e.g., Local Agenda 21), demands from organized citizens shifted towards the quality of their habitat. In the final (and current) stage, activism is more strategic and proactively addresses sustainability (ecological restoration, alternative programs, sustainable plans and policies). A new cycle is predicted for the current decade, in which socio-ecological resilience will be the central issue, requiring even more complex interventions by the environmental movement (climate adaptation, degrowth, decision-making regarding trade-offs between energy transition and biodiversity conservation, etc.). In practice, each new period will continue to show features of the previous ones, as environmental conflicts are diverse and mobilizations tackle the issue from a multiplicity of visions, demands and interests; but in terms of territorial governance, the global evolutionary process is what we find relevant.

The relationships that the population of each city or territory has with its own sea, river, water, mountain, plain, etc. not only serve a functional value, but also a social and cultural one; they are an essential part of the Genius loci.

In this sense, we see how such a reading brings out the role of civil society in shaping landscapes in the two contexts. What emerges from the mobilizations demonstrates this precise interrelation of factors: not so much from an organizational perspective, but from their background, and the cultural outcome they propose.

- For the Genoese case, a land of limited space and insufficient agricultural resources, the exploitation of the territory has always played a role of primary importance: on the one hand it is an assurance of survival, on the other it is perennially threatened by an unstable equilibrium. Change has always been allowed, but very carefully: environmental sensitivity in the Genoese area has not acted to safeguard unspoiled natural resources, but should often be seen to be an alert of the risks resulting from excessive change, which often causes identity construction and also disappointment and resentment [27]. This is not due to a precise stance of the movements themselves, but to what has always been a "love/hate" relationship between the population and its geographical context. This is demonstrated by the lengthy Ligurian environmental planning tradition (one of the first, and most clearly defined in Italy), despite the massive change the landscape has been subject to.
- The case of Girona is, essentially, very much the same. The privileged location of the territory is its most important asset. It has enabled tourism to develop (including holiday homes), and is a highly favorable setting for industry and its related sectors, such as logistics; making it a source of socioeconomic progress. Furthermore, the landscape is a vital part of the cultural identity of its inhabitants, whether they are natives or newcomers. The landscape of Girona province is, it could be said, the other side of the coin to that of the Metropolitan City of Genoa. It is not a narrow stretch of land between steep mountains and the sea and it is a much wider mosaic of natural features and settlements. Despite such differences, the main reason why people in both areas come together and "fight" is the same; to prevent excessive change and its impact on the environment. Success in these environmental battles

becomes the primary ingredient for long-term engagement and the survival of the organizations. This, in turn, enables them to mature and better adapt to emerging socio-spatial challenges, and adopt more complex proposals and commitments.

In summary, after exploring a range of conflicts in the Genoa and Girona areas over a 50-year period, we conclude that territorial defense movements, whether in urban or polycentric territories, are decisive factors in sustainable territorial governance. The conflicts that such groups engage in add value to the decision-making processes and are vital in redrawing the limits of territorial development towards a revisionist-regenerationist scale of impacts. If the economic stakeholders are the only agents involved in formal development processes, there would no critical mass that forced public bodies to review or adapt them. Conflicts, such as that of the Gronda in Genoa, have shown the weakness of territorial governance, and the need for effective collaborative solutions to contentious development plans or, at a minimum, clear contingency plans to impede results that are detrimental to the environment.

We have also found that identity is a crucial driver of mobilization, and that place attachment (with a physical dimension that may be regional regarding territory and landscape) is one of its essential components. This means that conflicts will often depart from the NIMBY position, and that defeating a single plan that would have a negative impact on the environment is the tipping point between success or defeat of the mobilization. In territories that have undergone widespread and accelerated change since the 1950s, curbing any scale of new impacts is also a social demand for environmental justice and the right to a long-lasting sense of place. This, in turn, enhances the emotional and mental security and well-being associated with the feeling of recognizing "where we are (from)".

Finally, this place attachment triggers a co-evolutionary process with the territory, which runs in parallel to, and is fed by, more global environmental challenges. The movements often develop new approaches over time, moving from the reactive to the proactive, that eventually forms the culture of sustainability of the area in question. Thus, successfully stopping a specific plan, program, legislation, or activity, leads the groups to assume more complex challenges, that include ecological restoration initiatives, alternative projects, or strategic sustainability policies. This demolishes the concept of a paternalistic government that takes care of society, and results in the strengthening of responsive and adaptive governance as the way in which to enforce the official sustainability paradigm in real life. The impacts of territorial defense movements are not only tangible, but very clearly cultural and societal.

The nature of the proposal of such a taxonomy codified by the authors should also be emphasized. In fact, this approach presupposes an inductive methodology that, starting from the analysis of a series of case studies, allowed the authors to formulate a possible classification. However, further research could focus instead on deepening the systematic approach proper to deductive methodologies.

For this reason, future lines of research will be able to explore how this type of analysis on movements and their activation is also pertinent to other contexts which, not necessarily must have such a marked landscape value, but which from different bases may or may not reach the same impacts. In this sense, the chronological reading of the mobilizations suggests that there are "invariant" motivations of the processes inherent in the conflicts with which the authors have dealt. At the same time, there are distinctly local characteristics which constitute peculiar triggers, but which could contribute to the strengthening of the proposed taxonomy.

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Optimizing Sustainable Suburban Expansion with Autonomous Mobility through a Parametric Design Framework

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Abstract: Today, suburban areas are home to an ever-increasing majority of the global population. Models indicate that the next generation of US metropolitan growth will rapidly continue outside of urban cores, where car-based development patterns have served as the dominant paradigm for more than a century. With the emergence of autonomous mobility technologies and services, the suburbs of the future offer key opportunities to tackle pressing environmental challenges, such as significant GHG emissions from private vehicle trips, underutilized and fragmented landscape spaces, and a high proportion of impervious surfaces. To leverage this opportunity, our research team employed a novel scenario-based parametric modeling framework to generate and optimize suburban land use patterns and block configurations that leverage autonomous mobility to optimize environmental performance and accessibility metrics. The framework performed through our project, NOGAS (Next Optimized Generation of Autonomous Suburbs), consists of five key parametric modules and a heuristic design process covering various planning and design decision-making stages including scenario generation, analysis, optimization, and visualization. It is the first of its kind tailored for suburban settings with emerging mobility systems, which, more importantly, prioritizes landscape performance and accessibility over the traditional automobile-centric approach in suburban development. One of the most significant findings from this research is that substantial enhancements to a neighborhood's environmental performance and overall accessibility can be achieved by modifying existing suburban land use patterns and individual block configurations, without the necessity of increasing density. The results of the framework further suggest that a strategic atomized land use scheme, combined with an innovative clustered block typology, is favored for the anticipated widespread adoption of autonomous mobility systems and improved environmental performance. The innovative methods and findings introduced in this research illuminate an alternative approach to sustainable suburban development, offering valuable insights for city planners and developers to shape future suburban master plans, zoning regulations, and design guidelines.

Keywords: suburban expansion; sustainable development; environmental performance; autonomous mobility; parametric urban design

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1. Introduction

1.1. Environmental Opportunities in the Suburbs of Today and Tomorrow

Although often castigated as environmental disasters [1–6], suburban areas offer an abundance of opportunities for expanding ecosystem services, including habitat, biodiversity, hydrology, and carbon sequestration, at the metropolitan scale. For instance, urban ecologists have found that biodiversity, understood as the richness of species, is most pronounced in suburban settings [7]. Similar results have been found with various pollinators and birds [8,9]. Ecologist Robert Blair, who has studied avian biodiversity in urban, suburban, and rural settings, found that suburban sites have the highest levels of species richness when compared to both urban and rural sites [10].

Research also shows the environmental significance of residential landscape design choices and planting patterns in suburban areas. For instance, with current design and maintenance practices, suburban lawns account for a major portion of the urban watershed nitrogen budget [11]. However, redesigned suburban landscapes with mature trees, shrubs, undisturbed soil, and swaths of land with vegetative litter left in place are likely to sequester more atmospheric carbon [12,13]. One of the most important opportunities for increasing the environmental performance of suburban areas has to do with the size and quantity of leftover landscape surfaces in these areas. In suburban areas, the abundance of these landscapes, coming with potential redistribution opportunities for enhanced continuity, presents a distinct advantage for promoting crucial ecological functions and boosting landscape system services in ways that the urban core could never achieve [14].

In the near future, the adoption of emergent transportation technology such as autonomous electric vehicles (AEVs), micro-mobility, and mobility as a service (MaaS) [15] presents a generational opportunity to reorganize suburban development patterns and roadways for massive new gains in environmental benefits. By redesigning infrastructure to prioritize connected autonomous vehicle fleets and ride-hailing services over privately owned vehicles, substantial reductions in street widths become feasible [16]. The space needed for parking lots can be reduced by an average of 62 percent, thanks to the significantly smaller parking footprint of self-parking cars [17], while dedicated curbside parking can be supplanted by more efficient pickup and drop-off zones [18]. With the adoption of MaaS, the demand for private cars can be significantly reduced as well [19], and thus garages and driveways can be eliminated or repurposed to support other programs, like home offices and gardens. In addition, through the reorganization of traditionally fragmented and underutilized landscape buffers, as well as the enormous potential to reduce impervious surfaces and paving, it becomes possible to create a more contiguous collection of higher-performing landscape spaces inside suburban neighborhoods. This can not only enhance ecological performance but also provide ample room for a diverse range of activities, maximizing the block's functionality and livability.

1.2. Historic Car-Based Suburban Expansion and Its Consequences

Historically, suburbs did not develop with these environmental performance objectives in mind. Using the US as a geographic example, car-based suburban expansion has been the dominant model of metropolitan growth for a century (Figure 1).

Cities first passed land use regulations beginning in the early 1900s, as new building forms, like skyscrapers, elicited responses from citizens about their impacts on light and street presence. The 1924 Standardized State Zoning Enabling Act (SZEA) expanded and further standardized this power, granting broad regulatory oversight of local land use to municipalities [20]. In 1926, the supreme court case Village of Euclid vs. Ambler Realty Co. codified the most common form of local land use control found in new suburban development [21]. Euclidean zoning, named after the case, allowed municipalities to divide communities into districts or zones that each allowed a single type of land use, such as single-family residential, multifamily residential, commercial, industrial, etc., and set parameters for block configurations, including minimum lot sizes, density limits, setbacks and massing requirements [22]. During this era, the rise of the automobile marked a paradigm shift in the way people traveled and perceived distance. From a planning standpoint, the car was the missing link between town and country and enabled dispersion of different uses from the city center. As an illustrative example, Checkoway describes how, by the 1920s, the widespread adoption of trucks enabled factories in the Philadelphia metro area to relocate to suburban locations [23]. This trend of jobs and residential relocations was further fueled by the growing prevalence of telecommuting [24,25].

The increasingly dynamic feedback loop between zoning policies and technologies progressively influenced people's travel behavior, subsequently bolstering governmental initiatives in favor of car-based suburban development. As the number of registered automobiles in the country ballooned almost exponentially—with approximately 1 million

registered vehicles in 1913, 32 million in 1940, 108 million by 1970, 221 million by 2000, and 275 million by 2020 [26]—governments at all scales organized to lay down roads, highways, and bridges. The passage of the 1956 Federal-aid Highway Act, the largest public works project in American history, cast this proclivity toward an auto-oriented transportation network into concrete, as the federal government agreed to back 90 percent of the funding for municipalities to build new highways [27]. Gone were the days of the walking city; rather, car-based development, which has become the paradigm for suburban expansion, was designed with the driver in mind, with wide roads, garages, and carports becoming standard residential features, and parking saturating commercial and public places [28].

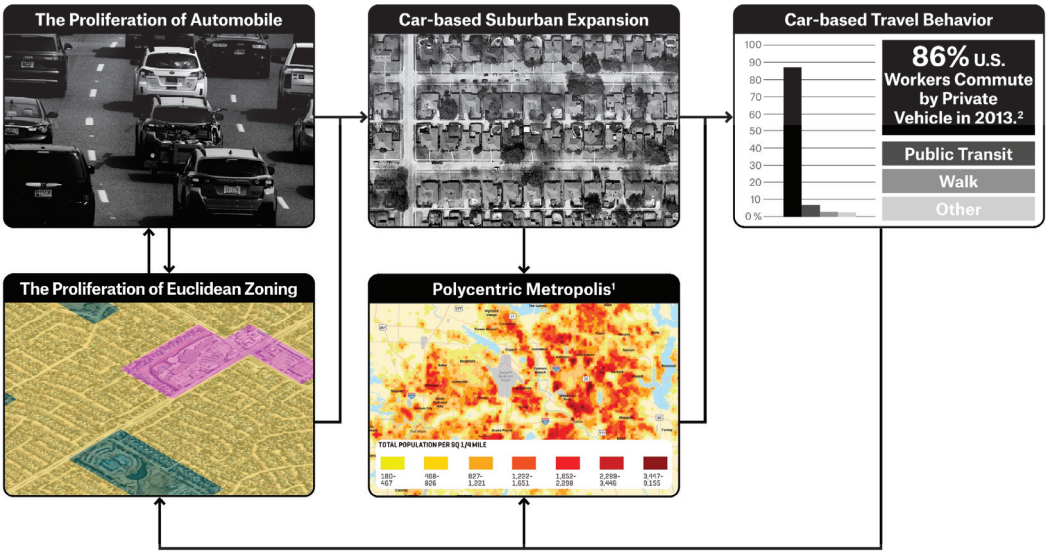

Figure 1. The typical process of car-based suburban expansion.

The proliferation of the automobile, coupled with favorable governmental policies, served as the foundation for car-based suburban expansion. As a result, the changing travel patterns between suburbs and urban cores have contributed to the solidification of car-based travel behavior among suburban residents. The concept of the encapsulated garden city characterized by distinct nodes has evolved into a paradigm of extensive polycentric urbanization, an occurrence initially examined by Jean Gottmann in his seminal 1961 work *Megalopolis: The Urbanized Northeastern Seaboard of the United States* [29]. Contemporary suburbanization exhibits a diminished tether to the urban core, with predominant growth regions consisting of multiple employment centers and commercial development [30]. Currently, intra-suburban trips (suburb-to-suburb commutes) outnumber metropolitan commutes to central business districts in the US by a factor of more than two [31]. In this new model, the prevailing transit infrastructure, traditionally designed to facilitate commuting between urban cores and suburban regions, fails to adequately cater to the mobility demands of contemporary suburban workers [32,33]. Simultaneously, as indicated by the criteria from previous studies, the economic viability of establishing a new high-frequency transit system between sparsely populated suburban areas is constrained by the dearth of potential users [34,35]. Consequently, in the American suburban landscape, the automobile reigns supreme and is anticipated to maintain its dominance. According to the latest National Household Travel Survey, more than 93 percent of US households own at

least one car [36]. Conversely, per the 2019 census Journey-to-Work survey, a mere 5 percent of the U.S. working population utilized public transit for their daily commutes [37].

Reflecting on today's awareness of climate change, one major consequence of car-based development patterns is a larger carbon footprint due to an increased dependency on fossil fuels [38]. Each household in the United States makes an average of 5.1 vehicular trips per day, with the majority (65 percent) of these trips dedicated to shopping, running errands, and engaging in social or recreational activities [36]. According to the Environmental Protection Agency (EPA), transportation is the largest single source of greenhouse gases in the US, and nearly 60 percent of those emissions come from the country's millions of passenger cars, SUVs, and pickup trucks [39].

1.3. The Significance of Suburbs and Potential of Autonomous Mobility

These issues are particularly significant given the current rate of suburban growth. Today, 55 percent of the world's population lives in urban areas, which are largely defined by vast suburb fields outside small downtown cores. This number is expected to increase to as much as 68 percent by 2050 [40]. A steadily increasing urban population intensifies the reliance on surrounding areas to provide essential environmental resources and ecosystem services vital for sustaining adjacent high-density population hubs because most cities rely heavily on imported resources to sustain dense populations in the urban core [41]. Furthermore, the vast majority of people are moving to urban areas not to inhabit their centers but to suburbanize their peripheries [42]. Studies indicate that the next generation of metropolitan growth will rapidly continue outside of urban cores [43,44].

This trend holds when looking at development patterns in the United States. According to the American Housing Survey (2017) of nearly 76,000 households nationwide, about 52 percent of people in the United States describe their neighborhoods as suburban [45]. Moreover, 70 percent of US workers from metropolitan areas now live and work in the suburbs [46]. As population, production, and jobs continue to head toward the periphery, it is here that planners and designers can innovate new forms and environmental solutions to the growth challenge, particularly around carbon-based transportation.

Due to the increasing significance of the suburbs, planners and politicians have looked for ways to mitigate the negative externalities of car dependency in these areas. One common approach to this challenge is to increase the density of existing inner suburban neighborhoods by introducing housing around transit hubs to boost ridership and encourage residents to forgo car ownership [47,48]. However, numerous studies show that residential density in suburban settings does not have a direct impact on local transportation choices [49,50]. Furthermore, in the public sector, not only has increasing density within established communities been met with various resistance, such as the NIMBY movement [51], but baby boomers, who now make up 39% of home buyers [52], show a clear preference for single-family homes over other housing types, as reported by the NAHB [53].

Meanwhile, for the majority of the US population, commuting without an automobile is scarcely appealing, particularly in the wake of the COVID-19 crisis, as individuals seek safer and more private means of transportation [54]. Therefore, it is almost predictable that simply adding density or up-zoning may have a very limited impact on changing suburban travel patterns in the near future. Moreover, the "middle neighborhood" or up-zoning strategy itself is not harmless or an easy-to-achieve success. Without careful decision-making, the "middle neighborhood" development may neglect considerations of existing infrastructure, destroy the neighborhood's social fabric, and ultimately lead to gentrification [55–57].

In this context, the emergence of new mobility technologies and services, including AEVs, micro-mobility, and Mobility as a Service (MaaS), presents untapped possibilities for addressing car dependency while unlocking the potential environmental benefits inherent in suburban areas. According to a report from the transportation research board, "The world is on the cusp of three revolutions in transportation: vehicle electrification, automation, and

sharing of vehicle trips. Separately or together, these revolutions will fundamentally change urban transportation around the world over the next few decades [58]". Hundreds of companies have begun rolling out various forms of driverless technology along with rapid advancements in micro-mobility offerings and shared mobility services. Cumulatively, these investments have surpassed USD 200 billion, as revealed in public disclosures [59].

Technological innovations including advanced sensors, artificial intelligence, and enhanced user interfaces have brought a slew of operational and environmental benefits, including higher energy efficiency [60], lower operational costs [61], less idle time [62], and so forth. Still, the second- and third-order effects of new mobility technologies, which are more likely to benefit the suburban areas, outside the reaches of established mass-transit systems where personal vehicular transport is the most ubiquitous, may be of even greater consequence. Arguably, based on the advanced features of autonomous mobility, its implementation could enhance the environmental performance of existing suburban areas.

However, technology itself is not the silver bullet. Drawing on a comprehensive body of research examining the potential impact of autonomous mobility systems on future urban development, it becomes evident that the realization of an ideal suburban development scenario through appropriate planning and design paradigms leads to more sustainable results. These results, in turn, hold promising prospects for addressing challenges related to greenhouse gas (GHG) emissions [63,64], land use efficiency [65], operational costs [66], pedestrian safety [67], and other pertinent environmental factors [68]. Adopting a technocentric approach can only result in solutions that fall short of achieving sustainable objectives due to a lack of comprehensive thinking. Furthermore, the introduction of autonomous vehicles, without appropriate policy measures in place, has the potential to increase both car ownership and miles traveled, rather than curbing them as intended [69].

1.4. Pre-Adapting Future Suburban Development through Urban Planning and Design

Based on all constraints, the main research gap filled by this research is that very few studies are suitable for influencing the design of autonomous mobility systems in suburban areas with a focus on environmental performance. This research is aimed at supporting urban planners and designers, who will have unprecedented opportunities for reinventing the suburbs of the future through new approaches to zoning, land use planning, and urban design that effectively anticipate the impacts of new autonomous mobility innovations.

The result of this research is NOGAS—a parametric design framework [70] developed in the P-REX Lab at MIT to help planners and designers effectively usher in an innovative suburban development paradigm that prioritizes environmental performance targets without compromising traditional engineering goals with neighborhood and block infrastructures. The NOGAS framework is specifically developed for greenfield development in suburban areas. Compared to the multifaceted challenges of retrofitting existing inner suburbs, greenfield developments typically follow similar procedures and goals. This consistency increases the reliability of applying the NOGAS framework in various contexts without extensive customization.

One important assumption of NOGAS is that autonomous mobility systems will become ubiquitous in future suburban areas. The autonomous mobility systems we refer to throughout this research are imagined as a collective bundle that not only encompasses new mobility technology and services, such as AEVs, (autonomous) micro-mobility, and (autonomous) MaaS systems, among others, but also incorporates a set of spatial elements that are either newly proposed or retrofitted through innovative planning, design, and policy solutions, which are essential to achieve an optimized operational environment for the future implementation of these new mobility technologies and services. We acknowledge that reaching ubiquity is a paradigm shift in transportation and lifestyle that will require significant structural change.

1.5. The Study Site—Northridge, McKinney, TX

To test the utility of our parametric design framework, we worked with the City of McKinney, Texas[1], to find sites for exploring scenarios to help inform planning and urban design decision-making over the next 20 years in tandem with emergent autonomous mobility systems at two distinct scales: the district scale and block scale. The city's 2040 vision plan (hereinafter, 2040 plan [71]) was used to establish baseline conditions from which the effectiveness of proposed outcomes could be measured. The design issues, assumptions, and objectives of each scale are outlined as follows:

- At the district scale, the parametric design framework was used to explore potential spatial relationships between different land uses within the context of a widespread autonomous mobility system. The predetermined objectives for these new land use configurations were to increase access to a more distributed array of commercial and recreational amenities.
- At the block scale, the parametric design framework was used to experiment with various block configurations. These configurations were developed to respond to opportunities related to the adoption of an autonomous mobility system, such as narrower vehicular rights-of-way or more distributed multi-modal mobility hubs. The predetermined objectives for these optimized block configurations were to achieve improved accessibility, reduce impervious surfaces, and achieve more contiguous inner-block landscape space.

McKinney has experienced rapid population growth during the past three decades. From 1990 to 2022, the city's total population grew from 21,283 to 206,654 [72]. In order to accommodate this growth McKinney created a 2040 vision plan in which unincorporated areas slated for annexation along the edges of McKinney provide a generalized framework for the future of suburban development broadly. According to the 2040 plan, more than 50 percent of the total undeveloped area is slated for single-family land uses, with the rest mostly allocated to low-lying riparian corridors and other hard-to-develop parklands (about 20 percent) along with a few small clusters earmarked for potential employment centers and commercial districts (less than 10 percent) [71].

Northridge district, which is designated as a residential area for one-third of the city's projected new population, is located in the northwest sector of McKinney. Zooming into the portion of the Northridge district, it is clear that the city's vision plan presupposes the addition of many more car-dependent neighborhoods (Figure 2). The district plan calls for mostly (80 percent) single-family residential land uses with lot sizes ranging from a half-acre to two acres. Neighborhood commercial development is planned, including small freestanding buildings located almost exclusively at major arterial intersections.

As shown in Figure 2 (the area within the red-bordered square), the selected study site is situated in the northeast corner of the Northridge district. This area encompasses four predominant land uses found in American suburbs: suburban living, estate residential, neighborhood commercial, and landscape space. By applying our framework to these prevalent land uses, we aim to demonstrate the potential adaptability of the NOGAS framework across various suburban contexts.

As planned, the selected site would largely repeat the typical car-based suburban expansion pattern, which we have already taken a critical position on, producing an inequitable and inadequate distribution of public open space with nearly 60 percent of the total expected population situated outside of a five-minute park walkshed. Furthermore, only 25 percent of households would have walkable access to commercial amenities, further reinforcing vehicle dependency, even for relatively short trips—once again putting a disproportionate burden on working-class households and residents with disabilities. Under this planning scenario, the absence of adequate access to amenities will be very likely to lead to a large number of vehicle trips and VMT. The findings also suggest that if new development followed the protocols and standards of existing suburban forms, a substantial portion of land within the study area would be designated for impervious

surfaces, landscape buffers, or private yards with minimal provision of ecosystem services.

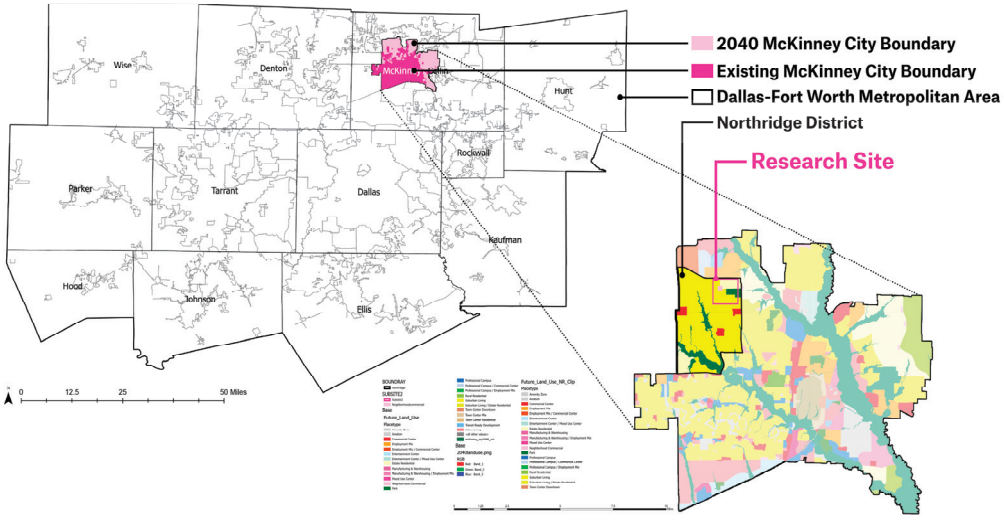

Figure 2. The geolocation of the study site.

The most significant finding from this research is that a collective bundle of autonomous mobility technologies combined with modifications to traditional suburban land use patterns and block configurations can have significant impacts on a community's environmental performance, capacity for integrating new forms of mobility, and overall accessibility, without the necessity of increasing density.

The subsequent section provides a comprehensive introduction to the proposed parametric design framework, elucidating its intricacies and functions. In the third section, a case study is presented to showcase the practical application of the proposed design framework within a real-world setting. In the end, design interpretations derived from the model outputs are discussed, followed by a conclusion.

2. Materials and Methods

2.1. A Heuristic Parametric Design Framework—NOGAS

Extensive research has shown that under ideal conditions, autonomous mobility systems have various positive impacts on development, while several studies have also highlighted that in the absence of appropriate regulations and designs, widespread implementation of autonomous mobility systems could have adverse effects [73,74]. Therefore, the implementation of new mobility technologies alone will not lead us toward a more sustainable future. To fully capitalize on the advantages of autonomous mobility, it is imperative that communities simultaneously adopt new approaches to development with specific objectives, such as prioritizing landscape performance and environmental services.

A crucial challenge encountered in the pursuit of a new suburban development paradigm lies in effectively reconciling divergent development objectives sought through such transformation, which further involves a large amount of design iterations. Employing conventional design methods to conduct numerous design iterations, even with assistance from computer-aided software, can be excessively time-consuming and resource-intensive [75]. However, design approaches that include generative and parametric features increase designers' ability to explore wider sets of potential solutions [76].

In this context, a significant body of research has been dedicated to exploring the potential role of computational algorithms in establishing more efficient and accurate design workflows. These research efforts encompass various design stages, including design

generation, pre-/post-design analysis, and design optimization. Moreover, they cover a wide range of design topics, such as land use allocation [77], transportation planning [78], building structure optimization [79], and more [80,81].

An increasing number of studies have attempted to develop a parametric design framework with computational optimization techniques at various scales (Table 1). However, very few of them are suitable for influencing the design of autonomous mobility systems in suburban areas with a focus on environmental performance.

To fill this gap, a toolkit has been developed as a part of the NOGAS framework (Figure 3) to execute several key functions. Firstly, it can generate design scenarios by considering input parameters and predefined design logic. As the input parameters are altered, the generated scenarios will adapt accordingly. The performance of these scenarios can be assessed using predefined targets, which are formulated based on specific design objectives. The toolkit also has the ability to optimize input parameters in order to enhance performance. Lastly, the toolkit can be used to analyze key performance metrics across all generated scenarios and provides analytic graphs, which aids designers in comprehending the quantitative costs and benefits associated with each scenario with respect to various design objectives. In this research, the process of assessing and evaluating the costs and benefits of a given scenario, with the aim of ultimately selecting the optimized option, is referred to as trade-off analysis.

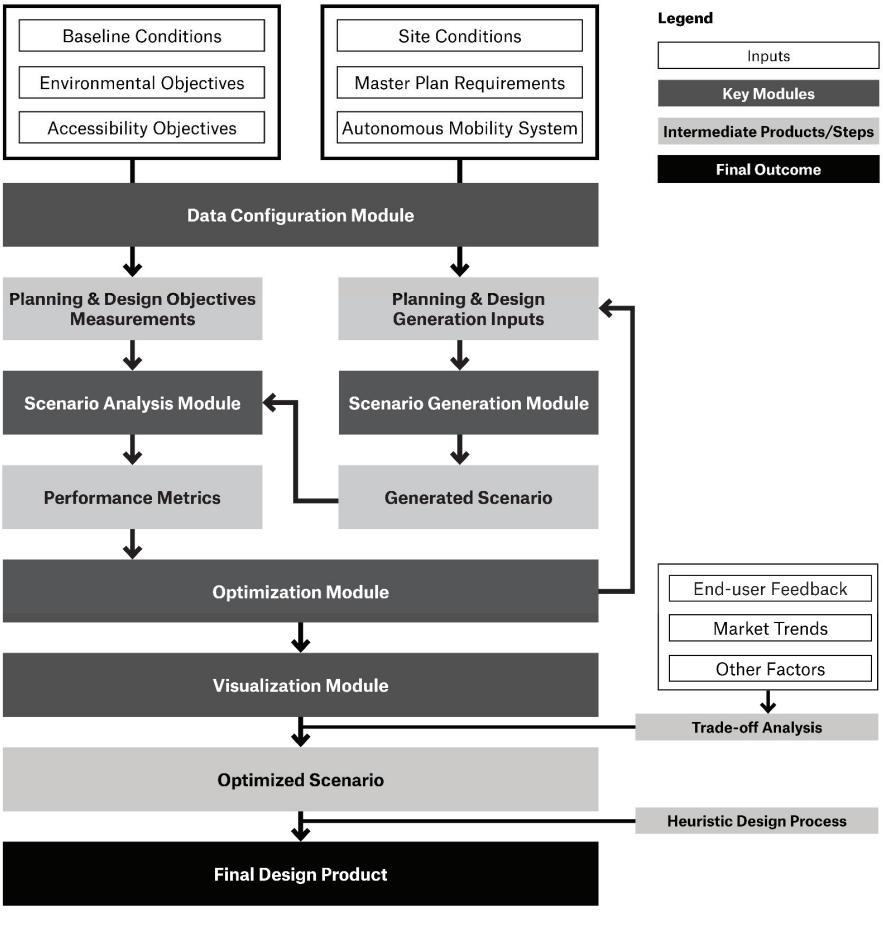

Figure 3. Roadmap of the NOGAS parametric design framework.

Table 1. A literature review on parametric design research with optimization techniques.

Land Use Allocation Optimization Reference	Planning and Design Context			Planning and Design Scales				Main Optimization Algorithm					Planning and Design Objectives			Operation Environment	
	Urban	Suburb	Rural	Regional	City	District	Block	Linear Optimization	Genetic Algorithm	Particle Swarm Optimization	Ant Colony Optimization	Simulated Annealing	Economic Performance	Environmental Performance	Mobility Access	GIS Platform and Coding	Rhinoceros/ Grasshopper Based Platform
Berawi et al. (2020) [82]	•						•	•							•		
Cao et al. (2012) [83]	•				•				•				•	•	•	•	
Caparros-Midwood et al. (2015) [84]	•				•							•		•	•	•	
Eikelboom et al. (2015) [85]			•	•					•					•		•	
Haque and Asami (2014) [86]						•			•				•			•	
Janssen et al. (2008) [87]			•			•			•					•		•	
Koenig et al. (2020) [88]	•					•									•		•
Li and Parrott (2016) [89]	•	•	•	•					•				•	•		•	
Liu et al. (2012) [90]	•	•	•	•							•		•			•	
Liu et al. (2013) [91]	•	•	•	•						•			•			•	
Liu et al. (2015) [92]	•	•	•	•					•				•	•		•	
Makki et al. (2019) [93]	•					•								•	•		•
Mi et al. (2015) [94]	•	•	•	•							•		•	•		•	
Mohammadi et al. (2016) [95]		•				•				•		•	•	•		•	
Porta et al. (2013) [75]	•	•	•	•					•					•		•	
Sante et al. (2016) [96]	•	•	•	•								•	•			•	
Sharmin et al. (2019) [97]	•					•			•				•			•	
Stewart and Janssen (2014) [98]			•	•					•					•		•	
Zhang et al. (2016) [99]	•	•	•	•						•			•	•		•	
This research		•				•	•			•				•	•		•

• This symbol indicates that the paper contains relevant topics.

Trade-off analysis is a central tenet of our research that is trying to address a multi-objective issue. In the context of land use planning and urban design, different objectives can be at odds with one another [100,101]. This means that as the performance factor of one design objective is increased, the performance factor of another design objective may be decreased due to their associative relationships. The theoretical trade-off point is represented by the equilibrium at which both performance objectives achieve their highest level possible given these associations. However, in reality, the trade-off point is also determined by many other factors, such as feedback from end users, particular governmental regulations, market trends, and more.

Another integral aspect of this modeling workflow is its adoption of a heuristic architecture. By heuristic, we mean the proposed parametric workflow is designated to provide quantitative and spatial information for early-stage planning and design decision-making. For this purpose, the outputs from the model, as suggested by previous research, are more suitable for starting the exploratory design process rather than offering a final design product [102]. The outputs serve as valuable references, insights, and sources of inspiration for planners and designers to develop a more comprehensive understanding of diverse future conditions. The ultimate design scheme can then emerge from an integrated consideration of the insights gleaned from the model, as well as other external factors.

2.2. Key Modules

To realize the proposed parametric design framework toward generating scenarios that are not only customized for autonomous mobility transformation in suburban contexts but also exhibit optimal sustainability performance, a series of models were developed utilizing Rhinoceros 3D (Rhino3D) and Grasshopper (GH)[2]. A cluster of models that serve a similar purpose constitutes a module. In total, the toolkit of the NOGAS framework contains five key modules. These five modules are presented in sequential order:

1. Data configuration module: This module provides users with the capability to set or input parameters in multiple formats. Some of these parameters are associated with the generation of design scenarios, such as block size, building height, and land use attributes. Other parameters are typically linked to specific design objectives and are utilized later on in the scenario analysis module. This module can accommodate various data formats, including but not limited to Rhino3D vector data, ESRI Shapefile data, and matrix data. Different data formats are then converted into appropriate formats for future usage.
2. Scenario generation module: With the input parameters from the data configuration module, this module is used to generate design scenarios based on predefined spatial objectives. As the parameters are modified, the generated results adapt accordingly.
3. Scenario analysis module: This module is specifically designed to measure the performance factors of each generated scenario based on predefined metrics and predetermined objectives, as described in Section 2.2.
4. Optimization module: This module is used to execute the design optimization processes. It serves as a crucial link between the scenario generation module and the scenario analysis module. By utilizing the performance metrics obtained from the scenario analysis module, this module dynamically adjusts the parameters that are input into the scenario generation module. This iterative process aims to refine and optimize the scenarios to achieve enhanced outcomes. It can accommodate various algorithms, including linear optimization [103], simulated annealing [104], particle swarm optimization [105], and others. After careful evaluation of different algorithms, Non-dominated Sorting Genetic Algorithm II (NSGA-II [106])[3] is applied for its efficient non-dominated sorting procedure [107], performance in optimizing problems with two or more objectives [108], and ability to generate a comprehensive set of Pareto-optimal solutions rather than a single optimum solution [109].
5. Visualization module: This module encompasses a collection of scripts that enable real-time visualization of output scenarios and performance metrics. By utilizing

this module, designers gain a clear understanding of the generated and optimized scenarios, facilitating improved design communication.

2.3. Optimization Factors

This design framework evaluates and optimizes the performance and design objectives at two distinct scales.

2.3.1. District Scale Optimization Factors

The district scale or neighborhood scale refers to a sub-division of urban, suburban, or rural locations in which people live [110]. In this research, a district is defined as a site between 500 and 1000 acres with a typical inner suburban population density of 1000 to 3000 people per square mile [111].

- Land Use Distribution

As illustrated in the introduction (Figure 1), land use planning, as an indispensable component of suburban form, has a profound impact on people's travel behavior and the perpetuation of car-based suburban expansion. The proliferation of autonomous mobility systems provides an unprecedented opportunity to rethink land use planning approaches that may facilitate mixed-use suburban development patterns with improved access, walkability, and environmental performance [112,113].

A land use matrix was developed to examine various land use distribution scenarios through a parametric cross-impact method. Cross-impact analysis, as a scenario-planning methodology, was first developed by Theodore Gordon and Olaf Helmer in 1966 to help determine how relationships between elements would impact outcomes and reduce uncertainty in the future [114,115]. Similarly, the proposed land use matrix can assist planners and designers in testing and evaluating various land use distribution scenarios. Furthermore, by integrating future needs into this land use matrix, we can enhance our understanding of potential outcomes based on specific assumptions.

The land use matrix is structured with the first row and column representing given land use types in a specific order. Within this matrix, each cell is assigned an incentive score (2, 1), indicating the degree to which two land uses should be pushed together, a penalty score (-1, -2), indicating the degree to which two land uses should be pulled apart, or a score of 0, representing no preference for their spatial relationships (Figure 4). By utilizing these incentive and penalty scores, new land use configurations can be generated under specific constraints, representing different assumptions for future conditions.

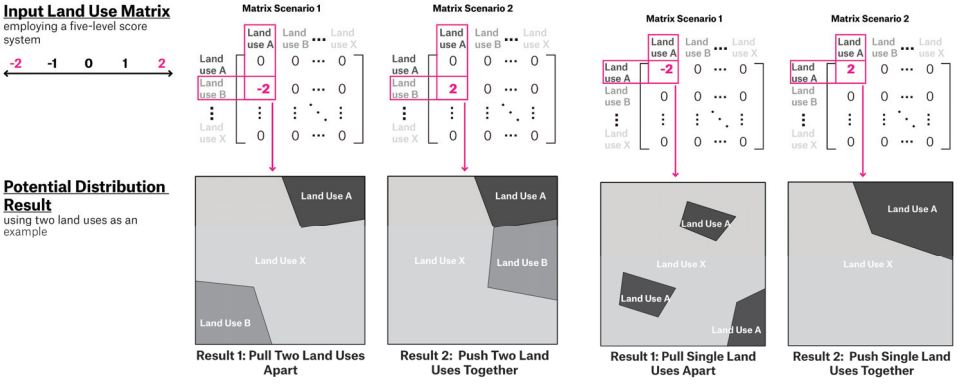

Figure 4. A set of diagrams that show how the land use distribution matrix and incentive scoring affects the potential land use distribution results.

The final score of a given land use cell is calculated by summing the scores between that cell and all adjacent land uses. Consequently, the performance factor of the entire

site is determined by summing the scores of each individual land use cell (Figure 5). The quantitative formulation of the analysis process is shown as follows:

$$f_{\text{dist}} = \sum_{i=1}^{n} \sum_{j=1}^{r} disti, j \quad (1)$$

In the function, n is total land use cells in the study area, i represents any given land use cell, and r is the number of neighbor land use cells of cell i. In this research, r equals four, which means that in a grid system, any given land use cell has four neighbor cells. j is one of the neighbor cells of cell i. $disti,j$ is the score between land use types located in cell i and cell j. This value is derived through the Delphi method [116].

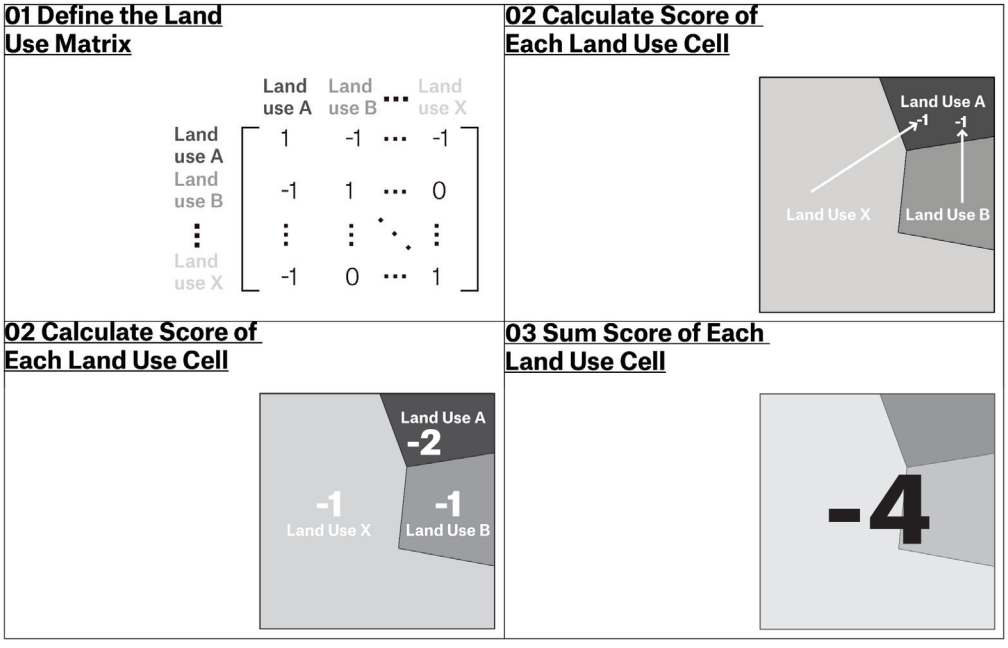

Figure 5. A set of diagrams that show how the final land use distribution score is calculated.

- Landscape Space Allocation

The possibility of new land use distribution models aimed at capturing the benefits of autonomous mobility systems may yield new approaches to landscape space allocation. When large contiguous and homogenous land use clusters are broken into smaller pieces, new configurations of public landscape space become possible. This presents a tremendous opportunity for improving the environmental performance of suburban areas, which can further bring benefits related to public health [117], heat mitigation [118], stormwater detention [119], the preservation of ecologically significant areas [120], and carbon sequestration [121]. Consequently, the allocation of landscape spaces, a crucial component of contemporary sustainable development [122], will assume even greater significance in the era of autonomous mobility. When evaluating the performance of public landscape space allocation, two key factors are closely interrelated.

Access (Distance from Residential Areas): Research emphasizes that the proximity of landscape spaces to residential areas significantly influences the frequency of their utilization. In other words, when residential areas have direct access to nearby landscape spaces, the utilization rate of those landscape spaces tends to be higher. This helps ensure a shorter distance between residential areas and landscape spaces, which is crucial for encouraging their utilization [123,124].

Contiguity: Contiguity plays a vital role in the ecological performance of landscape spaces. A well-connected landscape space usually has higher ecological production, more ecosystem resilience, and greater biodiversity [125]. The level of contiguity also determines the range of programs or activities that can be accommodated within it. Therefore, enhancing the contiguity of landscape spaces is essential for maximizing their ecological benefits and accommodating various activities.

As illustrated below, (Figure 6), a high contiguity of landscape space allocation (Figure 6, Scenario 1) contributes to the appearance of inequalities, which means that fewer residents have direct access to the landscape space [126]. However, another set of landscape space allocations (Figure 6, Scenario 2) with high access performance may have low contiguity and thus degraded environmental performance [127]. The optimized solution should consider both contiguity and accessibility of landscape spaces.

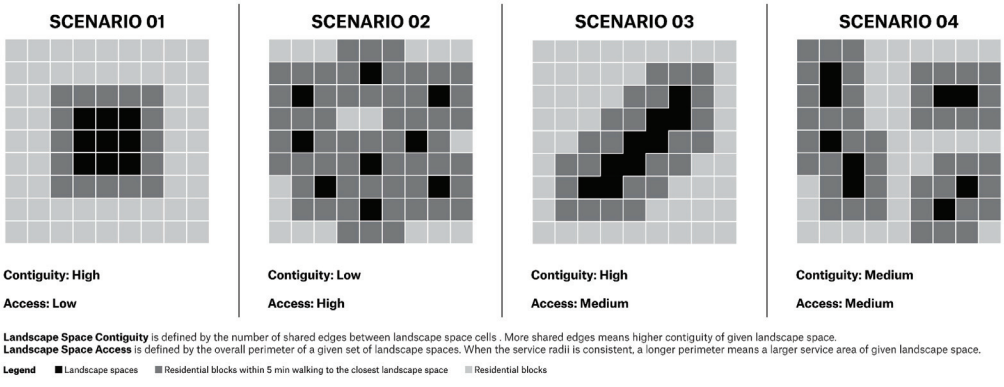

Figure 6. The diagrams show how access and contiguity can affect the potential results of landscape space allocation.

Hence, two measurements are formulated to measure landscape space accessibility and contiguity. Landscape space access is represented by the overall perimeter of a given set of landscape spaces [128]. The longer the total perimeter, the more residents will likely have direct access to it. Landscape space contiguity is defined by the number of shared edges between landscape space cells [129]. The higher counts of shared edges represent higher contiguity of landscape spaces. The quantitative formulations of two indices are shown below:

$$f_{access} = \sum_{i=1}^{n} P_i \quad (2)$$

In the function, n is the total number of landscape spaces, which is composed of adjacent landscape space land use cells. i is any given landscape space. P_i is the perimeter of the landscape patch i. Finally, by summing the perimeters of all landscape spaces, the landscape space access is measured.

$$f_{contiguity} = \sum_{i=1}^{n} \sum_{j=1}^{r} S_{ij} \quad (3)$$

In the function, n is the total number of landscape space land use cells, i is any given landscape space cell, and r is the set of neighbor cells of cell i. S_{ij} is a binary variable. When cell i and cell j are both landscape space cells and share an edge, S_{ij} equals 1; otherwise, S_{ij} equals 0.

2.3.2. Block Scale Optimization Factors

The block represents the smallest cohesive group of buildings enclosed by streets within a particular area.

- Impervious Surface Reduction and Landscape Space Contiguity

The widespread adoption of autonomous mobility systems presents a significant opportunity to address issues related to excessive impervious surfaces in suburban areas and to facilitate the creation of more contiguous landscape spaces. According to the US EPA, "Impervious surfaces are materials that do not allow the penetration of water, such as buildings, roads, and parking lots [130]". Much research has proven that impervious surfaces have various negative impacts on the environment such as a reduction in watershed protection [131], the conveyance of urban pollution [132], an increase in local temperatures [133], threats to biodiversity [134], and so forth. Hence, the investigation of impervious surfaces has emerged as a significant area of scientific interest concerning the management of Nonpoint Source Pollution (NSP) and as an indicator of the ecosystem quality of a given site [135].

As mentioned in the introduction, with the adoption of an autonomous mobility system, it becomes possible to reduce impervious surfaces and create a more contiguous collection of landscape spaces inside the block. This can not only enhance ecological performance but also provide ample room for a diverse range of activities, maximizing the block's functionality. Typical suburban areas are awash with impervious surfaces including driveways, sidewalks, parking lots, etc. The formula for calculating the ratio of impervious surface is shown below:

$$f_{impervious} = \frac{\sum_{i=1}^{n} A_i}{A} \quad (4)$$

In the function, n is the total number of driveways. i is any given driveway. A_i is the area of a single impervious surface i. A is the area of the whole block.

Given the different granularity and resolution, landscape space contiguity at the block scale is represented by the area of the largest single landscape space inside the given block.

$$f_{conti} = Max\ (A_L) \quad (5)$$

In the function, A_L is the area of each landscape space inside the block.

- Multi-modal Mobility Hub Access

As shown in many studies, in order to achieve a scenario in which an autonomous mobility system results in an overall reduction in vehicle miles traveled (VMT) and transportation-based GHG emissions, it is essential to roll out AEVs alongside a MaaS system, such as shared mobility or mobility on demand [63,136]. With this in mind, the design of passenger loading zones, as a fundamental infrastructure for MaaS, will become more important than ever [18]. In many cases, a key strategy will likely entail promoting a seamless mobility mode transfer by co-locating these spaces with other mobility infrastructures, like e-bike docking stations, to form a multi-modal mobility hub.

It may be challenging for planners to determine the ideal distribution of these hubs to ensure that optimal accessibility is achieved within the budgetary constraints of a project. The level of accessibility is typically a key factor in determining how many users will be willing to use these hubs and thus the overall mobility system. According to the research by TRB (2014), access (walking distance) will affect people's willingness to use a particular mobility mode, such as a bus. While at short distances (e.g., 0–50 m), most people are willing to walk to a bus stop, but less than 5 percent of people walk to destinations further than 600 m [137]. Similar empirical results have been found in other studies [138,139]. Furthermore, when access analysis is applied to analyze block configurations, trade-offs need to be negotiated between two measurements (Figure 7).

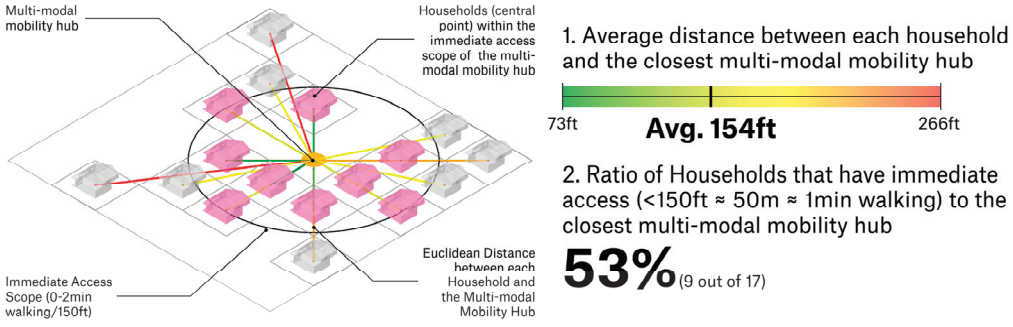

Figure 7. The diagram employs a block configuration to illustrate how the two metrics mentioned above are calculated.

One is the average distance between households and the closest multi-modal mobility hub. This formulation is shown below:

$$f_{avgdistance} = \frac{\sum_{i=1}^{n} D_i}{n} \quad (6)$$

In the formulation, n is the total number of households. i is any given household. D_i = Euclidean distance between the centroid of household i and multi-modal mobility hub.

Another is the ratio of households that have immediate access (<150 ft ≈ 50 m ≈ 1 min walking) to the closest multi-modal mobility hub. This formulation is shown below:

$$f_{householdaccess} = \frac{\sum_{i=1}^{n} X_i}{n} \quad (7)$$

In the formulation, n is the total number of households. i is any given household. X_i is a binary variable. When household i in inside the 1 min service buffer of the multi-modal mobility hub, the $X_i = 1$; otherwise, $X_i = 0$.

2.4. Baseline Analysis and Input Configurations

2.4.1. Baseline Analysis

A baseline analysis for two distinct scales was conducted to obtain inputs for the framework. The outcomes of this baseline analysis served two purposes. Firstly, these data were employed in the scenario generation module to establish essential parameters. Secondly, they were used as a basis for comparison against the outputs produced by the proposed framework. This comparative analysis aimed to evaluate the framework's effectiveness in improving scenario performance compared to the baseline conditions.

District scale: The research site has four land use types (Figure 8), which were identified in the plan as "Suburban Living", "Estate Residential", "Landscape Space", and "Neighborhood Commercial". Among them, suburban living (SL) takes the largest area (60 percent), followed by estate residential (ER), which takes 23 percent of total land. Landscape space (LS) and neighborhood commercial (NC) take 14 percent and 3 percent, respectively. Only 9 percent of the residential zones, including the SL and ER areas, are within a 5 min walk to the closest LS and NC areas.

Block scale: SL—the dominant block type within the research site—was selected as the survey object. Two of the most common SL block configurations—linear configurations and cul-de-sac configurations—are analyzed (Figure 9). The survey results revealed that these two configurations exhibit comparable landcover attributes. In both cases, approximately 25 percent of the total land area is allocated for vehicular use, indicating a significant portion dedicated to impervious surfaces. Additionally, nearly 50 percent of the land area consists

of fragmented turf areas, which generally exhibit low environmental performance [140] and high maintenance costs [141].

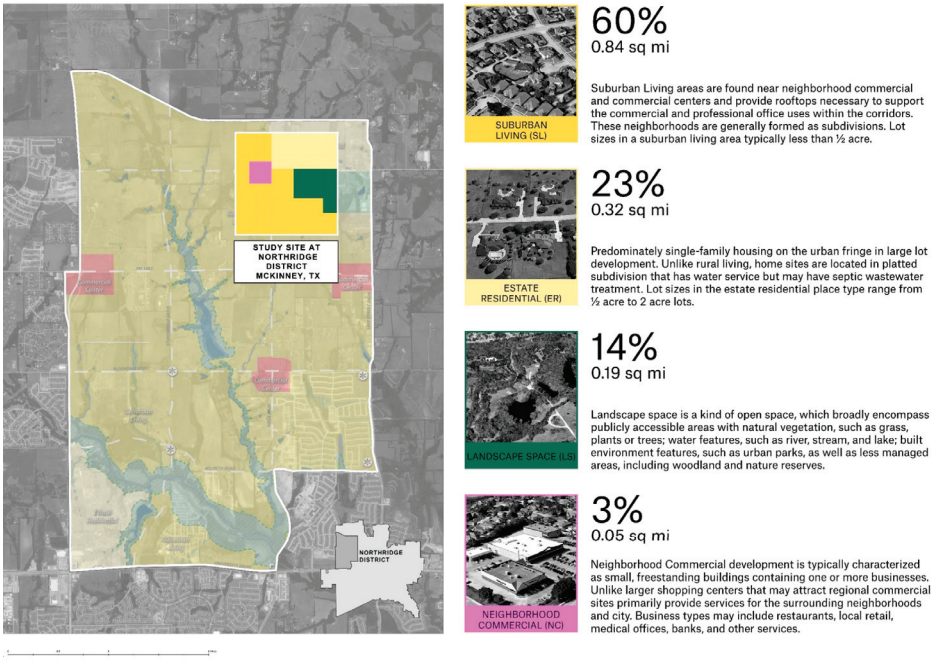

Figure 8. Existing land use allocation of the study site.

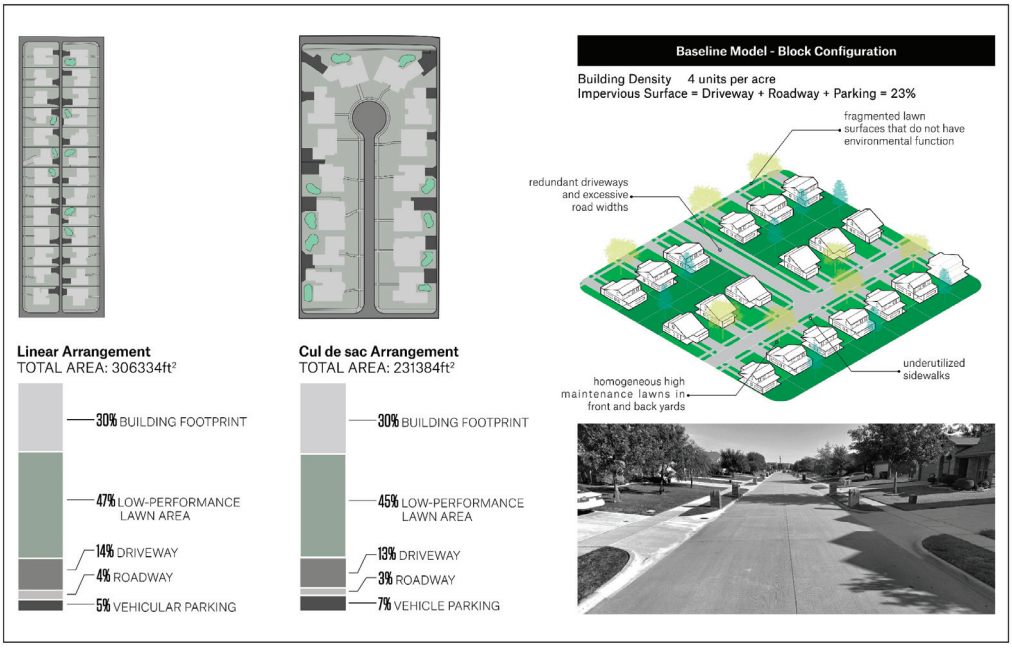

Figure 9. Block survey of suburban living block configurations in McKinney.

2.4.2. Input Configurations

For each scale, three different sets of parameters were input into corresponding modules. The first set of parameters, mainly including baseline data obtained from the baseline analysis, was input into the scenario generation module. The second set of parameters related to the optimization factors was input into the scenario analysis module. The last set of parameters was utilized for configuring the optimization process. All parameters are shown in Tables 2 and 3.

Table 2. Model inputs.

District Scale **Inputs -> Scenario Generation Module**	
1. Land use cell size	4.5 acres
2. Land use cell type	Suburban living; estate residential; Neighborhood commercial; landscape space
3. Land use cell count of each land use type	Suburban living: 114; estate residential: 45; Neighborhood commercial: 9; landscape space: 28
4. Site boundary	A spatial data input from Rhino3D
Inputs -> Scenario Analysis Module	
1. Land use matrix	See Figure 10 for detailed information
Block scale	
Inputs -> Scenario Generation Module	
1. Block size	4.5 acres
2. Building density	4 units per acre
3. Lot area	5400 ft^2
4. Building footprint (without garage)	1400 ft^2
5. Number of multi-modal mobility hub	1
Inputs -> Scenario Analysis Module	
1 min walking distance	150 ft

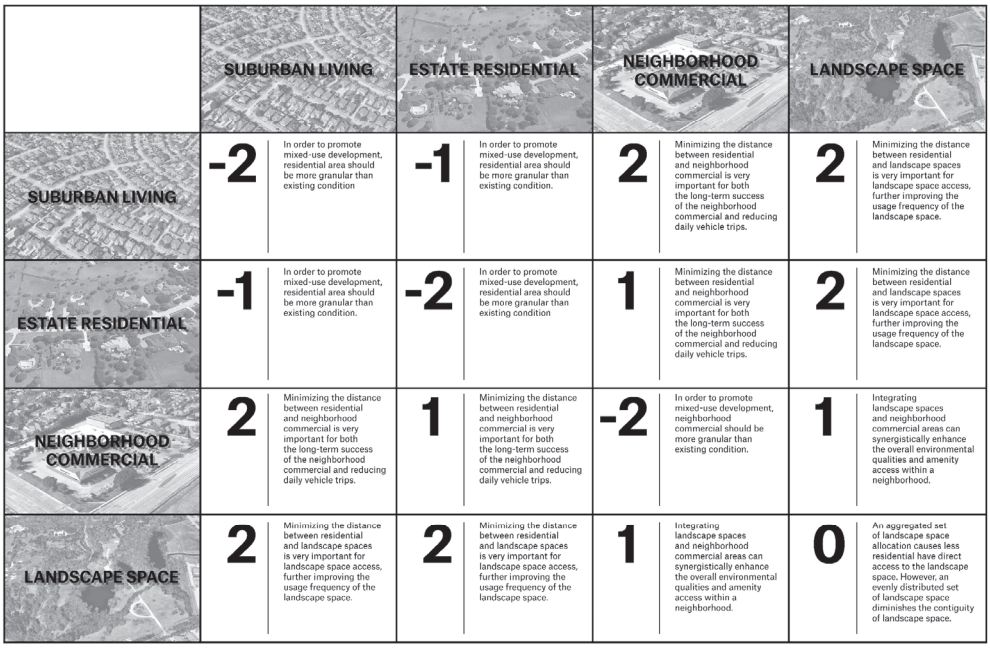

Figure 10. Applied land use distribution matrix with incentive and penalty scores.

Table 3. Optimization settings.

Optimization Size	District Scale | Block Scale	Algorithm Settings	District Scale | Block Scale
Generation size	50 | 50	Mutation rate	1/n | 1/n
Generation count	100 | 100	Crossover probability	0.9 | 0.9
Population size	5000 | 5000	Mutation distribution index	20 | 20
Number of variables	784 | 10,002	Crossover distribution index	20 | 20
Size of search space	1×10^{118} | 2.5×10^{7}	Simulation runtime	4 h 36 min | 18 min

It is noteworthy that at the district scale, a grid system has been adopted to adhere to the governmental master plan. As depicted in Figure 8, the local government utilizes a grid system to partition the land for future development. By incorporating a grid system that aligns with the established grid by the local government, our proposal can seamlessly integrate into the regional development framework. Moreover, the land use cell has been defined with a size of 4.5 acres (450 ft × 450 ft), which is equivalent to the dimensions of an average single block, which we considered as the minimum operational unit. The determination of this block size is based on the average block dimensions prevalent in the local context.

The land use matrix shown in Figure 10 is determined by researchers, developers, and planning officials from McKinney based on not only current development objectives but also future needs for mixed-use communities, improved environmental performance, enhanced accessibility, and autonomous mobility adaptations.

The modules were run on a PC with the following specifications: Intel(R) Core (TM) i7-8700 K CPU @ 3.70 GHz (3696 MHz) processor with 64.0 GB (2133 MHz) of RAM. The following settings have been applied to the optimization module (Table 3). For each scale, the generation size was set as 50, while the generation count was set as 100. The total number of generated scenarios is 5000. The value of crossover probability was set as 0.9.

3. Case Studies and Results

Based on the analysis of the standard deviation for each optimization factor across generations, the success of the model run is evident. As shown in Figure 11, compared to a larger variance of earlier generations (represented by red lines in the graph), later generations (represented by blue lines in the graph) typically display a convergence toward lower fitness values, indicating improved performance for each optimization factor. This suggests that an optimized value range emerges as the process progresses. More detailed analyses at two distinct scales are presented in the subsequent sections.

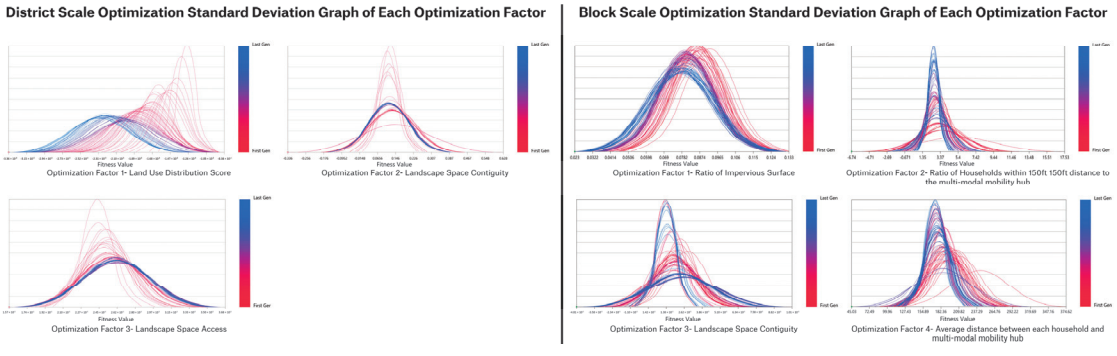

Figure 11. Standard deviation graph of each optimization factor.

3.1. District Scale Results

The performance of various district scale scenarios generated through this process is shown in various forms, including before/after land use plans, a parallel coordinate plot[4], and a radar chart (Figure 12). The plot indicates that no scenario has the best performance across all objectives, hence it is important to negotiate trade-offs between different objectives. Particular emphasis has been placed on prioritizing the land use distribution score and landscape space access when selecting the output. This choice is driven by the overarching goals of promoting a mixed-use land use pattern that aligns with the anticipated autonomous mobility system and ensuring convenient access to landscape spaces. Additionally, a minimum land use cell size has been established to maintain a certain level of contiguity for single landscape space land use. However, the selected scenario can vary based on different objectives derived from different stakeholders' viewpoints and site conditions.

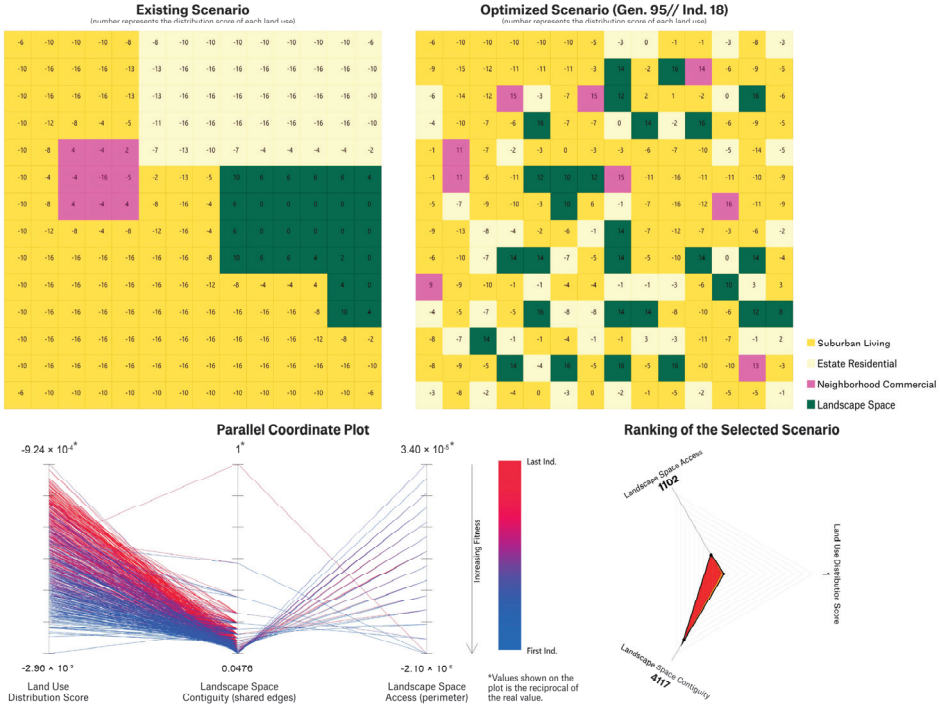

Figure 12. District scale outputs vs. the existing scenario.

The selected scenario has the highest performance in the land use distribution score, which means it aligns most closely with the predefined objectives. By comparing the baseline against the optimized land use plan (Table 4), it is clear that the landscape space allocation of the selected scenario has an improved balance between distribution and contiguity. Meanwhile, the NC land use areas are more equitably distributed across the site, which provides improved access overall. Moreover, the overall perimeters of the LS land use clusters have been increased by 300 percent, which means there is greater access for residents to public landscape spaces throughout the district. While this expansion has led to a decrease in the overall contiguity of landscape spaces, effective planning techniques, such as landscape corridors and innovative block configurations, can help mitigate this issue. Furthermore, the block configuration proposed in this research promotes a more contiguous landscape space connection through the residential block (as explained in the

following sections). Overall, all four types of land use are more granular, providing various opportunities for mixed-use development through distribution.

Table 4. District scale output vs. existing scenario.

Optimization Factors		Existing Scenario	Optimized Scenario (Ranking out of 5000)	ΔVariation
Land Use Distribution (f_{dist})		−1820	−388 (1)	+1432
Landscape Space Allocation	Access (f_{access})	10,618 ft	42,472 ft (1102)	+300%
	Contiguity ($f_{contiguity}$)	27	8 (4117)	−70%

3.2. Block Scale Results

The performance of various block scale scenarios generated from the design framework is shown in Figure 13. In the optimization process, the complex block configuration was simplified into line and point elements, as shown in the diagram. The plot shows that no scenario has been found to possess the best performance across all objectives, hence it is important to negotiate trade-offs between different objectives. When selecting the output scenario, balanced performances across all four metrics are considered optimal. One scenario with the highest performance in one metric may fall short in all other metrics, which will ultimately lead to an unfeasible scenario when applied to real-world conditions.

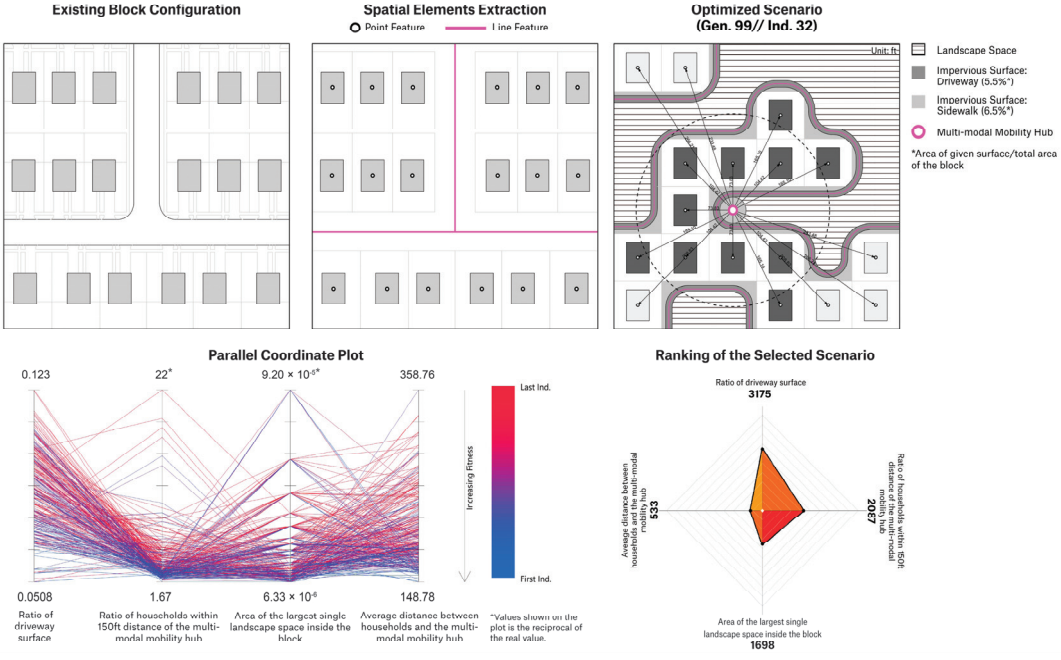

Figure 13. Block scale outputs vs. the baseline scenario.

The selected scenario has a balanced performance across all objectives (Table 5). As shown by the radar chart, the selected scenario has a relatively high capacity to help minimize the average distance between each household and multi-modal mobility hub and maximize the area of contiguous landscape space inside the block. It has a moderate capacity to help maximize households within a 150 ft distance to a multi-modal mobility hub and minimize the ratio of impervious surfaces. In the selected scenario, the ratio of impervious surfaces, mainly including driveways and roadways, is approximately 11 percent lower

than the baseline scenario, which represents almost a 50 percent reduction. Moreover, through strategically clustering households, narrowing driveways, integrating landscape buffers, and reducing the household yard, a more contiguous communal landscape space is established within close proximity to all households. The largest single landscape space is 50 times larger than the largest landscape buffer that can be found in the baseline configuration, which can provide better recreational functions and environmental benefits. Meanwhile, a multi-modal mobility hub is strategically installed within a 1 min walking distance to 65 percent of all households.

Table 5. Block scale output vs. baseline conditions.

Optimization Factors		Baseline Solution	Optimized Solution (Ranking out of 5000)	Δ Variation
Ratio of impervious surface ($f_{impervious}$)		23%	12% (3173)	−11%
Landscape Space Contiguity	Area of the largest single landscape space inside the block (f_{conti})	1755	92,673 ft2 (1698)	+5180%
Multi-modal Mobility Hub Access	Average distance between each household and multi-modal mobility hub ($f_{avgdistance}$)	N/A	160 ft (533)	N/A
	Ratio of households within a 150 ft distance to the multi-modal mobility hub ($f_{householdaccess}$)	N/A	65% (2087)	N/A

4. Discussion: Design Interpretations from the Model Outputs

Inspired by the model outputs of the proposed design framework, several further design interpretations have been drawn at two distinct scales to achieve a more sustainable environment with higher accessibility and landscape performance in the era of autonomous mobility.

4.1. District Scale Design Interpretation

The output indicates that by breaking up large homogeneous land use clusters and distributing them more evenly, it becomes easier to accommodate mixed-use development patterns within the context of future autonomous mobility systems. This atomization of large land use clusters can also facilitate a more walkable and accessible living environment with reduced VMT [142,143]. As shown in the analytic diagram (Figure 14 and Table 6), in the selected scenario, 89 percent of residences are situated within a 5 min walking distance from the nearest landscaped area, 70 percent are within a 5 min walk of the closest neighborhood commerce, and in total, 46 percent of households are within a 5 min walk of both landscape space and neighborhood commercial land uses.

Table 6. District scale proximity analysis.

		Existing Scenario	Optimized Scenario	ΔVariation
Neighborhood Commercial	3 min walking *	10%	36%	+26%
	5 min walking **	25%	70%	+45%
Landscape Space	3 min walking *	12%	62%	+50%
	5 min walking **	27%	89%	+62%
Both	3 min walking *	0%	15%	+15%
	5 min walking **	4%	46%	+42%

* 3 min walking—one block away (450 ft), ** 5 min walking—two blocks away (900 ft).

Meanwhile, in the future, neighborhood commercial land uses can be utilized as strategic sites for shared mobility/mobility-on-demand dispatching centers, autonomous mobility idling, mobility maintenance, and more (Figure 15). Consequently, a reduced distance between neighborhood commercial areas and households results in shorter wait times for a mobility-on-demand/shared-mobility system. This, in turn, enhances the

reliability and responsiveness of the system, which are crucial factors influencing its usage frequency [144]. Additionally, atomized land use patterns provide significant opportunities to configure a fine-grain urban fabric with pedestrian-scale circulation networks, which can further yield improved accessibility and higher mobility capacity [145,146].

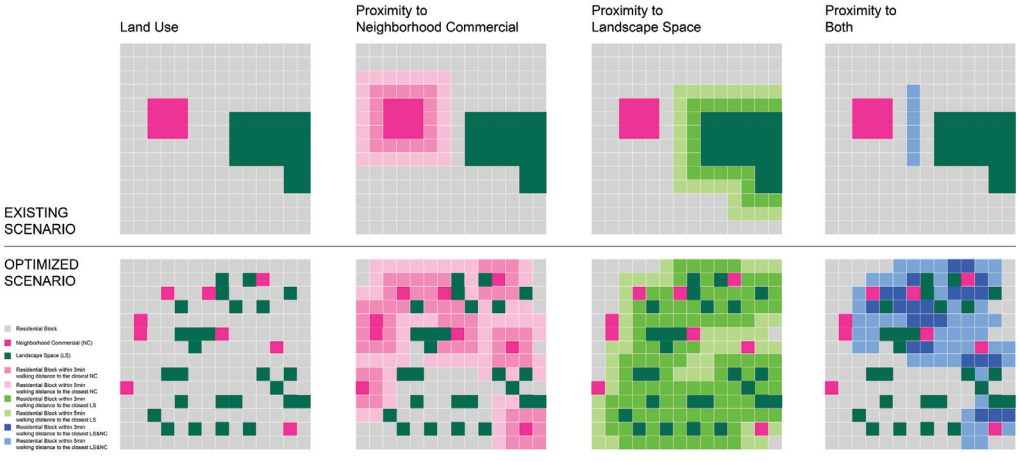

Figure 14. Proximity analysis of the district scale outputs.

Figure 15. Rendering of the future neighborhood commercial district.

It is worth noting that the output that reveals an optimized approach to distributing various land use types should also be developed based on their distinct characteristics. For example, the NC land use designation benefits from an equitable distribution throughout the site, ensuring access for all. On the other hand, the allocation of landscape spaces requires a delicate balance between access and contiguity. As a result, unlike neighborhood commercial land use, the distribution of landscape space land use tends to form small clusters, providing a balanced performance between ecology and accessibility.

4.2. Block Scale Design Interpretation

The model output shows that through strategically reducing private yard space and setbacks, combined with the extra spaces freed from driveways and household front parking, which is made possible by the autonomous mobility system, a large communal area, which is separated from vehicular traffic, can be gained. These larger open spaces can provide environmental advantages, public health benefits, and extra spaces for necessary infrastructure that is vital for future autonomous mobility systems, such as charging spaces. Meanwhile, a smaller private yard space aligns with current market trends. Research has shown that adults spent less than 15 min of time per week in their yards, while children averaged less than 40 min per week [147].

In the optimized scenario, with less demand for impervious surfaces, the block with the same number of houses can be designed with more permeable surfaces for vastly better environmental outcomes. These advantages might be accentuated in the context of multifamily zoning, where expansive parking spaces usually constructed within a block can be supplanted by on-site stormwater retention mechanisms and augmented recreational facilities. Replicating this re-envisioned block design across multiple blocks to establish a corridor and incorporating appropriate trees can markedly reduce summer temperatures and enhance the carbon sequestration capacity by over 300 percent (Figure 16).

Figure 16. A possible multi-block configuration inspired by the model outputs.

When it comes to the location of the multi-modal mobility hub, the outcome is somehow counterintuitive. Usually, in order to maximize the accessibility of the multi-modal mobility hub, the optimal location is the center of the block. However, there are two sets of trade-offs that need to be further considered. One is the accessibility of the multi-mobility hub versus the landscape space contiguity, another is the number of households with immediate access to the mobility hub versus the average distance between all households and the mobility hub. In the selected scenario, a relatively balanced outcome has been achieved. Approximately 67 percent of all households have immediate access to the hub, requiring less than a minute of walking. On average, the walking distance between all households and the hub is approximately 160 feet. As the crucial role of the proximity between households and mobility hubs in promoting higher usage of the given mobility service [148], this output achieves a balanced performance in both access and equality.

5. Conclusions

This research illustrates that with the proliferation of an autonomous mobility system, some environmental impacts of car-based infrastructures in suburban areas can be greatly reduced. The NOGAS framework provides a heuristic model for implementing new mobility systems in future suburban land use planning and block forms. Through it, city planners and other development decision-makers can easily envision future integrations of autonomous mobility systems with little cost, risk, or disruption.

The research results reveal that transitioning to autonomous mobility has vast potential for new types of land use distribution, landscape space allocation, and accessibility in suburbs without radically altering typical density ranges. Increased amounts of permeable surfaces, more equitable access to commercial and recreational amenities, and placement of multi-modal mobility hubs in the output scenarios further suggest a more walkable and livable suburb is achievable, ironically, by reducing the past century's development layouts dominated by car-based forms. Furthermore, as shown by the research, new types of mixed-use suburban neighborhoods can be created by leveraging new autonomous mobility technology, additional mobility path systems, and micro-mobility platforms. Based on the research findings, we offer several recommendations for future development and policy implementation in suburban areas.

1. When developing future suburbs, policymakers, developers, and planners must move away from the last century's car-centric models. Mobility in and around metro areas is much more diverse than the outdated transportation and policy model of planning solely for suburb to downtown core trunkline commuting patterns. People and jobs have spread out well beyond the historic cores of cities. Cities and towns should adopt a more dynamic transportation system for polycentric suburb-to-suburb linkages that prioritize accessibility and integrate a range of new mobility technologies and services.
2. Leveraging emerging mobility solutions and innovating zoning codes to allow for new mobility patterns will give policymakers, developers, and planners the opportunity to reimagine the current car-based mixed-use development paradigm, which forces an extraordinary number of extra household trips.
3. In shaping future suburbs integrated with new mobility systems, policymakers, developers, and planners should consider employing a landscape performance-oriented method of design optimization over the traditional pavement-come-first method, which can offer novel opportunities to devise more comprehensive and sustainable development strategies.
4. In formulating policies and plans for future suburbs, policymakers, developers, and planners ought to consider integrating a parametric design framework, like NOGAS. This not only enhances the process's efficiency and precision by accelerating iterations and delivering data-driven outcomes but also maximizes future prospects by offering a large testbed of innovative solutions in a relatively short period of iteration.

Admittedly, planning and design for future suburban development is a complex issue, encompassing various fields and specializations. This research delves into reinventing suburban development patterns to integrate autonomous mobility systems for better environmental outcomes. However, there are several other promising directions for future exploration. Firstly, while the current focus is on achieving improved environmental and access performance, it is essential to also consider universal access as an objective factor of the design framework. Given the increasing aging population and people with disabilities in the US [149,150], the distributed, hyper-flexible future offered by fully automated mobility systems could provide the most equitable remedy to this systemic mobility-access deficit, as substantiated by extensive research findings [151,152]. Secondly, the proposed design framework can be augmented with road network-based and efficiency-related metrics and algorithms, such as the traveling salesmen model [153] and the minimum cost paths model [154]. This integration would bolster the system's capacity to optimize the scenario's performance in mobility efficiency. Thirdly, in order to enhance the safety of the

autonomous mobility system, new roadsides that can curb infrastructures are needed to support V2X (vehicle-to-everything) development [155] and provide a way for information exchange between pedestrian and autonomous mobility [156]. Hence, how to allocate these new infrastructures is an important aspect to be incorporated in reimagining future block configurations.

To conclude, the evolution of autonomous mobility systems will significantly influence future suburban development and further investigate how environmental benefits can be accrued and equitably distributed throughout increasingly suburban metropolitan regions. If policymakers and urban planners genuinely aim to curtail GHG emissions and achieve other environmental benefits in suburban areas, they ought to contemplate instituting contemporary land use regulations that align with physical planning and design innovations built around autonomous mobility technologies to greatly reduce the need for household trips to do everything outside the block or neighborhood. Incorporating ecological performance requirements into the retrofitting of middle suburban neighborhoods and new greenfield suburban developments could ameliorate overarching environmental impacts by removing vast amounts of paving and integrating ecological priorities such as corridors, continuous canopy habitats, and hydrological catchments, all of which can mitigate the impact of land consumption and climate change.

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Notes

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2 Rhino3D is a widely adopted professional 3D modeling platform developed by Robert McNeel & Associates, renowned in the planning and design industry. GH, serving as a plugin for Rhino3D, enables users to generate, analyze, and optimize design scenarios in a parametric manner. Additionally, GH provides a comprehensive coding environment, including Python and C++, allowing users to implement customized functions using programming languages. These capabilities grant Rhino3D and GH the necessary flexibility and usability to serve as the foundation for developing a new parametric design framework.

3 During optimization process, NSGA-II employs the crossover and mutation operation to generate new scenarios from old scenarios. These two operations mimic the process of natural evolution. The crossover operation is switching several parameters of two old scenarios to generate new scenarios. The mutation is randomly changing several parameters of an old scenario create new scenarios. Several open-source NSGA-II plugins are available on the market. The Wallacei evolutionary simulation engine was selected for this research.

4 The values shown in the plot are fitness values. Fitness value is an intermediate value used by algorithm to judge which scenario have better performance in terms of given objective. The smaller fitness value, the better performance of given scenario.

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Urban Parks Quality Assessment Using Multi-Dimension Indicators in Chengdu, China

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Abstract: High-quality urban parks are considered an integral part of health resources as they can deliver diverse ecosystem services. However, the quality of parks is not always similar, resulting in different levels and values of the services provided. A systematic and complete assessment frame of urban park quality is limited. From the perspective of landscape architecture and design, this study aims to propose a comprehensive assessment framework of urban park quality based on six dimensions (planning and design, cultural services, complete and various facilities, landscape planting, landscape management, and landscape ecology), consisting of 27 indicators with different weights by using the objective and subjective weighting method. Taking the city of Chengdu, China as a case study, 100 urban parks are studied via field investigation and scored using methods that consist of a category count, existence score, field measurement, experts score, and photo review and recheck (13,589 images). The results reveal the spatial distribution and differences in park quality, including six quality dimensions and five districts, and the proportion of the existing quality elements in 100 parks. Based on the results, the spatial areas (Barren area, Low-quality area, Medium-quality area, and High-quality area) are identified, which leads to the establishment of the improvement strategies of spatial equity regarding multi-quality parks. The results can help improve the assessment index system of urban parks, guide the landscape planning and design of urban parks for sustainability, as well as provide a reference for future environmental and social equity development, so as to provide insight and reference for decision-makers and designers considering the landscape planning and design of parks.

Keywords: urban parks; park quality; assessment framework; environmental equity; landscape planning and design; landscape architecture

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1. Introduction

Urban parks can provide plenty of human well-being benefits and advance sustainable development [1–4] by delivering a variety of ecosystem services, such as regulating services, provision services, and cultural services [5–8]. They can also supply health benefits [9] such as reducing the incidence of diseases [10] by providing spaces for people to carry out physical activities and exercises [11], bringing people close to nature [12], and developing social activities [13] for the residents' daily lives. Most empirical studies have proven that urban parks have a positive impact on residents' health, both physical and psychological [10–12]. So, they are considered one of the most important strategies for improving public health [14].

Although parks are an important health resource, urban parks and their benefits do not always have equitable access and enjoyment [15–18]. Existing research regarding the environmental equity of urban parks mostly focuses on two aspects: (1) "land equity" (e.g., spatial distribution), such as the equity of sports facilities [19]; and (2) "human equity" that mainly focuses on the equity in terms of age or gender [20–22], socioeconomic status [23],

national ethnicity, or class differentiation [24]. For example, communities with a high proportion of high-income people have more park resources [25]; conversely, communities with a high proportion of minorities (such as Blacks and Latinos) lack park resources [26]. However, most of the existing literature ignores the "equity of urban park quality", that is, the category and quality of ecosystem services provided by urban parks vary from the parks' quality.

In addition, the evaluation indicators of park equity are mostly based on those of the urban green space evaluation system, such as the number of parks, per capita green space area, and green coverage rate, which focus on a quantity or area occupation assessment that tends to be more egalitarian. Further, the accessibility can effectively reflect the spatial rationality of urban parks and become a mainstream evaluation method such as in measuring objective and perceived proximity [27], density [28], and distance and travel time [29]. The quantitative characterization method and visual analysis are combined with methods such as the shortest path distance method [30] and the two-step floating catchment method [18]. This is simple and enables an intuitive measurement and interpretation of accessibility. However, none of these may accurately reflect the potential availability of parks. Current studies believe that the physical environment (e.g., park quality) affects people's potential choices and visits to parks [10]. For example, by improving the quality of parks, this can effectively increase the frequency of visits of people [31]. High-quality parks can provide a large number of different ecosystem services [5], such as climate regulation services [32]. More precisely, the park's vegetation elements (such as trees and grassland) [33], vegetation planting forms [34], water coverage, and landscape characteristic factors (such as green space rate and canopy density) [35] all significantly affect the supply capacity of climate regulation services.

The existing literature mainly focuses on the visual quality such as aesthetic features [36–39], the environmental quality such as air and sound quality [40–42], the usage and recreation quality (e.g., facilities, furnishings) [43,44], and vegetation quality [45–48] of urban parks. Moreover, most studies propose specific indicators based on the research objects and use them as standards for evaluating park quality, for instance, the indicators, such as the water surface area, vegetation coverage, and visual greening, are often used to assess the cooling effects or thermal comfort (physical or psychological) [49–51]. There is no such common and comprehensive assessment and evaluation index system for the quality of urban parks. Further, it is difficult to propose one common framework of park quality to assess and evaluate the practical design since there are no specific standards for design quality assurance.

However, landscape architecture provides the possibility to build a common assessment framework of park quality due to it being responsible for the design process that integrates aesthetics, functionality, harmony with nature [52], and landscape sustainability [53]. Although the objects of landscape architecture involve a very wide range, such as from gardens and parks to natural heritage, landfills, and brownfields, LA is dedicated to designing for sustainability, a healthy and harmonious environment for people, flora, and fauna. To a large extent, LA determines the quality of the park. Constructing a complete evaluation framework from LA helps to improve the quality of the park from the source. The proposal of an assessment index system of urban park quality is still lacking, particularly regarding the logic of landscape architecture and design. However, from a global perspective, there is no world-class standard definition of landscape architecture, nor is there a standard index system [54]. The current research related to park quality from the perspective of LA mainly focuses on different criteria instead of a comprehensive and logical index system. For example: (1) the characteristics of landscape design, such as planting design (e.g., composition, color, diversity, and conservation) [55,56], the water surface area [36], park pathway characteristics [57], the land slope, and buildings [58]; (2) the functionality of parks, such as the convenience and recreation facilities [44], accessory elements [37], and the physical activities [59]; (3) the management of parks [42], such as the park's cleanliness [60]. Evaluation methods and tools also vary with different indicators.

Meanwhile, as landscape architecture continues to develop, its core concerns are also constantly changing and expanding [61,62]. To compare the definitions, studies, and practical scopes of landscape architecture and design in different countries, this involves landscape planning, landscape design, landscape management [63,64], and landscape planting [65], as well as concern for human well-being [66]. Hence, all the design principles and the core field mentioned here that can improve park quality can be used as the reference indicators of this study.

Therefore, the main objective of this study is to propose a comprehensive and diversified assessment framework of urban park quality from the perspective of landscape architecture, then taking the city of Chengdu in China as the empirical study to verify the assessment framework. The continuation of this paper consists of the following parts. The methods and materials are presented in Section 2. Section 3 reveals the main findings. The implications, limitations, and future research directions are discussed in Section 4. The last section summarizes the conclusion. This study is not only a supplementary study on the theories and methods of environmental equity considering urban parks, but also an optimization study on the quality evaluation system of urban parks, providing a reference for future sustainable landscape planning and design.

2. Materials and Methods

2.1. Study Area

Chengdu is the capital of Sichuan Province with a current population of around 20 million, a built-up area of 94,958 ha, and an urbanization rate of 74.41% [67]. In 2018, General Secretary Xi Jinping proposed the concept of "park city" for the first time in Chengdu. In early 2022, the State Council approved Chengdu's construction of a park city demonstration area that implements new development concepts. In recent years, the Chengdu government gave great importance to the supply and restoration of urban green spaces to improve human welfare and advance the urban environment. This study focuses on Chengdu's five districts of the central city: Jinniu, Qingyang, Wuhou (does not include the four sub-districts under control in Gaoxin District), Chenghua, and Jinjiang District, covering an area of 421 km^2 and being inhabited by over 5.7 million residents [67].

According to the <Urban Green Space Classification Standard (CJJT85-2017)> published by the Ministry of Housing and Urban-Rural Development of China, this study only considered three kinds of urban parks, including urban comprehensive parks, community parks, and special parks (e.g., zoos, botanical parks, heritage parks, and amusement parks). Because these parks provide spaces for residents to engage in daily recreation and socialization with enough area, urban public gardens were excluded since they are usually too small. Finally, 100 urban parks in the central five districts of Chengdu were targeted. However, these park resources are not always equitably distributed and enjoyed in such a compact city. Figure 1 shows the location of the study area, and the spatial distribution of urban parks in the study area.

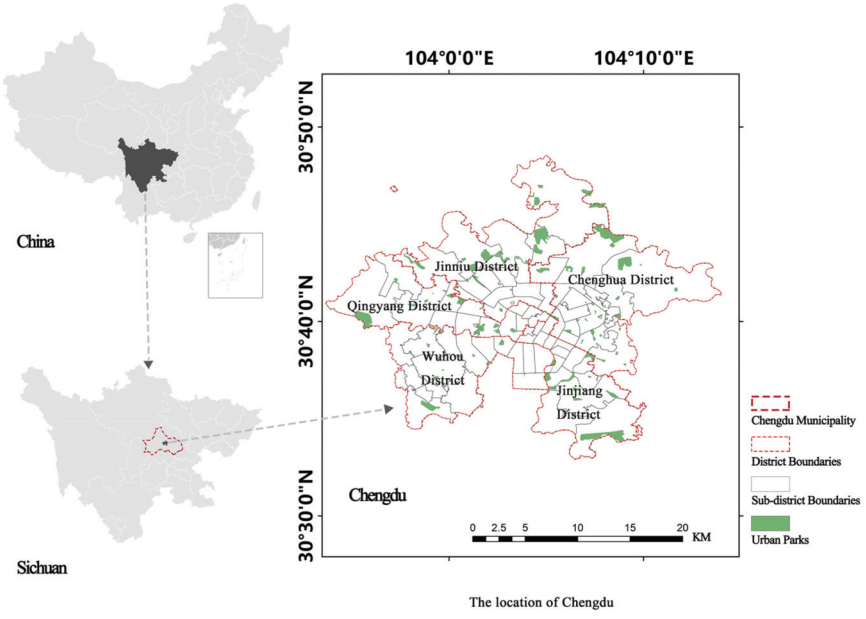

Figure 1. The location of the study area and the spatial distribution of urban parks.

2.2. Assessment Framework of Multiple-Quality Urban Parks

This study proposes an assessment framework of urban parks to assess their diversified qualities from the perspective of landscape architecture and design. Specifically, various facts and dimensions should be considered [54] while we are considering the quality of a certain park. First, the quality of a park largely depends on its landscape planning, design, and management. However, there is no universal definition of landscape architecture and design (LAD). It involves landscape planning, landscape design, landscape management [63,64], landscape planting [65], and human welfare [66], which combines the definitions, studies, and projects of LAD in the world. Hence, this study identifies six dimensions that are capable of representing park quality, according to the nature of LAD, based on prior studies, including: (1) landscape planning and design [39,48,64,66,68,69], (2) cultural services [44,70,71], (3) complete and various facilities [43,44,70,71], (4) landscape planting [45–47,72], (5) landscape management [9,43,71], and (6) landscape ecology [48,73] (see Table 1). Second, some criteria that are directly related to the six dimensions are also taken from the <Urban Park Grade Rating Standard in Chengdu (DB 5101/T 135—2021)> (UPGRSC), such as artistic, historic, cultural, and scientific values. Those indicators in the UPGRSC were not chosen since they are not closely related to LAD, and some of them cannot directly represent park quality (e.g., visitors' satisfaction, park construction investment, and operation funds). Thus, we created a complete and multi-dimension assessment framework to evaluate the park quality, consisting of 27 indicators, and considering various stakeholders such as residents, managers of urban parks, landscape planners, and designers.

Table 1. Assessment index of multi-quality of urban parks.

Index	Explanation and Examples	Weight	Method
Planning and design (PD)			
Concept	It is an original and typical concept.	3	M4
Planning and layout	Scientific and reasonable spatial layout planning.	2	M4
Functional diversity	All age friendly. Diverse functions and rich content settings.	1	M1
Traffic organization	Reasonable tour route and classification. Accessibility.	1	M3 and M4
	Use the terrain wisely, e.g., meet the drainage and rainwater collection requirements.	1	M4
Adjust measures to local conditions	E.g., terrain combined with green space to create a diversified landscape.	2	M4
Water features	Maintain reasonable water levels, and make sustainable use of water resources.	2	M2
Cultural services (CS)			
Artistic value	Integrate public art into the urban park, e.g., sculpture and land art.	2	M2
Aesthetic value	Attractive landscape features and views.	3	M4
Historical and cultural value	It has profound cultural connotations, historical values, and cultural landscape displays.	3	M4
Scientific and educational value	It has important research, science popularization, and environmental education value in the aspects of natural heritage, animal and plant resources, etc.	3	M4
Complete and various facilities (CVF)			
Basic facilities	The water, electricity, gas, and monitoring systems are complete and running well.	2	M1
Architectures and buildings	Buildings with high artistic construction techniques and historical value.	2	M1
	A variety of functional buildings in harmony with the surrounding environment.	2	M1
Guided tour facilities	It has a guide sign system with comprehensive and accurate tour information.	2	M2
Leisure and recreation facilities	Provide daily or periodic recreation activities for people, e.g., cafes and chess rooms.	3	M1
Facilities for convenience	Equipped with fixed convenience service points and daily convenience facilities, e.g., drinking water, public seats, toilets, shops, and parking lots.	3	M1
Sports and fitness facilities	Provide facilities for different people to exercise, e.g., tennis courts, swimming pools, basketball play courts, etc.	3	M1
Accessible facilities	There is barrier-free access and signage at the main entrance and exit, and the toilets are equipped with barrier-free toilets.	1	M2
Landscape planting (LP)			
Rational plant allocation	The trees and shrubs are dense and have distinct layers, and the canopy line and the forest edge line are beautiful.	3	M4
Regional characteristics	Mainly native tree species.	2	M1
Vegetation coverage	Plants (including lawns) grow lush, and the vegetation coverage rate of the park is $\geq$80%.	4	M3
Old trees and famous wood species	There are positive protection measures, and the protection rate reaches 100%.	2	M4
Landscape management (LM)			
Plant maintenance and management	The plants in the garden are kept in the best condition, and there is no random cutting or naked phenomenon.	3	M4
Environmental hygiene	The facilities (i.e., ground, toilets, walls, etc.) are clean, tidy, and without odor.	2	M4
Water quality	Water security for human, flora, and fauna.	2	M3
Intelligent facilities	Intelligent management system. A certain number of intelligent facilities.	1	M1
Landscape ecology (LE)			
Low carbon and environmental protection	E.g., effective use of green lighting and clean energy.	1	M1
	The application of sponge city (e.g., roads, parking lots, permeable paving), and low carbon environmental protection measures of resource recycling.	2	M1
Biodiversity	Plant and animal diversity, including the invasive species.	2	M2 and M4

Therefore, the assessment framework of multiple-quality urban parks was established that includes 27 indicators under six dimensions (see Table 1). There are four methods to rank the quality score of urban parks: category count, existence score, field measurement, and field research and experts score. The details are explained below.

1. Category count (M1). Scores are given by the number of categories. The more categories, the higher the score. For example, in terms of leisure and recreation facilities, a park with both a café, a tea room, and a chess room, etc., could receive more points.
2. Existence score (M2). The criterion is whether it exists or not. Scores for presence and 0 for absence. For example, it would be 0 if there are no accessibility facilities.
3. Field measurement (M3). Use different tools and techniques to measure and calculate a specific indicator. The evaluation results are used to determine the score of this indicator. In this study, only the vegetation coverage is measured by calculating the ratio of the vertical projection area of green spaces to the total area of the park.
4. Field research and experts score (M4). A panel of experts from different fields marked the scores by conducting field research (see Section 2.3).

2.3. Quality Score System of Urban Parks

To process this study, a panel of experts was organized and was responsible for the indicators' selection, the weight assignment of each indicator, field investigation and research, and the review and check of all scores, consisting of eight experts from different academic or practical backgrounds (must have a senior title or more than five years of employment). The panel included one landscape planner, two landscape architects, two botanists, one nature education practitioner, one zoologist, and one park manager. Two residents are included when the check of the final scores occurs.

The quality score system of urban parks consists of two main steps: (1) the weight assignment of each indicator's value; and (2) the identification of the final score of each park. First, 27 indicators represent different aspects of the park's quality, and likewise, they should be assigned different weights. So, each sub-criterion was weighted from 1 to 4 using the objective and subjective weighting method. The value 4 represents the maximum weight matching. Specifically, the document UPGRSC and the prior studies (e.g., [71,74]) guide the adjustment of the weight of each indicator (objective). The panel evaluation adjusts for relatively important indicators (subjective) based on their professional knowledge and several discussions.

Finally, the quantitative score system of the multi-quality urban parks is carried out (see Table 1). Table 1 demonstrates the certain weights of each indicator. The sum of the score is 65.

Second, field investigation and research were conducted from 7 September 2022 to 8 October 2023. A total of 100 urban parks in the central five districts of Chengdu were studied, as well as scored by the assessment framework (including four methods). About 20 thousand images of urban parks were obtained during the investigation, and 13,589 images were selected for further review. Further, after integration with 27 indicators, the authors and the panel of experts rechecked the previous scores and rated the quality of the urban parks by reviewing 13,589 images to ensure the fairness and reliability of scores. Thus, the final scores were obtained.

3. Results

3.1. Assessment of Multi-Dimension Qualities of Urban Parks

3.1.1. Total Points and Spatial Characteristics of Urban Parks

According to the field investigation and the official statistics, there are 100 urban parks (UPs) in the study area, with a green area of 2010.79 ha, including 27 UPs in Jinniu District, 14 UPs in Wuhou District, 14 UPs in Jinjiang District, 15 UPs in Qingyang District, and 30 UPs in Chenghua District. According to the assessment framework of multi-quality urban parks, a total of 100 UPs are scored for six dimensions of quality. Table 2 shows

the number, area, and average score of three types of parks in different districts. We can see that the area of parks in the Jinniu District is much higher (904.09 ha) than that of the other four administrative regions. The area of parks in the Wuhou District is the lowest (204.58 ha). Moreover, from the perspective of the administrative region, the average points of UPs in the Jinjiang District are the highest (38.07). This was followed by the Qingyang District (37.53), Chenghua District (35.22), Jinniu District (31.22), and Wuhou District (25.54) (see Figure 2). Although the Jinniu District occupies the largest park area, its average point of quality is only 31.22. The quality of the parks in the Jinniu District varied, with points ranging from 16.5 (lowest) to 52 (highest). We can see that the indicators in terms of the number and area of parks are not enough when evaluating environmental equity, therefore park quality should be included as an important index.

Table 2. The general information of urban parks in the five districts of Chengdu.

Districts	Comprehensive Parks	Community Parks	Special Parks	No. (Total)	Area (ha)	Quality Score (Mean)
Jinniu	7	10	10	27	904.09	31.22
Wuhou	4	7	3	14	204.58	25.54
Qingyang	5	5	5	15	288.04	37.53
Chenghua	14	9	7	30	395.48	35.22
Jinjiang	7	6	1	14	218.6	38.07

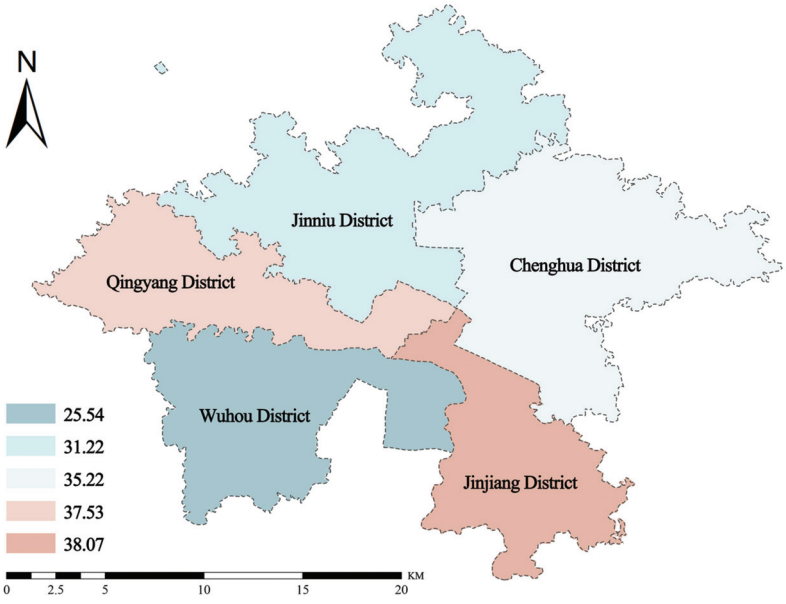

Figure 2. The average points of urban parks in five districts.

Further, Figure 3 shows the spatial distribution of the scores of urban park quality in the study area. Of 100 UPs, the highest score is 56.5 points, while the lowest score is 9, indicating a huge difference in the parks' quality. There are 64 UPs under 39 scores out of 65, accounting for 64%, which means most of the UPs are not qualified regarding their multi-qualities. A total of 26 UPs were scored from 39 to 50, representing 26% of UPs of an average or above average quality. Only 10% of UPs are above 50 points out of 65. Moreover, we can see that 15 sub-districts do not contain any parks. Among them, 8 sub-districts are located near First Ring Road representing the central area of Chengdu. Furthermore, we can see that the scores vary widely between regions considering the park

quality. The distribution of high-level areas and low-level areas is staggered from the core to the periphery. Judging from the main traffic arteries of the First and Second Ring roads in the study area, although there are 8 sub-districts with a 0-score (no UPs) within the First Ring Road, there are also many high-score areas (high-quality parks). Additionally, there are many moderate-scoring areas (with average-quality parks) scattered around the Second Ring Road. In terms of east–west distribution, the spatial differences are more clear. Generally, the East has more high-quality parks compared to the West.

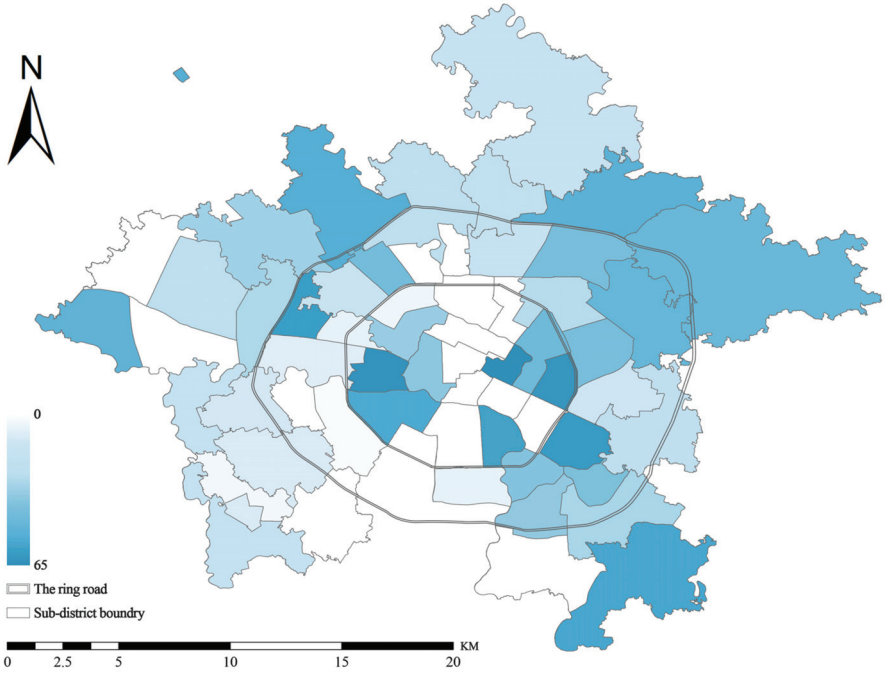

Figure 3. The spatial distribution of the scores of park quality.

3.1.2. Analysis of Six Quality Dimensions

An assessment of the multi-dimension qualities of urban parks is established with six dimensions, including planning and design (PD), cultural services (CS), complete and various facilities (CVF), landscape planting (LP), landscape management (LM), and landscape ecology (LE). The scores of 27 indicators are normalized from 0 to 1 for comparison. Figure 4 shows the proportion of existing quality elements (27 indicators) in various parks of five districts and in 100 parks.

Comparing the five administrative districts, we can see that UPs in the Jinjiang District have more balanced scores regarding quality elements, more diverse infrastructure and facilities, high-quality plant resources, and beautiful plant landscapes. UPs in the Qingyang District provide more and various cultural services. The parks in the Jinniu District are better maintained. Further, the sum and average scores of CVF and LP are the highest, indicating that UPs of Chengdu attach great importance to the integrity and diversity of facilities, as well as the configuration and design of plants. This also shows that planners and designers will give priority to meeting the basic needs of residents such as leisure and recreation, fitness and sports, convenience, shading, etc., and have high requirements for plants when they are planning and designing urban parks. In addition, PD ranks third, indicating that landscape planning, layout, and design concepts are well-considered during park construction in the study area. LM ranks fourth, which also represents the importance of the management and maintenance of UPs. CS ranks fifth, demonstrating that planners

and designers do not pay much attention to the provision of cultural services in the UPs of the study area. Additionally, the park's artistic value, aesthetic value, historical and cultural value, and scientific and educational value are low. LE ranks last, and its score ratio is significantly lower than that of the other five dimensions, indicating that the plan and design of urban parks in the study area have largely ignored landscape ecology, especially considering low carbon, environmental protection, and biodiversity.

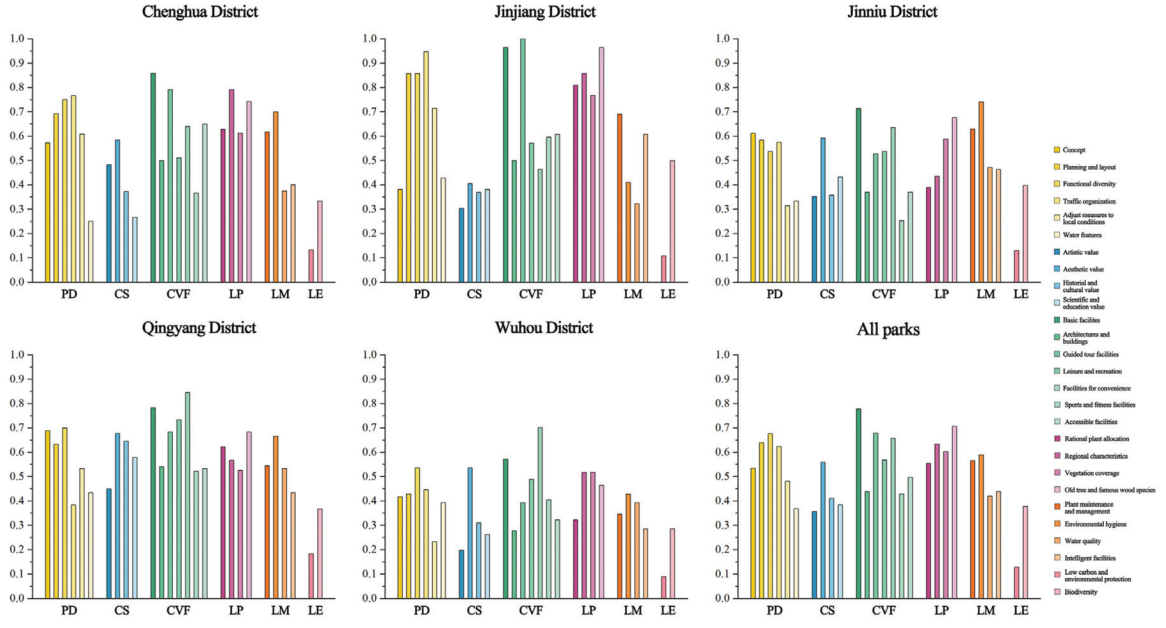

Figure 4. The proportion of existing quality elements (27 indicators) in various parks of each district and in 100 parks.

Further, all parks are divided into three levels based on their area, i.e., small parks (<5 ha), medium parks (5–10 ha), and large parks (>10 ha). The statistical results are shown in Table 3. This shows the statistics of six dimensions of urban parks with three sizes. It reflects that the larger the park, the higher the quality score in four dimensions (PD, CVF, LP, LM). Yet, regarding the dimensions of CS and LE, the fraction does not increase with increasing area.

Table 3. Statistics of urban parks with different sizes.

	No.	Score (Mean)	PD (Mean)	CS (Mean)	CVF (Mean)	LP (Mean)	LM (Mean)	LE (Mean)
Small parks (<5 ha)	30	28.13	5.53	3.45	8.8	6.39	3.25	0.72
Medium parks (5–10 ha)	24	34.85	6.71	5.44	9.79	6.77	4.65	1.65
Large parks (>10 ha)	23	36.36	7.09	5.30	10.90	6.91	4.75	1.32

Notes: The total score of the assessment system is 65, and the scores of six dimensions are 12 (PD), 11 (CS), 18 (CVF), 11 (LP), 8 (LM), and 5 (LE), respectively.

3.2. Identification of Spatial Areas Based on Multi-Quality Parks

Quantitative data and maps can be used to identify spatial areas [5] relative to the quality of urban parks. For better comparison, we normalized the score from 0 to 1 based on the final scores of 100 parks. Note that we took the average of the sum of the scores

if there is more than one park in the same sub-district. Further, we identify four spatial areas that reflect the various characteristics regarding the quality of the UP. In line with the previous results of this study, we code places with zero or extremely low quality as the "Barren area" (0–0.25) (BA), followed by the "Low-quality area" (0.25–0.5) (LA), the "Medium-quality area" (0.5–0.75) (MA), and the "High-quality area" (0.75–1) (HA). So, the spatial areas based on multi-quality parks are identified in Figure 5, reflecting the current situation and spatial characteristics of park quality in the study area. Further, different strategies are developed and proposed based on these four spatial areas (BA, LA, MA, and HA). In what follows, we outline critical strategies and concerns in the four areas considering park quality improvement and planning.

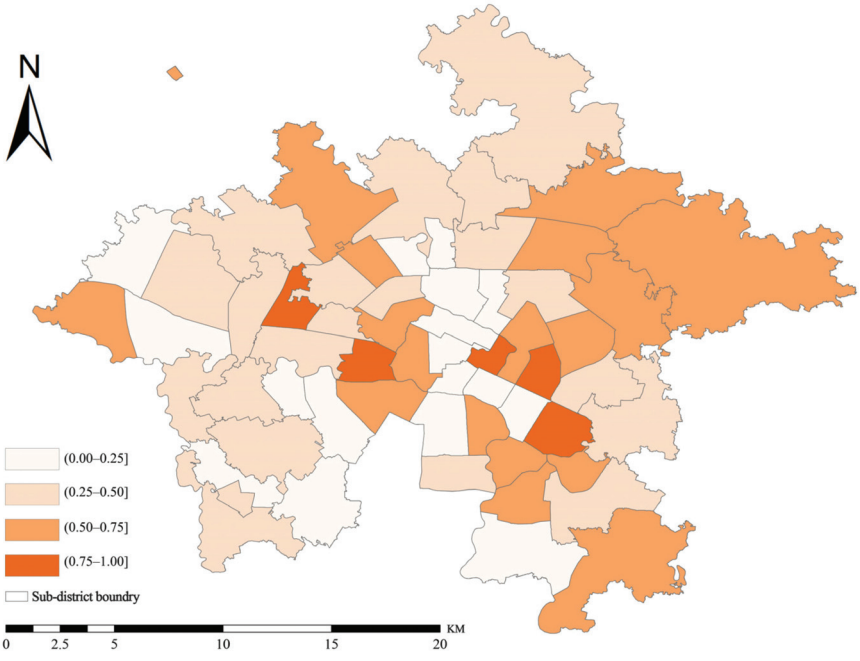

Figure 5. The spatial areas based on multi-quality parks.

BA is primarily a key area, which contains many sub-districts without urban parks at all. According to the assessment results of six dimensions of urban park quality, they are all extremely low. It is thus important to improve their multi-quality by redesigning and replanting, and it is essential to increase the coverage of urban parks regardless of the quality.

LA consists of many low-quality urban parks, which are mainly concentrated in the city center area, maybe because the land is too expensive, and it is rarely used for parks. Moreover, parks in LA failed to achieve a passing grade in all six dimensions of quality assessment. Considering PD, the concept and local suitability of landscape planning and design are weak, and there are no water features in most UPs in LA. Regarding CS and CVF, their values are extremely low, meaning that UPs in LA cannot meet basic needs, such as facilities for convenience, recreation facilities, accessible facilities, sports, and fitness facilities, which are particularly limited. Most UPs in LA lack cultural connotations and can provide very limited cultural services, especially artistic, historical, and scientific value. Furthermore, those parks in LA generally ignore landscape ecology when they are planned and designed. Thus, they should be developed and renewed by implementing ecological restoration, facilities improvement, and cultural services development.

MA is an area that needs further optimization. It includes many UPs that have been newly built in recent years within the context of park city construction in Chengdu, which ensures new modern technologies and tools, and the comprehensive consideration of landscape planning and design. Compared to parks in other regions, most of the parks in MA have made significant progress in LP and LE, including the improvement of awareness and the application of technologies. However, considering the provision of scientific and educational value, the water quality, and the biodiversity of UPs, it is essential to improve and advance.

Further, HA is primarily a protected area since it has UPs with high quality (the scores from 0.77 to 0.85), which are mainly distributed in the Qingyang District (there are two cultural and historical parks and three parks with local cultural characteristics that account for a great proportion in the assessment quality system). The scores of quality are high, considering PD, CS, CVF, LP, and LM, meaning that they generally have richer landscapes, more diverse facilities, diversified provision of cultural services, and suitable measures of park maintenance and management. However, in HA, planners and designers ignore sustainability and ecology, which should be paid more attention in the future to advance the delivery capacity of ecosystem services, particularly the regulating services.

Therefore, six dimensions should be considered comprehensively. In addition, it is necessary to carefully consider the park situation in different areas, making up for the shortcomings, instead of only thinking about one aspect.

4. Discussion

4.1. Implications

This study reveals the differences and spatial characteristics of park quality in five districts of Chengdu, and the proportion of 27 quality elements within six dimensions in 100 parks by assessing the framework of multi-dimensional qualities of urban parks. This extends the prior work on park quality assessment [40–42,44,70,71], and spatial and environmental equity [73,75]. The findings of this study are original and lead to guidelines for the development and improvement of landscape architecture and design considering urban parks.

The multicriteria of park quality build on many prior studies as we mentioned before (for example, [43,44,70,71]), and we verified some of them, for instance, the results of this study found that the facilities most relevant to people's basic needs are the most accessible and available in parks [44]. Compared with those studies, this assessment framework tends to be more comprehensive and complete. In particular, the six dimensions almost include most of the factors related to the LAD of urban park quality except for some invisible qualities (e.g., climate regulating), because it is not difficult to see the commonality among those indicators of the prior studies, which are based on the representation (e.g., aesthetic and cultural) and functionality (e.g., recreation, physical activities, and ecological function) of the park. Most of them only focused on certain factors that lacked a comprehensive system. For instance, some studies only focused on the park facilities and aesthetic features, e.g., [44] and [70], and vegetation and furnishings (e.g., lighting, benches, adult games, rubbish bins, and toilets) [56]. Some studies added factors such as maintenance level [76], biodiversity, architectural objects [71], and cleanliness [60].

Further, our research finds that the method in this study has some advantages over the photo selection and rating based on the social media platform that was used by many prior studies [26,44,77,78]. The method combines field investigation and photo rating, which is better for rating the park quality in particular, because the images provided on the social media platform have some limitations since most of them are uploaded by the users and visitors. The proportion of older adults who use social media platforms is generally small, which means that to some extent, some older adults have lost the right to speak about their preferences for parks. In addition, the photos uploaded by a social platform or review website may not always accurately represent the evaluated place. People often upload photos of the scenery that they think is good, rather than

some infrastructures in the park (such as toilets and seats). In addition, due to the social nature of social media platforms, people tend to embellish the photos when they upload, such as adding filters (distorting the scenery). Therefore, the image data obtained cannot completely represent the situation and characteristics of the park, resulting in the score evaluation of quality also having some uncertainties.

Considering the average score of the park quality in five districts, the score of the Jinjiang District is 38.07, ranked first, followed by the Qingyang District (37.53). These two districts have always been the two areas with the highest housing prices in the study area, which may result in the high quality of urban parks. Moreover, there are more high-scoring areas within the First Ring Road, that is, in the city center area. However, at the same time, there are also many 0-point areas, which do not contain any park resources at all. This may be because, in a densely populated city such as Chengdu, land prices are very expensive. Urban land use types have been established for many years that are difficult to change. Further, the spatial differences in park quality in terms of the total points are seen. There are more high-quality residential areas in the eastern region than in the western region, which may be due to Chengdu's policy trends in recent years. Chengdu has vigorously developed the Eastern New District and comprehensively promoted various construction projects there, including the development and renewal of urban parks, and has actively promoted and improved the quality of its eastern regional parks. It can be seen that policy guidance is very vital [79].

Regarding the quality concerns, the points of the six dimensions of park quality are, in descending order, LP, CVF, PD, LM, CS, and LE. The CVF and LP elements of 100 parks are relatively high, indicating that Chengdu UPs attach great importance to the integrity and diversity of facilities, as well as the configuration and design of vegetation. More specifically, most parks in Chengdu create beautiful plant scenery through rational plant allocation, the use of native species, the protection of old trees, and the improvement of vegetation coverage. Although CVF is the second most important park quality dimension, the sports and fitness facilities are uncommon and sufficiently diverse. Almost 39% of parks have no sports or fitness facilities. Without these facilities, residents may not be able to enjoy the sports and fitness benefits of parks, thereby impacting park visitation [80], as well as the residents' health [12]. Furthermore, accessible facilities are rare in most parks, maybe due to the inadequate implementation of accessibility regulations and design guidelines. However, the basic, guided tour and convenience facilities are common in almost every park, meaning that the basic needs of visitors are given priority. A total of 22% of parks have no accessibility facilities and 49% of parks have insufficient equipment. The absence of barrier-free facilities is extremely unfair to people with disabilities and some disadvantaged groups, depriving them of the possibility to fairly use park-related facilities and carry out related activities. PD ranked third, indicating that the planners and designers of Chengdu parks paid more attention to the landscape concept, spatial layout, diverse functions, and traffic organization by integrating local conditions. However, the water features are normally uncommon such as the lack of sustainable water resources. This may be due to technical and financial constraints in water purification and maintenance. In terms of CS, people tend to appreciate aesthetic values [81], while those invisible values or abstract artistic values are not always perceived and appreciated. Four indicators of this dimension are generally ignored during the process of landscape planning and design. Meanwhile, LE is a dimension that is often considered and mentioned in reality. However, it had few positive effects. In particular, the low carbon and environmental protection should be advanced and considered more in the future. Additionally, considering the low scores and proportion of LM, maybe not because of the outdated management styles, instead the management issues were not given too much consideration during the process of landscape planning and design of the park. For example, plant designers chose tree species that are more expensive or difficult to maintain, which makes subsequent maintenance more difficult and costly; or, some parts of the construction were not constructed in full accordance with the design drawings, resulting in increased maintenance costs in the later

period and poor maintenance. In summary, six dimensions should be considered as a whole throughout the entire design process of urban parks.

4.2. Limitations and Future Research Directions

This study has some limitations that point to directions for future research mainly related to two aspects: environmental equity and the methodology of park quality assessment.

Regarding the research on spatial and environmental equity, there are two important points. First, this study failed to consider indicators such as accessibility and the socio-economic data (demographic data and housing data) to analyze the environmental equity and justice integrating the park quality, since the prior studies show that there is significant social inequality in the accessibility of parks [42], and the park resources are affected by gender or age [22,82], socio-economic status [23], and race [15]. Future research should establish a research framework that combines both the demand and supply of park resources, rather than only consider the park quality, to create a multi-dimensional environmental equity assessment system by integrating park quality, accessibility, transportation, park area, geographical level, people's needs, and so on. Further, a sub-district with only one park would have a small area but a high score (the area would show higher value in the assessment scores of park quality), although this was not found in this study. It still deserves attention and consideration in future research. This also shows that, from the perspective of spatial and environmental equity, park quality is difficult to use as an evaluation indicator alone, but should be combined with criteria such as accessibility and population characteristics.

Moreover, there are some deficiencies in the methods of quality evaluation of urban parks in this paper. First, the park location, area, and visitation are important factors that affect the quality, thus, it is necessary to combine them with the park quality to improve the assessment framework of this study. It could establish models combining resident interviews or questionnaires to determine the appropriate proportion of the contributions made by the various indicators, integrating the experts' review and evaluation to adjust the parameter weights in future research. Furthermore, there are four methods (category count, existence score, field measurement, and experts score and research) to analyze and evaluate the indicators. The fourth method (field research and experts score) mainly relied on the panel's subjective opinion, and the panels of experts were also responsible for the review and recheck of the final scores. However, the members of the expert group are all from Chengdu (there may be regional or ethnic differences when it comes to subjective evaluation), and their participation in the decision-making process was sometimes likely to be influenced by the local social, institutional, and political environment. Therefore, future studies or replication studies in other regions should establish more scientific criteria for the selection of individuals or groups of experts. Whether the results of this study can be generalized to Chinese cities outside of Chengdu and even to other cities around the world remains to be verified. Moreover, the evaluation framework established in this paper has not been evaluated and analyzed for parks outside Chengdu, and its operability and extensibility need to be further verified. In future studies, this framework should be applied to evaluate other well-known parks around the world, and the evaluation methods and results should be compared to other studies to further verify the evaluation framework. Last but not least, the assessment framework of urban park quality proposed in this study is based on the background of LAD. Although it integrates aspects such as design, aesthetics, function, ecology, and human well-being, it cannot cover every aspect of park quality, such as the sound quality, air quality, the level of thermal comfort, etc. This still needs further development, and future research should consider adding more indicators of landscape ecology and ecosystem regulating services.

5. Conclusions

A total of 100 parks were surveyed and studied regarding their quality in six dimensions and 27 indicators in the study area of Chengdu, China. The results show that the quality of urban parks in the study area has great differences, and the spatial distribution is unfair. From the perspective of administrative regions, the average score of the Jinjiang District City Park is 38.07, ranking first, followed by the Qingyang District (37.53), Chenghua District (35.22), Jinniu District (31.22), and Wuhou District (25.54). A total of 15 sub-districts do not contain any park green space resources at all. The highest score among 100 UPs is 56.5 points, and the lowest score is 9 points, which shows that the quality difference between parks is huge. Among them, 64% of parks scored below 39, indicating that the overall quality of most UPs is unqualified. Moreover, the park scores vary widely from region to region. From the core to the periphery, the distribution of high-rise areas and low-rise areas is staggered. There are more high-scoring areas within the First Ring Road, and there are more high-quality residential areas in the eastern region than in the western region. Considering the six dimensions and 27 evaluation indicators of park quality, the planning and design of parks in the five districts have different trade-offs. For example, urban parks in the Qingyang District provide a variety of cultural services, while parks in the Jinniu District pay more attention to park management and maintenance. Furthermore, the larger the park size, the better the quality in four dimensions (PD, CVF, LP, and LM). It is worth noting that balancing the proportion of the six dimensions of quality elements should be the primary task of future planning and design, rather than just focusing on one aspect of the elements. Based on the results, we identified four spatial regions that reflect various characteristics of park quality, namely, BA, LA, MA, and HA. According to different spatial characteristic areas, corresponding park quality improvement strategies are proposed. In BA and LA, the improvement and adjustment of park quality have become more important to create a fair environment. In MA and HA, it is necessary to improve the quality of certain aspects of the park.

This study reveals the capacity of ecosystem services provision of different urban parks to residents by assessing the multi-quality of urban parks. It is essential to create a justice and equity environment particularly in the different communities by identifying and correcting the differences in park quality. The study can provide insight and reference for decision-makers and designers considering the landscape planning and design of parks. Overall, the findings of this study will help improve the urban park evaluation index system from the perspective of LAD, and help guide landscape planners and designers scientifically to plan and design urban parks. These findings also provide a reference for future environmental equity and social equity development.

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Enhancing Access to Urban Hill Parks: The Montjuïc Trail Masterplan and the 360° Route Design in Barcelona

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Abstract: The 2030 United Nations Sustainable Development Goals (SDGs) include ensuring universal and safe access to green spaces. Some cities feature extensive green areas on hills or elevated terrains integrated into the urban landscape. In such cases where the benefits for users are highly pronounced (e.g., views, isolation, etc.), it is challenging and particularly complex to design strategies to ensure accessible and spatial routes due to multiple slopes and a challenging topography. In Barcelona, the iconic Montjuïc mountain has been the focal point of a trail masterplan aimed at rethinking its various access points and internal network of routes. Furthermore, the city has committed to implementing an initial project from this plan, the so-called 360° route. This study presents an in-depth analysis of the Montjuïc mountain case, encompassing both the plan and the 360° project in hilly urban parks. The analysis reveals the values and transferability of the set of strategies proposed in the plan, such as activating inherent location characteristics by connecting the surrounding urban fabric with elements of recreational potential within the underlying traces of heritage value. Additionally, a quantitative assessment of the impact of the proposed accesses on the population is presented. The study highlights the improvements in quality of life for the diverse users of this type of green infrastructure.

Keywords: urban park; trail masterplan; green infrastructure; accessible green spaces; Montjuïc hill; Barcelona

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1. Introduction

The 2030 United Nations Sustainable Development Goals (SDGs) include "universal access to safe, inclusive, and accessible green and public spaces" as part of their objective 11.7 [1]. The strategic importance of urban parks has been highlighted from multiple perspectives. Beyond providing strictly environmental services (e.g., air or microclimate stabilization), green spaces offer diverse social and psychological benefits [2] that have a positive impact on the health and well-being of residents [3]. Currently, the emphasis is placed on the concept of green infrastructure, which is understood as a planned network of natural and seminatural spaces that provide ecosystem services and protect biodiversity [4]; this includes—and does not diminish—the importance of urban parks of considerable size [5].

Among urban green spaces and parks of some significance, we encounter natural spaces such as mountains, lakes, and rivers that were once on the periphery but have gradually become integrated into the expansion and development of urban areas [6]. Within this range of situations, there exists a specific typology that pertains to hills that have become entrenched within urban areas. While it may seem that hilly environments discourage walking along steep gradients [7], it is also true that various and complementary reasons enhance their recreational potential. Elevated locations significantly contribute to isolation from the city, enhancing parameters such as stress reduction and a sense of

peacefulness, as identified in the 1980s by Ulrich [8] and Kaplan [9]; they also provide benefits that are associated with distant views [10]. On the other hand, the strategic nature of elevated locations from the perspective of territorial control and symbolic significance often leads to an intense succession of changing land use patterns that result in a diverse mosaic of cultural ecosystem services [6].

Several examples confirm the importance and uniqueness of such settings in cities. For example, Holyrood Park in Edinburgh is a remarkable 260 hectares of upland landscape in the heart of the capital, shaping its identity and encompassing a range of habitats and heritage [11]. Mount Royal in Montreal covers 280 hectares and is a symbol of the city with its green spaces, heritage, and a range of services and activities [12]. Similarly, the Montjuïc hill in Barcelona, covering 338 hectares, is a symbolic place that combines historical importance, nature, and recreational opportunities [13].

All of these examples share a combination of nature, culture, and recreational services in complex spatial configurations that have a sedimentary nature (i.e., the succession of changing land use patterns), which lead to unstructured mosaics in challenging topographies. Both physical barriers (e.g., [14,15]) and the valuation of cultural ecosystem services (e.g., [16–18]) have been considered in assessing the quality of large green spaces. However, the need to organize the built and intangible heritage within complex green spaces has received less research attention.

In this context, trails have been identified as place-narrative tools that can improve visitors' engagement and contribute to the interpretation of complex green spaces [19,20]. Therefore, it is hypothesized that trail planning is a crucial element in engaging the community to use these large green spaces extensively, overcoming physical barriers and benefiting from a significant and purposeful spatial structure.

This research explores the case study of Montjuïc, Barcelona's largest and most visited urban park [21], focusing on the recent development of the Montjuïc Trail Masterplan (MTM), which was designed to enhance the system of accesses and itineraries [22]. The aim is to analyze the masterplan to identify planning tools that can be applied to similar situations, namely, unique urban parks located on hills with a significant heritage layout and subject to multiple transformation episodes. Complementarily, an analysis of the 360° route strategy [23] is considered due to its importance in the overall plan and its advanced level of implementation. Finally, a quantitative evaluation of the impact on the population within reach of the proposed access system in the plan is provided.

2. Materials and Methods

2.1. Case Study: Montjuïc Park in Barcelona, Spain

Barcelona, the capital of Catalonia in Spain, is among the most densely populated cities in Europe with an urban population of approximately 1.7 million. This represents 63% of the Catalan population and 10% of the Spanish population [24]. The city is located on the plain of Barcelona and is bounded by two rivers (Besós and Llobregat), the Montjuïc hill, the Collserola mountain, and the Mediterranean Sea. The city, much like Rome and Lisbon [25], has assimilated seven smaller hills and the Montjuïc hill, which is the largest (Figure 1).

Montjuïc is a 173 m high hill located in the southeastern part of the city, covering an area of 338 ha (Figure 2). This area serves as the focus of the research and corresponds to the limits outlined by the latest update of the Montjuïc land-use masterplan [21]. The hill has a complex orography formed by an irregular cone consisting of three hillsides, one of which is an impressive cliff facing the sea (Morrot) [26].

The hill is an unmistakable landmark that has played a significant role in the city's development. In fact, the earliest evidence of human settlements in Barcelona was discovered in Montjuïc (Epipalaeolithic), and since the Roman period, it has been utilized as a stone quarry to construct numerous monuments within the city [27]. Ever after, the Montjuïc hill has held strategic significance from a military perspective, providing visual control over the Mediterranean Sea and the city. It was fortified as early as the 17th century. Additionally,

the hill has hosted two internationally significant events: the 1929 International Exposition and the 1992 Summer Olympics. The former led to the construction of multiple buildings, such as the National Museum of Catalan Art, the Magic Fountain, and the Spanish Village, among other transformations. The latter resulted in the renovation of existing structures, including the Olympic Stadium, and the addition of new facilities, like the Palau Sant Jordi [13].

Today, the Montjuïc hill comprises a mosaic of multiple attractions and cultural institutions, such as the Fundació Joan Miró and the Jardí Botànic (a botanical garden with over 2000 plant species). It also hosts several festivals and events throughout the year, including the Grec Festival (a summer festival of music, theatre, dance, and circus), the Piromusical (a fireworks show with music), and the Fira de Barcelona (a trade fair) [28].

On the other hand, the Montjuïc hill offers stunning views of Barcelona and its surroundings, especially from its highest point, where the military fortress—the castle—is located. It can be accessed by various means of transportation, such as buses, the metro, a funicular, and a cable car. It is also a popular spot for hiking, biking, and picnicking [13].

However, the hill, with its diverse range of recreational opportunities and cultural attractions, lacks a meaningful structure of trails and accesses that could enhance visitor engagement from an active mobility perspective. The recent MTM [22] addresses this gap and is further analyzed in the article.

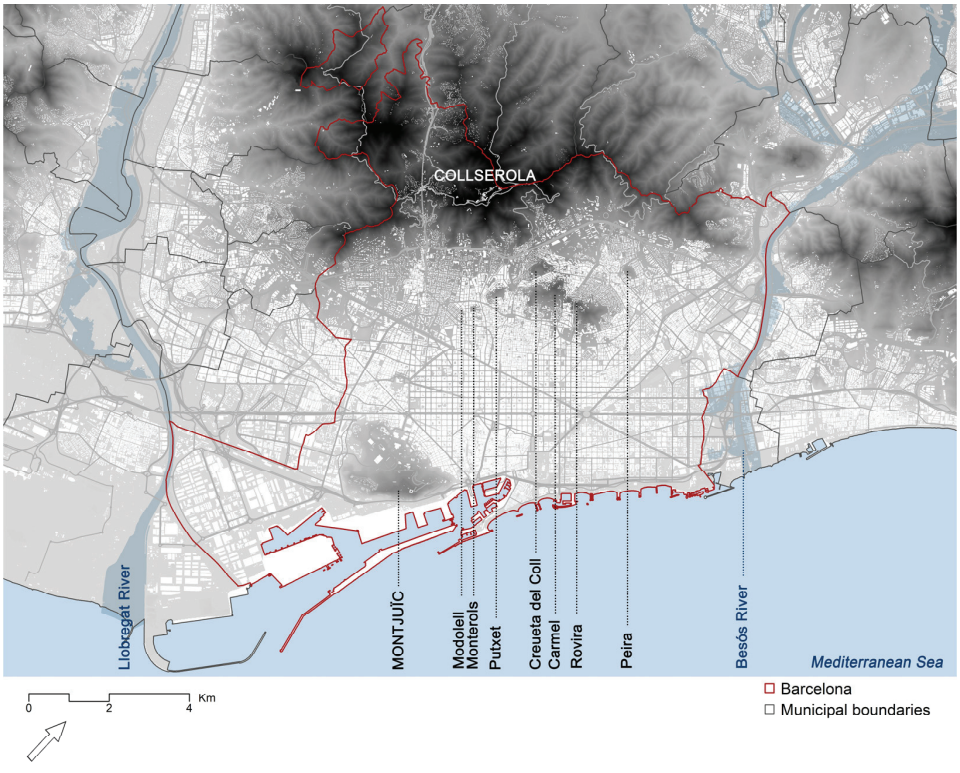

Figure 1. The Montjuïc hill's location in Barcelona—Montjuïc and the seven hills: Modolell, Monterols, Putxet, Creueta del Coll, Carmel, Rovira, and Peira. Source: the authors, based on regional data [29].

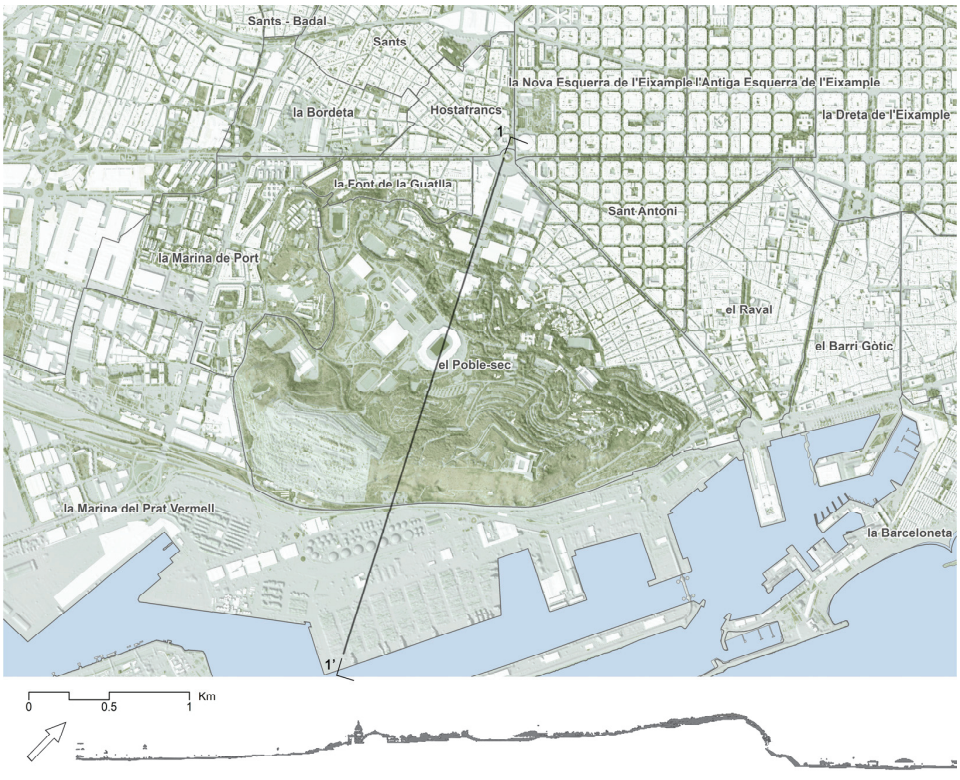

Figure 2. The Montjuïc hill and the surrounding neighborhoods of Barcelona: (**top**) floor plan and (**bottom**) cross-section 1-1′. Source: the authors, based on municipal [30] and regional LIDAR data [29].

2.2. Methods

The applied case study methodology encompassed three distinct phases derived from planning and design research approaches grounded in the case-based literature [31]: (1) definition, including the selection of the case study based on the research gap and the hypothesis set out in the first section; (2) preparation, data collection, and analysis of the case study; and (3) elaboration of the synthesis of the findings, leading to further discussion and conclusions (Figure 3).

To address the second phase, a comprehensive analysis was conducted on the MTM [22], with particular focus on the system of accesses and trails it provides. Simultaneously, a review of prior plans, studies, and initiatives related to the MTM [22] was conducted. The most relevant planning instruments included the 2014 Montjuïc Hill Plan [21] and the 2018 Action Plan for Montjuïc Park [32], which are a binding land-use plan and a set of corresponding actions, respectively. Among the notable studies, we found the 2019 Study of Landscape Intervention Strategies for the Montjuïc Paths [33], the 2020 Proposal for Public Space and Mobility for Montjuïc [34], the 2019 Strategic Plan for the Coastal Spaces of the City [35], the 2019 Preliminary Study for the Recovery of the Infanta Canal and the Old Canal [36], and the 2018 Urban Landscape Study Font de la Guatlla [37]. Among the initiatives arising from or involving civil society, the Montjuïc 360° route [23] is particularly noteworthy and, as will be shown, is the first component to be executed following the MTM [22] presentation. A further collection of initiatives can be found within the participatory budget processes that occurred in the neighborhood in 2021 [38].

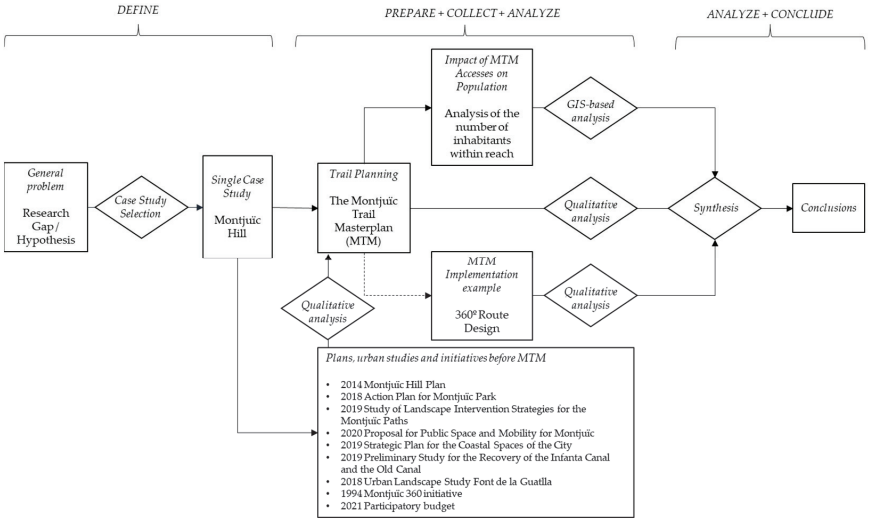

Figure 3. Methodology flow chart. Source: the authors.

Additionally, two further insights have been pursued: firstly, a comprehensive exploration of the 360° route [23] as included in the MTM [22], analyzing its physical implementation and impact, and secondly, the computed impact of the MTM [22] accesses, evaluating the number of inhabitants within reach. This approach is solely quantitative and does not encompass economic and social aspects, such as the initiatives' impact on the local property market [39]. Specifically, the method refers to the intersection between the influence buffers originating from the accesses to the Montjuic hill proposed in the MTM [22], measured along the street network, and the population recorded in the blocks according to the January 2023 census data [40]. This type of approach has been widely used as a measure of proximity in green spaces (i.e., evaluation of the number of users with reference to a certain service) [41].

To establish the catchment areas for each access, travel times of 15 and 30 min along the shortest paths were considered, with a reduced speed of 2 km/h to include most residents (e.g., children and older adults). Studies and manuals on walking accessibility usually set values between 0.75 m/s (2.7 km/h) and 1.22 m/s (4.32 km/h) [42–44]. However, when considering an inclusive approach, these values are generally reduced to 2 km/h, as was the case in a recent study carried out for Barcelona by the institution Barcelona Regional [45] in relation to access to urban green spaces.

The distances and travel times considered capture the notion of proximity to the daily or semiweekly visitor but do not take into account the other less frequent use patterns, which would have a considerably larger footprint given the size and importance of Montjuïc Park [43]. In this sense, the hypothesis that the size of a park increases the desire of visitors to use it and therefore to travel greater distances is only valid for those who visit the park occasionally [46]. Moreover, the considered proximity distances and travel times align with the standards of various supranational agencies. For instance, the World Health Organization [47] considers spaces of 0.5–1 hectares at a distance of 300 m (approximately 5 min at a speed of 2 km/h), and the European Environment Agency [48] recommends a 15 min access measure to green spaces. Of greater significance, the proposed analysis integrates the concept of the "15 min city" [49] by incorporating this isochrone within the population evaluation (500 m at a speed of 2 km/h). In addition, a 30 min isochrone (1000 m at a speed of 2 km/h) was considered to overcome two factors: (1) the fact that the park perimeter is often occupied by nonresidential transitional facilities and (2) to implicitly

account for a less conservative speed (i.e., 1000 m is actually a 15 min distance at a speed of 4 km/h).

Finally, the accesses were evaluated by merging the 15 min isochrones (500 m) by foot from each access to account for the total population nearby. Another additional check was carried out by recalculating the 15 min isochrones using public transportation, following the trend of extending the notion of the "15 min city" to transit-oriented development [50]. To do this, the General Transit Feed Specification (GTFS) files of the public transportation systems that operate within the study area of the city of Barcelona were utilized for a typical weekday morning. Specifically, the GTFS files of the following operators were used: Direcció General de Transports i Mobilitat (DGTM) [51], Transports Metropolitans de Barcelona (TMB) [52], Ferrocarrils de la Generalitat de Catalunya (FGC) [53], Renfe Operadora [54], and TRAM [55]. All of the modeling, for both walking and using public transportation, was conducted using the network analyst module of ArcGIS Pro [56] considering the vector road network data from OpenStreetMap [57].

3. Results and Discussion

3.1. Analysis of Previous Plans, Studies, and Initiatives before the Masterplan

The studies and planning documents preceding the MTM [22] that form the fundamental framework for developing the new spatial organization can be categorized into three groups: (1) planning instruments exclusively covering the Montjuïc hill, (2) urban studies and sectoral plans, and (3) civil society initiatives. Table 1 outlines the reviewed documents, elucidating their primary objectives, underscoring their contributions to the forthcoming access and trail system of the park, and expounding on their limitations for this purpose.

Table 1. Analysis of previous plans, studies, and initiatives before the MTM. Source: the authors.

Category	Title	Scope	Main Objectives	Strengths	Limitations
Planning instruments	2014 Montjuïc Hill Plan [21]	Montjuic Hill	Land-use plan; new mobility model; improvements to park–neighborhood relations	Zoning according to prevailing attributes (e.g., heritage, sports, green spaces); identification of a set of accesses	Mobility model lacks cultural ecosystem service-based trail planning
	2018 Action Plan for Montjuïc Park [32]	Montjuic Hill	Proposed specific actions based on 2014 Montjuïc Hill Plan	Entities and associations participating (up to 530 face-to-face); identification of trail potential as crucial	Lack of explicit inclusion of a comprehensive trail plan
Urban studies and sectorial planning	2019 Study of Landscape Intervention Strategies for the Montjuïc Paths [33]	Montjuic Hill	Tool for developing future interventions on historical paths	Sketch of initial route structure with 18 physical barriers	Absence of comprehensive network (emphasis on thematic tours)
	2020 Proposal for Public Space and Mobility for Montjuïc [34]	Montjuic Hill	Measures to reduce car usage and promote active mobility	Emphasis on public transport access; proposal of safety measures for active mobility modes	No internal trail structure provided
	2019 Strategic Plan for the Coastal Spaces of the City [35]	Barcelona's coastline	Coastal areas as a quality public space; definition of a model with key stakeholders	Envisioning urban transit corridor and cliff-side sea-facing bike lane	No substantial impact on Montjuic Park observed

Table 1. *Cont.*

Category	Title	Scope	Main Objectives	Strengths	Limitations
Urban studies and sectorial planning	2019 Preliminary Study for the Recovery of the Infanta Canal and the Old Canal [36]	Linear heritage infrastructure	Acknowledgment of current heritage infrastructure for integration into public space	Comprehensive delineation of current linear infrastructure; identification of future intervention sites	Limited to southwestern foothill
	2018 Urban Landscape Study Font de la Guatlla [37]	Neighborhood on north-western slope (3.20 ha)	Emphasis on highlighting neighborhood's urban landscape for future decisions	Difficulties due to slope in accessing the park from this area	Small scope relative to the entire hill study
Civil society initiatives	1994 Montjuïc 360° initiative [23]	Perimeter of Montjuic Hill	Converting circular route into designated signposted trail	Inspiring bottom-up initiative driven by the social organization's promotion	Need to incorporate isolated route into broader trail plan
	2021 participatory budget [38]	District of Sants-Montjuïc	Empowering citizens to identify, prioritize, and vote on future public investments in their neighborhood	Hill ecosystems, ecological balance, and pathway improvement selected among various projects	Isolated actions lacking comprehensive park-wide vision

Among the planning instruments, the 2014 Montjuïc Hill Plan [21] stands out by examining historic pathways in contrast to the present roadways in its diagnosis. From the perspective of land-use planning, it envisions a park with distinct zones: the classic park, the sports park, the natural interest park, and the transformed park. The classic park refers to areas containing heritage-value facilities. The sports park includes buildings and open spaces dedicated to sports. The natural interest park acknowledges protected natural spaces as well as their transitional perimeter areas. The transformed park identifies themed garden areas that should be permeable to users at predetermined times. Additionally, the plan identifies strategic intervention points as measures to facilitate sustainable mobility. Secondly, the 2018 Action Plan for Montjuïc Park [32] revisits the 2014 Montjuïc Hill Plan [21] in conjunction with contributions from entities and organizations with interests in the hill, grouped under the name Montjuïc Park Council. The document primarily develops a set of four key ideas: (1) a park for the neighborhood with citywide projection, (2) a park with diverse spaces to regain the concept of a lung for the city, (3) an accessible park that optimizes mobility, and (4) the development of governance tools.

In addition to the planning in the abovementioned documents, subsequent studies were conducted that are relevant for understanding the starting point of the MTM [22]. For instance, the 2019 Study of Landscape Intervention Strategies for the Montjuïc Paths [33], stemming from the 2018 Action Plan for Montjuïc Park [32], offers an initial approach to proposed itineraries and identifies up to 18 specific intervention points to address accessibility issues.

Furthermore, the 2020 Proposal for Public Space and Mobility for Montjuïc [34] explores the relationship between the city and the hill based on the proposals for green accesses in the city of Barcelona [58] as priority access points to the large park. Within the hill's interior, there is a specialization and prioritization of the internal road system to discourage private vehicle use in favor of public transportation, cycling, and pedestrian mobility.

Other studies that have a more tangential focus include the 2019 Strategic Plan for the Coastal Spaces of the City [35], which envisions an urban public transportation corridor and a bike lane on the southeastern slope connected to the Port of Barcelona. The 2019 Preliminary Study for the Recovery of the Infanta Canal and the Old Canal [36] evaluates the preservation of the historic infrastructure bordering the southwestern slope of Montjuïc.

Lastly, the 2018 Urban Landscape Study Font de la Guatlla [37] focuses on the Font de la Guatlla neighborhood located on the northwestern slope in order to identify its values and establish future strategies, including mitigating topographical fractures and creating a panoramic ridge walkway.

Finally, among the initiatives originating from and/or involving civil society, the route known as Montjuïc 360° [23] and the resolution of the participatory budgets driven by the Sants-Montjuïc district in 2021 [38] are noteworthy. The Montjuïc 360° route [23], which began in 1994, was proposed by the Hiking Promotion of Barcelona to highlight a perimeter route that minimizes its passage through paved streets and maximizes paths through the park, connecting points of interest along its approximately 10 km course. On the other hand, the participatory budgets identified several sets of relevant proposals, emphasizing improving the hillside environment, ecological balance, and pathways.

Table 1 demonstrates that the majority of approaches lack an all-encompassing relational structure to effectively organize the park's attributes and content via active mobility infrastructure. However, notable progress has been made in recognizing access points, identifying heritage traces, incorporating green infrastructure, and characterizing attractors; this is particularly highlighted in the 2014 Montjuïc Hill Plan [21]. These insights will serve as valuable inputs for the MTM [22], enabling the development of a comprehensive relational structure that encompasses the entirety of the park.

3.2. Analysis of Key Factors Influencing the MTM Proposal: Heritage and Green Infrastructure

Beyond the detailed study of plans, studies, and initiatives related to the park, the MTM [22] stands out for considering two key aspects: heritage and green infrastructure.

In the case of heritage, one of the objectives of the MTM [22] is to activate traces of the site's relational elements, referred to as heritage infrastructure, in order to become part of the new trail network (Figure 4). To address this consideration, previous studies that drew upon specialized literature enable the identification of up to four main elements: (1) the ancient paths of Montjuïc, (2) the so-called Canal de la Infanta, (3) the Paseo de Jean Forestier, and (4) the Funicular de Montjuïc. Concerning the ancient paths of Montjuïc, specialized literature has emphasized certain traces that are already identifiable through 18th century cartography, medieval texts, and the still recognizable fossilized reality [22]. The most significant set of elements is centered around the toponym of the Camí de València, traversing the hill from southwest to northeast in successive evolutions from an origin believed to be Roman [13]. The Canal de la Infanta represents one of the most valuable heritage infrastructures, although its relationship with the park is somewhat tangential, embracing the southwestern foothill. It was built between 1817 and 1820 to carry water from the Llobregat River to irrigate the left bank of its delta. From the initial agricultural, demographic, and industrial explosion, there was a progressive absorption of the irrigation network by the urban fabric, turning the system into an improvised drainage network. Eventually, it was covered, cut, and redirected according to the needs of each municipality, resulting in a collection of disconnected built heritage elements [36]. The Passeig de Jean Forestier was part of the monumental layout designed for the 1929 International Exhibition of Barcelona. It is now named after Jean Claude Nicolas Forestier, a landscape architect who played a vital role in landscaping Montjuïc's slope [59]. The Funicular de Montjuïc, with a slightly less than 100 m development, was inaugurated for the 1929 International Exhibition and is currently out of use [60]. The strategy of defining a trail network with heritage content and historical significance goes beyond the conceptualization of a set of tourism products. For instance, MacLeod [19] pointed out that constructing a specific narrative around trails significantly contributes to increased visitors and the appreciation and "active engagement" of local communities.

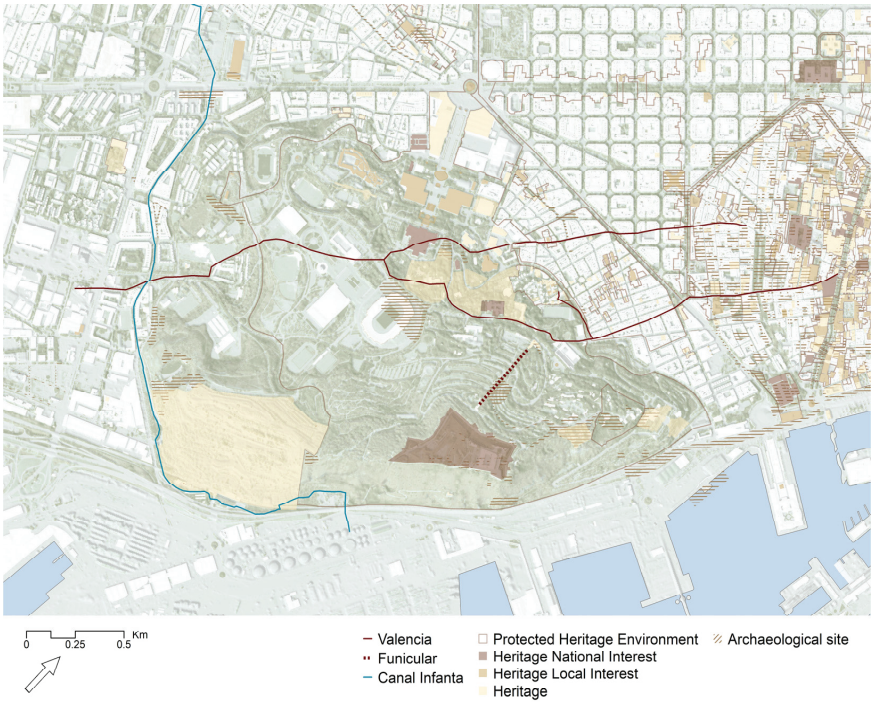

Figure 4. The heritage values of the Montjuïc hill. Source: the authors, based on the Montjuïc Trail Masterplan [22].

In the second case of heritage, recognizing a broader framework beyond the mere construction of local urban green infrastructure is involved. The 2018–2030 Climate Plan for the city of Barcelona [61] addresses climate change objectives for the horizon for 2030, including a 40% reduction in CO_2 emissions per capita compared to 2055 and an increase in urban greenery by 1.6 km^2 (1 m^2 per current resident). Among the evidence gathered by this plan, it was noted that Barcelona experienced eight heatwaves in the last 34 years, and from a health perspective, the Sants-Montjuïc district ranks among the worst according to the Urban HEART tool [62]. Focusing on Montjuïc, the document highlights the Montjuïc cliffs as reserves for preserving fauna that are vulnerable to climate change. In addition, the 2021–2030 Nature Plan of Barcelona [63] aims to increase the city's green infrastructure and identifies Montjuïc as one of the most exciting areas in terms of green spaces and biodiversity concentration.

3.3. The Montjuïc Trail Masterplan Proposals

The MTM [22], drawing from previous plans, studies, and initiatives, conceives a comprehensive trail network that takes into account both heritage and green infrastructure. The new proposal establishes the following: (1) a range of up to 12 city–park access points, including transition transects between urban fabrics and the hill; (2) a closed circuit called Montjuïc 360° [23] inspired by the mentioned contribution of the Hiking Promotion of Barcelona, which encompasses all access points; (3) a set of five trails linked to historical traces; and (4) a set of future connection provisions that the plan does not consider a priority. In the case of the five historical trails that are reinterpreted, they include those mentioned in the previous subchapter: (a) Funicular, (b) Valencia, (c) Sta Madrona, (d) Forestier, and (e) Canal de la Infanta. The proposed network is capable of integrating the considerations made by previous studies and is represented as if it were a public transportation network following examples like Metrominuto in Pontevedra, Spain [64], or the Cambio Network of

cycle highways in Milan [65]. The new layout, which is represented in Figure 5, allows the categorization of nodes into (1) interchange nodes between lines, (2) link nodes between access points and the itinerary network, and (3) points of interest. The names of the lines and nodes correspond to their heritage infrastructure reference and the most representative toponyms within their respective areas of influence.

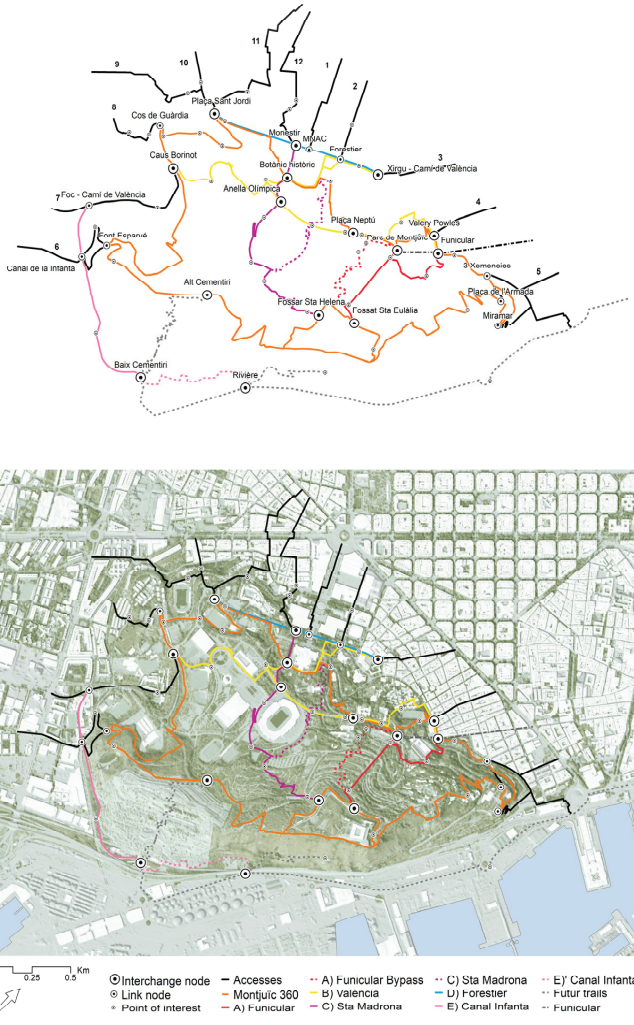

Figure 5. The Montjuïc Trail Masterplan: (**top**) trail network scheme with interchange and link nodes and (**bottom**) general layout of the proposal. Source: the authors, based on the Montjuïc Trail Masterplan [22].

In conjunction with the overall scheme, an identification of the necessary physical interventions was carried out to formalize the proposal, ensuring an acceptable level of accessibility. To synthesize the future interventions, the range of development actions was narrowed down, including intensive urbanization, light green area development, and pathway conditioning. Infrastructure-related actions, such as escalators, elevators, and stairs, were also considered. This approach enables an estimation of intervention costs and facilitates the establishment of priorities. In this particular plan, priorities are qualitatively determined, assessing the social benefits derived from the proposed actions [22].

3.4. 360° Route Design

After the presentation of the MTM, the City Council (District of Sants-Montjuïc) chose to endorse the 360° route (included in the plan) by initiating a design project [66] to develop its infrastructure, followed by subsequent homologation. Designated as PR-C229, the route became the first that is entirely within the city of Barcelona [67].

The circular itinerary, which covers a little over 11 km with a cumulative elevation gain and descent of nearly 400 m, materializes the connection between the park's numerous entrances. Moreover, by taking the route independently, one can enjoy multiple points of interest; from the gardens of Les Tres Xemeneies, crossing the lower part of the Poble-sec neighborhood, one can reach the viewpoints of Miramar and Alcalde and then continue to Montjuïc Castle and the Migdia viewpoint. After passing behind the Montjuïc Cemetery, one can reach the former Port Castle and return above to the Sot del Migdia towards the Olympic Ring, crossing the Foixarda tunnel and arriving at the Fundació Miró behind the MNAC and the Laribal gardens [67].

The adopted itinerary maximizes the percentage of the route that goes through parks and pathways at the expense of the conventional street network. Specifically, around 31% of the route takes place on generally unpaved and nonservice vehicle-accessible paths, 25% corresponds to internal routes within parks and gardens, 14% occurs on tracks that are vehicle accessible, and the remaining 30% involves the conventional street network [67]. The navigability of the route, which must link segments of very different natures, is ensured through signage: (1) vertical signage marking the route's start, as per the Barcelona City manual; (2) official PR®C (Federación Española de Deportes de Montaña y Escalada, Spain) trail markings, with the white line above yellow line indicators measuring 9 by 5.5 cm, which have already been implemented; (3) yellow paint pavement markings with informative QR codes at pedestrian crossings on regular streets along the route, progressively added to inform pedestrians in urban areas who are unfamiliar with the route; and (4) clusters of strategically positioned vertical wooden bollards guiding flow in ambiguous areas, each displaying the aforementioned informative QR code on top (Figure 6) [47].

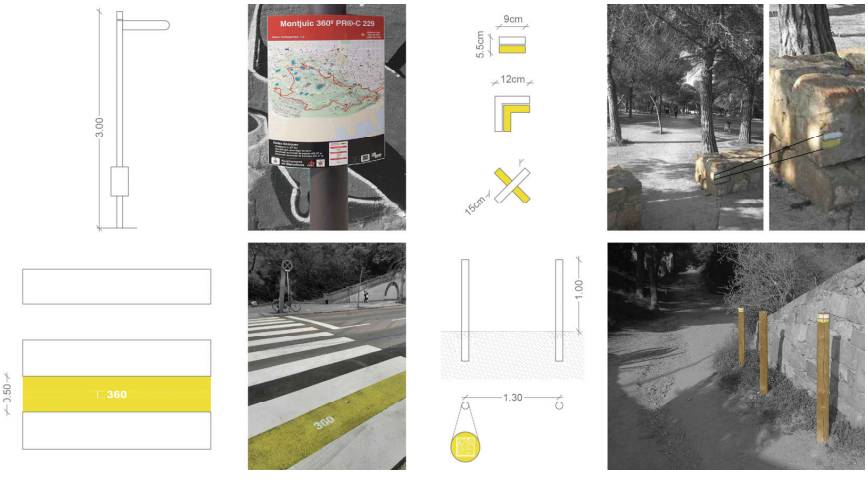

Figure 6. The signage of the Montjuïc 360° route: (**top left**) vertical signage marking the route's start; (**top right**) official PR®C trail markings—white line above yellow line; (**bottom left**) yellow paint pavement markings at pedestrian crossings; and (**bottom right**) clusters of strategically positioned vertical wooden bollards. Source: the authors, based on the Montjuïc 360° design [67] and pictures from Wikiloc's users [23].

The minimal signage interventions align with the findings of recent research, such as installing signage on a 3 km circular route connecting natural and heritage points of interest known as the Delapré Walk in Northampton [20]. The result of this intervention shows its ability to encourage the safe use of a route that is unfamiliar to the user. In the case of Montjuic, while there may not be usage counts available for the 360° route, there have already been reports of events like a group walk of over 200 people on 8 October 2023 (Figure 7) as part of "Viu Montjuïc", an annual weekend celebration offering multiple leisure and cultural activities on the hill [67]. Additionally, the route has an official entry on Wikiloc by the city council [23], a mashup where georeferenced routes with their points of interest can be stored and shared.

Figure 7. The inaugural walk of the Montjuïc 360° route on 8 October 2023: (**top left**) trail network scheme on Wikiloc and photographs of the group of 200 people who participated in the inauguration. Source: Wikiloc [23] and Town Council [67].

3.5. The Impact of Park Accesses on the Population

Beyond a qualitative evaluation, the MTM [22] does not include an explicit assessment of the impact of its proposals on the population. Below, we provide a specific analysis presenting the results based on the calculation of isochrones from the proposed accesses in the masterplan.

First, we addressed the individualized impact of each access, considering the 15 and 30 min isochrones to capture the population within these areas of influence. Figure 8 shows both isochrones; in the case of the 15 min cut-off, it has been divided into 5, 10, and 15 min to better understand its spatial configuration. Note that the areas of each access can overlap, so the population obtained refers to each access; thus, it is counted more than once if it is assignable to more than one access. It is also worth noting that these distances are evaluated on foot with an inclusive speed of 2 km/h, so we are referring to distances of 500 and 1000 m measured on the road network.

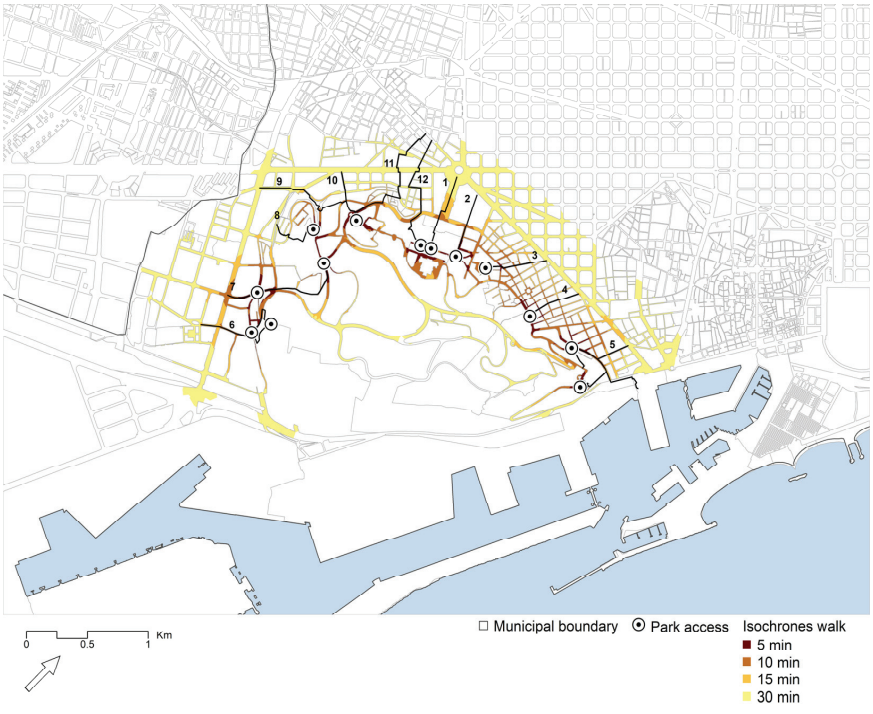

Figure 8. The proximity impact of the Montjuïc Trail Masterplan access points within a walkable distance. Source: the authors.

Table 2 summarizes the results obtained for the 15 min isochrone and highlights very diverse realities. Specifically, access points 3, 4, 5, and 7 show an increase in the population within the 0–15 and 0–30 min range that results in a multiplicative factor in the range of 2.3 to 3.0, tripling the population within the 15–30 min range in the most extreme case. Access points 3, 4, and 5 are located in the Poble-sec neighborhood, which has a predominantly residential character with traditional urban fabrics featuring 19th century buildings in direct contact with the northern foothills. These are the access points with the highest potential user population. In contrast, access points labeled as seven are situated on the southern slope near the Marina del Port neighborhood, where you find dense urban blocks, including recent developments from the 1990s.

Next, we have cases 2, 6, and 8, where the incremental range falls between 5.7 and 7.9. Access point 2 involves traveling through areas that are generally nonresidential, including the Fira de Barcelona's pavilions for congresses and corporate events. Hence, the population remains relatively distant in terms of proximity. Case 6 serves the district of Marina del Prat Vermell, which is currently undergoing significant transformations to introduce residential components into historically industrial areas. Gate 8 complements access point 7 by serving the Marina del Port neighborhood.

The next group comprises access points 9–11 and access point 12 (with incremental increases of 59.81 and 89.9, respectively). The population increase between the first ring of 0–15 min and the subsequent ring of 15–30 min is notably amplified.

An undeniable outlier is presented in access point 1, where the local population increases 735 times in the second ring (15–30 min) compared to the first ring (0–15 min). This is an extreme case, with only 33 people in the first ring, corresponding to the most monumental and well-known access point of Montjuïc: the Queen Maria Cristina Avenue from *Plaça España*.

Table 2. The impact of proximity on the population of the Montjuïc Trail Masterplan access points within a 15 min walkable distance. Source: the authors, with population data from Open Data BCN [40].

Access Name	Access Code	Population 0–15 min (500 m)	Population 0–30 min (1000 m)	Multiplier Factor for the Increase in Population in the Second Ring 15–30 min
MNAC	1	33	24,257	734.1
Forestier	2	5298	42,274	7.0
Xirgu—Camí de València	3	12,457	49,880	3.0
Valery Powles	4	17,975	59,821	2.3
Miramar/3 Xemeneies	5	14,196	53,342	2.8
Font Esparvé/Canal de la Infanta	6	2296	15,348	5.7
Caus Borinot/Foc	7	9366	35,756	2.8
Cos de Guàrdia	8	3573	31,747	7.9
Plaça Sant Jordi	9–11	392	23,553	59.1
Monestir	12	223	20,274	89.9
All accesses merged	1–12	47,125	134,686	1.9

Then, we set aside the individual analysis of the accesses and focused on them as a whole, considering a single 15 min walking isochrone. In that case, we found that it covers over 47,000 inhabitants, and the subsequent 15–30-min isochrone nearly doubles that value. Finally, the evaluation of the first 0–15-min isochrone using public transportation encompasses more than 225,000 inhabitants (see Figure 9).

The analysis revealed significant variability in the potential impacts when comparing different accesses, which stems from the rich relationships between the hill and the city.

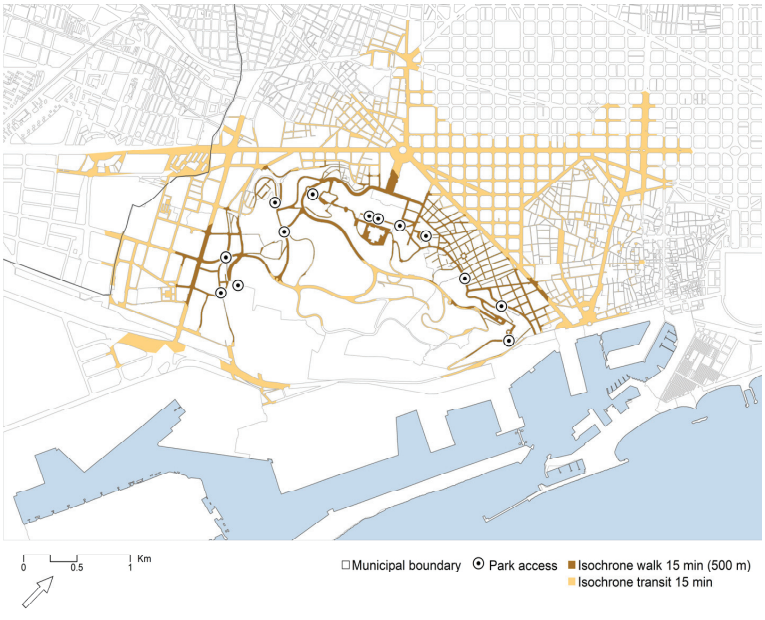

Figure 9. The impact of Montjuïc Trail Masterplan access points within a 15 min walk and public transit reach. Source: the authors.

4. Conclusions

Urban parks located on hills within established cities present complex spaces that can seamlessly blend culture and nature. The case study of the Montjuïc hill in Barcelona serves

as a privileged place for recreation while also being rich in cultural significance and points of interest. However, successive urban developments have led to a multifaceted reality with disconnected destinations and no comprehensible structure. The MTM offers a proposal for entrances and a network of trails based on an intertwined concept of heritage and green infrastructure. The analysis of the historical traces of the site allows the activation of a network of pathways named after ancient toponyms, which have become part of the narrative of the new order. These dormant internal networks are circumvented in a circular route called the 360° route, which originated as a bottom-up initiative from a local hiking group. The result presents like a railway system: thematic lines, interchange points between lines, and stops are understood as points of interest. The first steps toward the plan's execution were taken with the 360° route, which has become an undeniable attraction for users since its implementation and official approval.

On the other hand, the quantitative analysis of the impact on the population for the entire set of accesses and their 15 min (500 m) walking radius is quite significant: 47,000 inhabitants, which nearly quintuples when considering public transportation for the same travel time. However, there is considerable variability among the entrances when they are analyzed separately due to the diversity of city–park transects, from the iconic monumental axes of the city with nonresidential uses of a supralocal scale that distance the population from the large park to the presence of dense residential fabrics that are in direct contact with the hillside.

In summary, the approach that intertwines the activation of heritage sites and green infrastructure via a network of well-defined trails effectively addresses the psychological barriers associated with unfamiliar or perceived unsafe spaces; this fosters a purposeful and easily understandable utilization of complex urban parks. This innovative scheme facilitates a departure from the traditional limited movement that promotes internal mobility within familiar park sections and known entrances. It encourages spontaneous exploration by establishing a coherent structure that highlights various points of cultural and recreational significance.

Further research should prioritize investigating the role of storytelling in shaping active mobility networks within intricate green areas, promoting their comprehensive and intentional utilization. This pursuit presents numerous challenges, notably the need to strike a balance between fostering a universally understood and barrier-free perception of the pathway network while avoiding excessive transformation into tourist-oriented, theme-based products.

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Design Characteristics, Visual Qualities, and Walking Behavior in an Urban Park Setting

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Abstract: The design characteristics of urban parks' pathways are important in facilitating leisure walking and maintaining the minimum rate of physical activity, thus improving public health. This study examined and explored the relationships between design characteristics as well as certain visual qualities of Cautin Park, the biggest urban park in the Araucanian Region of Chile, and the tendency for walking as well as walking behavior. A mix of quantitative and qualitative methods was used to examine the objectives. Several design attributes were found to be related to the tendency for walking and the walking behavior in this urban park, including greater pathway width, more vegetation, tranquility along the pathways, and more comfortable pathway environments for pets. Additionally, these correlations were assessed based on gender and age, and it was found that adolescents showed the greatest difference from other groups. For instance, adolescents walk significantly more along pathways with more connectivity to activity zones. Among the visual qualities, only legibility shows a significant correlation with the number of all types of pedestrians, as well as subgroups of adolescents, adult men, and adult women. These results were reviewed, and their implications were discussed. Urban planners and designers could apply these findings when designing future urban parks in this context.

Keywords: urban park; pedestrian mobility; design attributes; visual qualities; Temuco; Isla Cautin Park

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1. Introduction

Chile is a country with a high sedentary rates [1]. Nearly 35% of people aged >15 years in Chile are living with obesity [2,3]. Obesity-related health conditions are the top risk factor for death and disability [4]. Meanwhile, regular physical activity has multiple health benefits [5]; thus, the level of physical activity should be improved in this country. Practiced by people of all ages worldwide, walking is an easily accessible physical activity [6] that contributes to maintaining the minimum rate of physical activity and improving physical health [7]. For instance, it is the most popular leisure-time physical activity among US adults [8]. According to ecological models, the built environment is an important factor that influences walking behavior [9,10]. Among the factors of the built environment, the presence of urban parks is an important factor in improving walking behavior, especially walking for recreation on the neighborhood scale [11,12].

Walking in parks is primarily considered a type of leisure walking [13]. Recreational walking is closely related to the characteristics of the immediate environment [14]. Accordingly, the design characteristics of urban parks' pathways are important in facilitating leisure walking. In addition, previous studies have raised the importance of both Attractiveness for walking and Walking behavior while considering leisure walking [15]. Thus, both of these aspects could be important when considering the association between the design-related attributes along the pathways and walking in the urban park's pathways.

Age and gender are frequently found to be connected to walking when socio-demographic factors are taken into account [9,16–18]. Prior research has mainly focused on the relationship between various design elements along pathways and the walking behavior of people of a specific age, particularly older seniors [19], with reference to walking behavior along the pathways of urban parks. However, because age and gender are important factors, it is possible to evaluate this association simultaneously based on different age and gender groups. In addition, affordance theory contends that public spaces should be designed in a way that meets the needs of different users from different categories, including those based on age and gender, while taking related theories into account. It is important to understand the needs of these users of different ages and genders to design urban park pathways that can appropriately satisfy the expectations of different users.

In addition, the criteria of landscape design give significant weight to the concepts of visual quality and visual preference [20]. According to Daniel [21], landscape quality is a result of the interactions between a landscape's features and how they affect people. The most important factor regarding the natural environment is its visual and/or landscape quality, and the attractiveness of recreational areas offered by urban parks is directly related to their visual quality [20,22]. Visual preference for a landscape is influenced by four main information variables, complexity, coherence, mystery, and legibility, according to Kaplan and Kaplan [23]. In natural or semi-natural settings, like urban parks, these attributes represent visual preferences along the routes. These elements also show up in the literature on urban design as characteristics of urban design that influence general walkability and walking behavior [24]. These four characteristics, which are crucial to the visual preference for a landscape, may therefore also be linked to walking behavior. Therefore, it is necessary to assess these key visual characteristics to comprehend the relationship between visual preference and walking behavior (Figure 1).

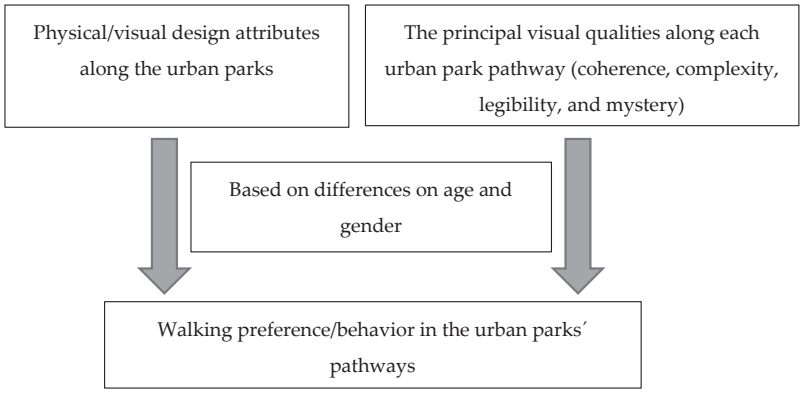

Figure 1. The conceptual framework.

It is also hypothesized that age and gender may have an impact on how visual characteristics contribute to walking behavior. For instance, women typically steer clear of situations where crime is a possibility, and certain visual characteristics, such as legibility and mystery, may be linked to the probability of crime. Additionally, compared to other age groups, adolescents have a greater desire to explore their surroundings, and some visual elements, such as mystery, may better meet this need by increasing the likelihood that they will explore the paths. The link between visual preferences and walking behavior must therefore take into account the roles of age and gender (Figure 1).

Cautin Park, with an area of 27.7 hectares, is the biggest urban park in Temuco and the region of Araucania, Chile. It attracts people from different parts of the city, who spend part of their recreational time in this park. As stated previously, the design aspects of the pathways in this park could play an important role in the improvement in the tendency to

walk, as well as the walking behavior of the inhabitants in this park, due to the importance of this park as the biggest park and the only urban park of this type in this city and the region. The local population's health and level of physical activity would benefit from this.

The impacts of both design characteristics and visual qualities on improving walking behavior in urban parks have rarely been examined simultaneously in previous studies. The main objective of this study is to evaluate the relationship between design characteristics (as well as visual qualities) and pedestrians' walking behavior (as well as their tendency to walk) in Cautin Park. This evaluation was carried out based on differences in age and gender. On this basis, the respondents were classified into the categories of adolescents, adults (male and female), and older adults (male and female). The conceptual framework of this study is shown in Figure 1. The main research questions of this study are as follows:

- What pathway design characteristics are associated with the tendency to walk/walking behavior of pedestrians in Cautin Park? And how do age and gender affect these associations?
- What visual qualities are associated with the walking behavior of pedestrians in Cautin Park? And how are these associations influenced by age and gender?

2. Literature Review

2.1. Walking for Recreation and Its Associated Built Environmental Factors

Previous studies on the neighborhood scale have demonstrated the relationship between walking for recreation and environmental factors, including land use mix [25]; the presence of walking trails [26]; infrastructure for walking, including the state of the footpath and the standard of its surface [27,28]; the proximity of recreational facilities [26,28]; the presence of accessible destinations (mostly services) like shops, parks, and beaches [27,29]; the availability of public transit services, including factors like proximity to bus stops and public transportation [29,30]; nearby non-residential locations [31]; and perceived and actual traffic safety, including elements like the percentage of street length with speed limits [26,29]; personal security, including less concern about crime [27,32]; and perceived neighborhood aesthetics, as well as the existence of aesthetic elements like the proportion of tree canopy coverage, the upkeep of walkways, cleanliness, and the view of the architecture [26,27,33]. In addition, Borst et al. [15] evaluated the relationships between the perceived attractiveness of streets for walking and (physical) street characteristics. They found that three main aspects affect the perceived attractiveness of streets for walking, namely the tidiness of the street, its scenic value, and the presence of activity or other people along the street [15].

2.2. The Contribution of Age and Gender to Walking Behavior

Age and gender are directly associated with walking behavior, sometimes through the impact on the association between the built environment and walking behavior [17,34–36]. Due to health and mobility problems that develop as people age, aging is inversely correlated with walking [17,18,34]. However, Paydar et al. [37] found a negative relationship between age and walking behavior in Temuco, Chile. According to studies by Harrison et al. [34] and Krogstad et al. [9], men walk much more than women. Giles-Corti and Donovan [38], for instance, discovered that women engage in less physical activity than men. Older women were less physically active, according to Mesters et al. [18], who sought to uncover sociodemographic and social-cognitive determinants of physical activity among Dutch women. Van Cauwen-berg et al. [39] examined the contribution of gender to the association between walking behavior and the built environment and discovered that women described their preference for walking more frequently and intensely when they found the environment more familiar and safer from crime.

2.3. Walking Behavior and Its Contributing Factors in the Urban Park Environment

Most design aspects related to walking behavior along pathways have been explored and examined on the neighborhood scale. Concerning the urban park setting, although

park pathways have been identified as important settings to encourage physical activity and walking [40], the relationships between the characteristics of the park pathways and walking behavior have rarely been considered in previous studies [19]. Compared with the neighborhood pathways, the aesthetics and comfort-related aspects were highlighted more than other aspects in the design of urban park pathways. Kaczynski et al. [40] found that parks with paved trails are more likely to be used for physical activity than those without paved trails. Zhai and Korca [19] evaluated the impacts of park design characteristics along the walkways on the walking behavior of older adults. They found that seniors prefer pathways that have soft and even pavement, benches, flowers, and light fixtures. Trails with soft pavement, the level of shade, the pathway width, the presence of benches, and the presence of flowers and trees contribute to improving walking behavior in the urban park setting [19,41,42].

In addition to the physical attributes along the pathways, the aspects related to pathway surroundings were also important to improve walking behavior on the neighborhood scale, as well as in the urban park setting [19,43]. The various aspects of path surroundings in these studies include visual interest, lateral visibility, the scale of street space, the visibility of landmarks along the pathways, the view of public gardens, the transparency of fronting structures, visible activity, street trees, the coherence of the built forms, and lighting [43–45]. The enclosure type along the pathways contributes to improving walking behavior in natural and urban park settings [19,46]. Water has a positive impact on observers' emotional state and the preference for walking as well [47]. According to Lynch [44], visual connection with landmarks may influence people's walking movement [44,48]. Finally, the pathway's connection with activity zones also influences the level of walking in the park environment [49].

2.4. The Contribution of Path Context and Landscape Visual Preference to Enriching Walking Experiences

The picturesque theory asserts that some spatial compositions and particular design elements elicit a more vivid aesthetic experience than other compositions [48]. The relationships between heightened aesthetic experience and specific design elements, such as the variety of open spaces connected by narrow and bending streets, the controlled view of spaces, the sense of enclosure, landmark objects as visual focal points, and complexity in the surfaces and details, were discovered by Isaacs, who supported this theory.

The relationship between the design aspects of the environment and walking experiences could also be considered in studies on visual landscape preferences [50]. Information-processing theory, one of the most significant theories in research on visual landscape preferences [51,52], suggests that the preference for a scene is dependent upon two basic human responses to an environment: the need to understand and a desire to explore. Information can be derived immediately from an environment or it can be inferred. According to Kaplan and Kaplan [23], the four primary information variables, complexity, coherence, mystery, and intelligibility, influence preferences for visual landscapes. Coherence, complexity, legibility, and mystery—the four significant environmental preference predictors—provide the knowledge to comprehend why people choose such places and how comfortable people are in one place [53]. Cheng [54] found that perceived landscape aesthetics contribute to visual landscape preference through four components: complexity, mystery, coherence, and legibility. Zhang [53] discovered that the most favored visual landscapes in public spaces include a combination of particular landscape elements, such as vegetation, trees, seasonal flowers, and open grassland, as well as the elements of perceived landscape aesthetics, such as intelligibility and coherence. According to Polat and Akay [20], water surface area, widths of pedestrian walkways, the function of recreational areas, plant composition, plant color composition, and plant species diversity can positively affect the visual quality of a landscape area. Kaplan and Kaplan [23] defined complexity as "the number of different visual elements in a scene". According to Ewing and Handy [24], complexity is a measure of a location's visual richness and is based on how many dis-

tinguishable differences a viewer is exposed to in a given amount of time. Duarte [55] discovered that complexity (more distinct types of landscape elements) implies a strong preference for the streetscape in the built environment.

Coherence in a scene refers to its structure and organization, as well as its patterns of brightness, size, and texture. Mystery relates to a scene's depth and the hidden qualities that may draw one closer to explore and gain more information. In earlier investigations of the natural environment, mystery and coherence were scored highly as predictors of preference [53]. However, Herzog and Kropscott [56] found that mystery is negatively correlated with preference in forest settings. Legibility helps people to understand an environment and "to comprehend and to function effectively" when the environment provides cues and landmarks that assist, for example, with wayfinding. These four variables are sometimes called "information variables" and have been suggested as predictors of landscape visual preferences [57–59]. These four variables have also been highlighted in the urban design literature as urban design qualities [24]. According to Lynch's research [44], legibility in urban environments can be defined as how easily a city's components can be identified and arranged into a logical pattern. In the context of the city, he contends that legibility is essential [44]. According to Isaacs [48], it is more effective to improve pedestrians' visual preferences when the pathway offers a balance between clarity, a variety of components, and interesting visual exploration. According to Ewing and Handy [24], these visual and perceptual aspects of urban design are also related to general walkability and walking patterns. Therefore, these key features, including coherence, complexity, legibility, and mystery, which are engaged in the pedestrians' visual preference along each pathway, may also be related to the walking behavior along parks' paths.

2.5. The Contribution of Age and Gender in the Association between Visual Qualities along Pathways and Walking Behavior

Previous research on visual preferences has demonstrated that age and gender also play a role in the relationship between physical characteristics and visual preferences. Balling and Falk [60] discovered a significant relationship between the age component and various preferences. High naturalism was determined to be an essential landscape component for young (age 12–19) and middle-aged adults (age 19–65) but less so for elderly (age above 65) persons, according to Zube et al. [61]. They claimed that young and older persons valued the complexity of landforms more than other age groups, making it a significant landscape feature. Additionally, the relationship between visual attributes and visual preference varies according to age and gender. Women, more than men, are sensitive to spatial conditions that evoke fear and react more strongly to it [62]. For instance, several academics have claimed that dense vegetation serves as a meeting place for criminals and fosters conditions that encourage criminal activity [63,64], which may go against women's aesthetic preferences. This lets us also infer that visual qualities such as legibility and mystery, due to their relationships with fear, may function differently for visual preference, as well as the walking behavior of women. Additionally, compared to adults, adolescents are more curious to learn about their surroundings [65]. This could lead to the conclusion that the visual quality that would encourage more curiosity—such as mystery—could be more consistent with the visual preferences and walking habits of adolescents along the pathways of urban parks.

3. Methods

3.1. Case Study

Temuco, the capital of the Araucania region, is a medium-sized southern city with a population of about three hundred thousand people, according to the 2017 census. The study was conducted in Cautin Park, which has an area of 27.7 hectares, making it the biggest urban park in Temuco and the region of Araucania (Figure 2). The park was developed within the framework of Chile's Green Area Plan between 2015 and 2016, aiming to improve the quality of life of the inhabitants by improving the quality of public

spaces in terms of their ecological, cultural, and social values. This urban park attracts people of different ages from different parts of the city who spend part of their daily time on recreation. According to Paydar et al. [37], Temuco lacks several parks and plazas, and this urban park, which was inaugurated in 2022, was created in response to the lack of urban parks in Temuco.

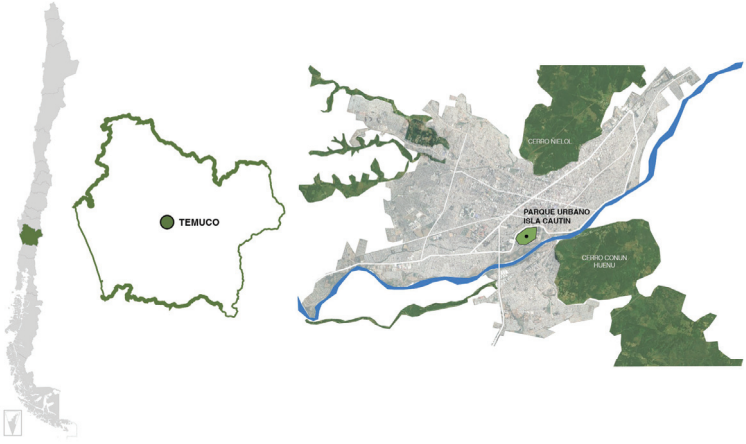

Figure 2. Location of the park in Temuco and in the Araucanía region.

This park is situated close to the city's historic core and is organized as a ring of six thematic squares connected by a central esplanade with views of the surrounding natural landmarks, like Ielol Hill. Plaza del Encuentro, which features an amphitheater for large gatherings; Plaza de las Tradiciones, which consists of a multipurpose esplanade and a soccer field; Plaza de la Infancia, which is intended for children in their various developmental stages; the Memorial of Human Rights, which serves as a place to remember the political executions that took place under the military dictatorship; Plaza Del Medio Ambiente, which has picnic areas and a flood area in case the river rises; and Plaza de los Deportes Urbanos, home to a BMX track, skatepark, and skating rink (Figure 3). These plazas are linked with a main circulation that surrounds the central esplanade, made up of a wetland, designed as a mitigation measure against eventual flooding and that serves as a birdlife habitat. Additionally, the park's core area (near to Plaza de la Infancia) has a place that resembles a native forest thanks to the abundance of native trees there. Figure 4 shows some images from different parts of this urban park.

3.2. The Quantitative Approach

This study includes all the pathways in the park, except for pathways that are too short (less than 3 m). A pathway segment, which is defined as an individual pathway that begins from one intersection to another intersection and with no other intersections on it, is used as the unit of analysis. To avoid any kind of bias, the path segments related to the entrances were eliminated. In total, 39 pathway segments were recognized in Cautin Park. The gate method was used during our on-site observation to collect the walking behavior data [66]. The researcher stood in the middle of a pathway segment during the observations and counted the number of park visitors who crossed an imaginary line at the researcher's position, which was perpendicular to the pathway's direction [67]. Digital counters were utilized by the observer to keep track of how many people were passing the "gate." We conducted the on-site observations over two months in November and December of 2022. Four randomly chosen weekdays and two weekend days were chosen each week for observations. For management convenience, we divided observations into two sessions, the morning period and the evening period. We conducted 30 rounds of

observations in Cautin Park. Each pathway segment was observed for two minutes in each observation round. Thus, each pathway segment was observed 30 times, each time for two minutes.

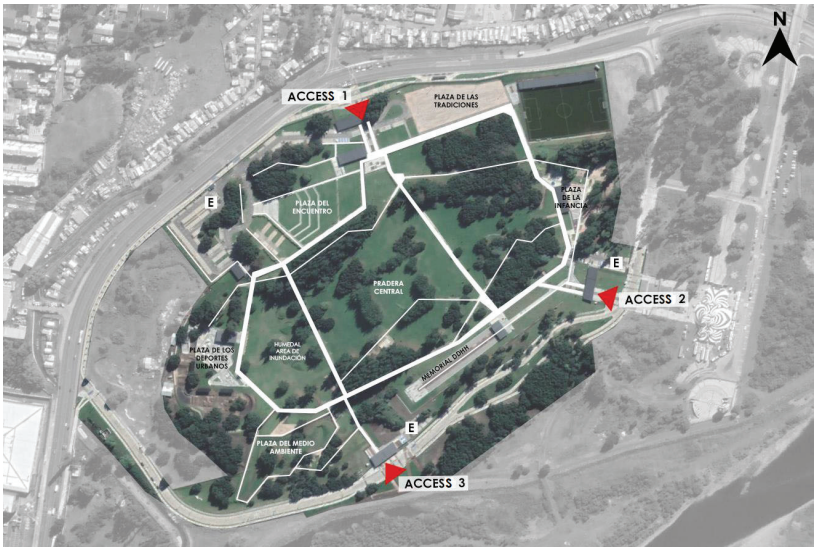

Figure 3. Isla Cautín Urban Park with its different areas.

Figure 4. Images of the urban park of Cautín Island (including the Memorial of Human Rights).

Seniors are easier to identify compared to other age groups since they typically have more face wrinkles, slower walking speed, and shorter step length [68]. Seniors also have unique facial features, such as noticeable lateral pouches, according to Pitanguy et al. [69]. Therefore, during the on-site observations, we identified seniors using the following criteria: the existence of prominent facial wrinkles, the appearance of white hair, short steps, or impaired motor skills.

In this study, park design characteristics refer to all spatial and physical attributes that shape a park environment. The physical/visual attributes were selected based on the literature review. Pathway attributes refer to the features of the pathway itself within or along its boundaries, such as pavement, width, and the presence of benches. Pathway

surroundings include the park environment around the pathway, comprising spatial and physical dimensions, such as the degree of enclosure and visual connections with water. The pathway connection with activity zones refers to whether the pathway segment can direct users toward an activity zone. The activity zones are the places where pedestrians can engage in activities, such as activities at the child playground plaza and the activities in the food feria.

Data on pathway design characteristics were collected through on-site observations. The protocol for measuring pathway characteristics was developed based on several existing measurement tools for park environments [70–72]. Each section of the pathway was traversed by the observer, who noted its characteristics. Every pathway segment was seen twice, and the outcomes of the two observations were compared. If the measurements from the first two rounds of observations were not consistent, a third round of observations was made. The same observer made all the observations. The pathway length was calculated in AutoCAD 2019 (Version 23.0) software. In the final process of the selection of design features, after the measurement of all variables along the park's pathways, the design features, including the level of cleanness along the pathways, the type of pavement material, the pavement quality in terms of its maintenance, slope or stairs along the park pathways, the presence of obstacle/s along the pathways, and the level of graffiti, did not show variability along the different pathways of Cautin Park. For instance, all the pathways have the same pavement material, and there are no slopes or stairs along any of the pathway segments from our observations. Likewise, the two variables related to water elements, "water on the side" and "visual connection with water", showed a lack of variability along the different pathways of Cautin Park due to the observation of just one waterfall along one pathway, which is visible just along the same pathway. Thus, all the aforementioned variables were excluded from further evaluation in the statistical process, since the variability is the prerequisite for the selection of the variables in our statistical models. In this way, the only remaining variable related to the pathway surfaces is the pathway pavement type, in terms of pathways with pavement (concrete) and unpaved pathways (covered by sand). The remaining 12 design features (variables), which showed variability along Cautin Park´s pathways, entered the statistical analysis. These pathway design characteristics, along with their types and measurements, are shown in Table 1.

We discussed the description of the urban design qualities and the criteria to measure them with three experts from the field of urban design concerning the measures of the four main visual qualities along the routes (legibility, coherence, complexity, and mystery). The consensus standards for each aspect of urban design are listed in Table 2 [73,74]. Then, based on the criteria for each visual quality, we asked these three experts to walk along each pathway and rate its level. These three experts' average measurements throughout each pathway served as the basis for determining the final level of each visual quality.

3.3. The Qualitative Approach

Regarding the qualitative approach of the study, we conducted 60 face-to-face interviews with five groups of users—adolescents (12 persons), adult men (12 persons), adult women (12 persons), older adult men (12 persons), and older adult women (12 persons)—in Cautin Park to inquire about their preferred and disliked pathway design characteristics for walking. The main criterion for selecting the participants for the interview was that they should have a habit of leisurely walking in the park and thus that they can answer the questions based on their experience. One person from the research team approached the people present in the park based on the specified number in each group and, while introducing himself and the summary of this research, asked if that person was willing to be interviewed. He also asked about the possibility of audio recording from the respondent and performing the interview.

The interview consisted of five questions: (1) Could you please show me where you usually walk? (2) What are the characteristics of these pathways that you like? (3) Which pathways in the park do you not use for walking? (4) Why? and (5) Would you please tell

me your age? Participants were given colored maps showing images taken along various park pathways to assist them in deciding which park places and pathways they liked and disliked. Each interview lasted between 10 and 15 min, and the data were entered using a data entry form.

Table 1. Measurement of Park Pathway Design Characteristics.

No	Physical/Visual Design Attribute	Type	Measurements
1	Pathway pavement	Categorical	a. Pathway with Pavement (concrete) b. pathway without any specific pavement (with sand)
2	Pathway form	Categorical	a. Curving b. Straight (Curving pathways are those that are straight in direction but have curved boundaries.)
3	Presence of Benches	Categorical	a. No Benches b. 1–3 Benches c. 4–7 Benches
4	Presence of flowers	Categorical	a. No flowers b. Have flowers on he sides (Flowers planted in any form; any amount was considered.)
5	Degree of shade	Categorical	a. Shade is less than 30% of the pathway b. Shade is between 30% and 70% of the pathway c. Shade is more than 70% of the pathway (The degree of shade is measured by the percentage of shade (projected on the ground) to the total area of the pathway segment for all the pathways between 10:00 a.m. and 11:00 a.m. on sunny days.)
6	Presence of light fixtures	Categorical	a. No lights b. Have lights on sides
7	Pathway width	Categorical	a. <2 m, b. ≥2 m, <3 m c. ≥3 m, <4 m d. ≥4 m, <5 m e. 5 m and wider
8	Pathway length	Numerical	Measured in meters based on master plan and satellite images
9	Enclosure type	Categorical	a. Tall objects on neither side b. Tall objects on one side c. Tall objects on both sides (The enclosure type, which is dominant in the longest proportion of the pathway, was used to represent the whole pathway.)
10	Degree of Enclosure	Categorical	a. No lateral visibility (The entire lateral sightlines are blocked on both sides) b. Moderate lateral visibility (The lateral sightlines are interrupted at some parts of the pathway on both sides.) c. Continuous lateral visibility (The lateral sightlines are not interrupted on the whole pathway on both sides.)
11	Visual connection with landmark	Categorical	a. No visual connection with landmark b. Landmark can be seen in the background c. Landmark can be seen in the foreground/middle ground (Landmarks refer to the canopy structures in different parts of the park.)
12	Pathway connection with activity zones	Categorical	a. No connection with activity zones b. Have connection with 1 activity zone c. Have connection with 2 or more activity zones (The connection with activity zones is determined by pathway's immediate neighboring areas in four directions, including its two ends and two sides.)

Table 2. The indicators for measurements of the visual qualities.

The Visual Quality	The Indicators for Measurements
Coherence	Unity or harmony in color and texture along the pathways
Complexity	Variety of objects, shapes, colors, and textures along the pathways
Legibility	Visual access along the pathways and the visibility of the landmarks along the pathways
Mystery	Limitations regarding visual and physical accessibility with surroundings along the pathways that may arouse curiosity and lead to surprise in pedestrians

3.4. Analysis

For categorical pathway design characteristic variables, we applied ANOVA analysis to explore the differences in the average number of observed pedestrians on pathways with different characteristics. For continuous pathway design characteristic variables (i.e., pathway length) and visual qualities, correlation analyses were used to investigate the relationships between the average number of observed pedestrians and the pathway's design characteristics. Finally, content analysis was performed to explore the interview data. In this regard, the factors were coded based on two major categories of pathways for walking, liked and disliked characteristics, as the responses to two consequent questions during the interview. Then, the number of repetitions of each factor and its frequency concerning each category were calculated for all respondents, as well as each subcategory, based on age and gender differences [19]. The comparison between the results of statistical and content analyses helped us to have a more credible understanding of the connections between pathway design characteristics and seniors' walking behavior.

4. Results

4.1. Descriptive Statistics

At the overall park level, a total of 7018 walkers we observed in Cautin Park, including 1385 pedestrians as adolescents, 5423 adult pedestrians, and 210 older adult pedestrians. The evening period is the peak period, whereas considerably fewer pedestrians were observed in the morning period. At the pathway segment level, the average number of observed pedestrians in all observations was calculated for each segment (30 rounds of observations for each segment) to represent the usage of each pathway segment (Figure 5). The average maximum number of users observed on a pathway segment (for two minutes) was 5.82 pedestrians per segment.

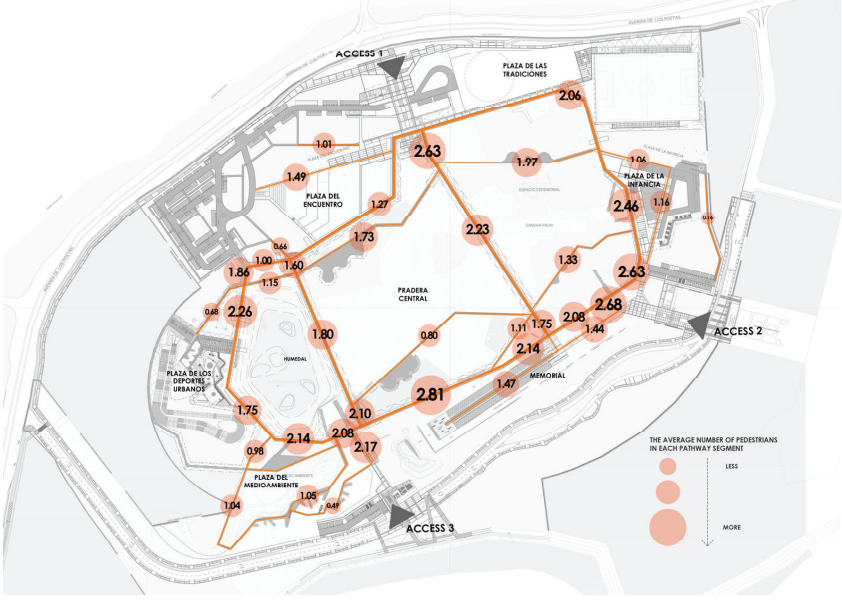

Figure 5. Average number of pedestrians on road segments (number of road segments: 39).

Concerning the physical/visual design attributes along the pathways, the majority of the pathways (69.2%) have pavement, as compared to unpaved pathways (covered by sand) (30.8%). The curving form (66.7%) is more common than the straight form (33.3%). The majority of the pathways have between four and seven benches (51.3%). "Less

than 30% shade" was observed along the majority of the pathways (64.1%). There are more pathways with light fixtures (59%) than pathways without light fixtures (41%). The pathways with more than 5 m (33.3%) are the most common type of pathways in terms of pathway width. The average length of the pathways is 91.77 m, which shows that pedestrians face rather long pathways to walk in this urban park. In terms of enclosure, the majority of pathways (61.5%) show moderate lateral visibility compared to "no lateral visibility" (12.8%) and "continuous lateral visibility" (25.6%). This shows that a medium degree of enclosure is observed along most of the pathways, and this enclosure is due to both "tall objects on one side" (46.2%) and "tall objects on both sides" (41%). Landmarks (as certain canopy structures in the parks) could be observed along most of the pathways (66.6%). In addition, most of the pathways are connected to one activity zone (46.2%) or do not have any connection to activity zones (48.7%). Finally, in terms of visual qualities, legibility shows higher values (mean: 3.97) than other visual qualities, including coherence (mean: 2.95), complexity (mean: 2.36), and mystery (mean: 1.82). This shows that the pathways, on average, show the highest value concerning legibility and the lowest values concerning mystery.

4.2. The Findings of the Quantitative Approach

4.2.1. The Associations between Walking Behavior and Park Pathway Design Characteristics (While Taking into Account the Age and Gender Subgroups)

Consistently, the results show that the average number of observed pedestrians is significantly larger on pathways with certain design characteristics. These pathway design characteristics include pathway pavement and pathway width. More specifically, the results indicate that the pedestrians significantly walk along the pathways with pavement compared to unpaved pathways (Table 3). Pedestrians also walk significantly more along pathways that are more than 2 m wide (all types which cover more than 2 m width) rather than the pathways less than 2 m wide (Table 4).

Table 3. One-Way Analysis of Variance of Average Number of Observed Pedestrians (for all pedestrians and adolescents) (Number of pathway segments: 39).

		All Pedestrians				Adolescent			
		df	**MS**	**F**	**Sig.**	**df**	**MS**	**F**	**Sig.**
1. Pathway pavement	Between Groups	1	4.880	16.693	0.000 **	1	2.697	7.542	0.009 **
2. Pathway form	Between Groups	1	0.430	1.043	0.314	1	0.017	0.040	0.843
3. Presence of Benches	Between Groups	2	0.845	2.171	0.129	2	0.906	2.311	0.114
4. Presence of flowers	Between Groups	1	0.001	0.002	0.968	1	0.079	0.185	0.669
5. Degree of shade	Between Groups	2	0.902	2.337	0.111	2	1.171	3.105	0.057
6. Presence of light fixtures	Between Groups	1	0.023	0.054	0.817	1	0.334	0.792	0.379
7. Pathway width	Between Groups	4	2.091	9.700	0.000 **	4	1.698	6.321	0.001 **
8. Enclosure type	Between Groups	2	0.463	1.127	0.335	2	0.603	10.475	0.242
9. Degree of Enclosure	Between Groups	2	0.535	1.317	0.281	2	1.244	3.331	0.047 **
10. Visual connection with landmark	Between Groups	2	0.807	2.063	0.142	2	1.893	5.612	0.008 **
11. Pathway connection with activity zones	Between Groups	2	0.519	1.275	0.292	2	2.010	6.080	0.005 **

Notes. ** Sig. < 0.05.

Table 4. ANOVA Post Hoc test (LSD) analysis of the Average Number of Observed Pedestrians (all pedestrians, as well as pedestrians separated based on age and gender) (N: 39) (only for the design features that showed the overall significance ($p < 0.05$) and have more than two values, which is the prerequisite of the post hoc test) (just the significant relationships are shown).

	(I)	(J)	Mean Difference (I–J)	SE	Sig.	Overall Sig.
Pathway width (all pedestrians)	<2 m	Between 3 and 4 m	−0.88735 *	0.23399	0.005	0.000
		Between 4 and 5 m	−1.27295 *	0.24472	0.000	
		More than 5 m	−1.08824 *	0.20134	0.000	
Pathway width (Adolescents)	<2 m	Between 3 and 4 m	−1.05590 *	0.26119	0.002	0.001
		Between 4 and 5 m	−1.12319 *	0.27316	0.002	
		More than 5 m	−0.88477 *	0.22474	0.003	
Pathway width (Adults)	<2 m	Between 3 and 4 m	−1.59075 *	0.48704	0.020	0.000
		Between 4 and 5 m	−2.52657 *	0.50936	0.000	
		More than 5 m	−2.17423 *	0.41908	0.000	
Pathway width (Adults Men)	<2 m	Between 3 and 4 m	−1.54175 *	0.44120	0.011	0.000
		Between 4 and 5 m	−2.51691 *	0.46142	0.000	
		More than 5 m	−2.01250 *	0.37964	0.000	
Pathway width (Adults Women)	<2 m	Between 3 and 4 m	−1.63975 *	0.55252	0.041	0.000
		Between 4 and 5 m	−2.53623 *	0.57784	0.001	
		More than 5 m	−2.33597 *	0.47542	0.000	
Degree of Enclosure (Adolescents)	Moderate lateral visibility	Continuous lateral visibility	−0.57447 *	0.22996	0.044	0.047
Visual connection with landmark (Adolescents)	No visual connection with Landmark	Landmark can be seen in the background	−0.58711 *	0.22777	0.037	0.008
		Landmark can be seen in the foreground/middle ground	−0.71572 *	0.22777	0.009	
Pathway connection with activity zones (Adolescents)	No connection with activity zones	Has a connection with 1 activity zone	−0.52547 *	0.18748	0.022	0.004
		Has a connection with 2 or more activity zones	−1.19565 *	0.42372	0.021	

*. The mean difference is significant at the 0.05 level.

Regarding the categories based on variations in gender and age, the findings are consistent with the findings regarding all pedestrians in terms of the kinds of routes, whether they are paved or unpaved (tables 3, 5 and 6). As compared to unpaved routes, all age groups walk more frequently along paved pathways (tables 3, 5 and 6). The routes with a greater width also result in significantly greater walking by all groups, except for older adults (tables 3, 5 and 6). The routes with width of more than 2 m (all varieties that cover more than 2 m) are significantly more frequently used for walking by adolescents, adults, adults (men), and adults (women) than the pathways with less than 2 m wide (Table 4). In addition, only older adults (men) walk significantly more along the pathways with the curb type (Table 6) as compared to other groups. The greatest differences between the subgroups of pedestrians were found for adolescents as compared to other groups. Adolescents walk significantly more along pathways with less enclosure, greater visibility of landmarks, and more connection to activity zones (Table 3). More specifically, adolescents walk significantly more along pathways with continuous lateral visibility rather than moderate lateral visibility (Table 4). They also walk significantly more along pathways that provide visibility to landmarks even in the background or foreground/middle ground rather than the pathways with no visual connection with landmarks (Table 4). Finally, adolescents walk significantly more along pathways with one, two, or more connections with activity zones rather than pathways with no connection to activity zones (Table 4).

Table 5. One-Way Analysis of Variance of Average Number of Observed Pedestrians (For Adults with gender separation as well) (number of pathway segments: 39).

		Adults				Adults (Men)				Adults (Women)			
		df	**MS**	**F**	**Sig.**	**df**	**MS**	**F**	**Sig.**	**df**	**MS**	**F**	**Sig.**
1. Pathway pavement	Between Groups	1	19.851	16.247	0.000 **	1	18.589	18.051	0.000 **	1	21.155	13.964	0.001 **
2. Pathway form	Between Groups	1	2.099	1.234	0.274	1	2.317	1.576	0.217	1	1.893	0.930	0.341
3. Presence of Benches	Between Groups	2	3.059	1.868	0.169	2	2.894	2.047	0.144	2	3.236	1.647	0.207
4. Presence of flowers	Between Groups	1	0.033	0.019	0.892	1	0.001	0.001	0.977	1	0.159	0.076	0.784
5. Degree of shade	Between Groups	2	3.154	1.933	0.159	2	3.642	2.654	0.084	2	2.715	1.362	0.269
6. Presence of light fixtures	Between Groups	1	0.004	0.002	0.963	1	0.033	0.021	0.885	1	0.003	0.002	0.968
7. Pathway width	Between Groups	4	8.326	8.914	0.000 **	4	7.658	9.992	0.000 **	4	9.084	7.557	0.000 **
8. Enclosure type	Between Groups	2	1.732	1.012	0.374	2	2.064	1.414	0.256	2	1.429	0.692	0.507
9. Degree of Enclosure	Between Groups	2	1.506	0.874	0.426	2	1.423	.951	0.396	2	1.597	0.777	0.467
10. Visual connection with landmark	Between Groups	2	2.079	1.229	0.305	2	2.268	1.566	0.223	2	1.972	0.969	0.389
11. Pathway connection with activity zones	Between Groups	2	0.998	0.570	0.571	2	1.389	0.927	0.405	2	0.688	0.326	0.724

Notes. ** Sig. < 0.05.

Table 6. One-Way Analysis of Variance of Average Number of Observed Pedestrians (For Older Adults with gender separation as well) (number of pathway segments: 39).

		Older Adults				Older Adults (Men)				Older Adults (Women)			
		df	**MS**	**F**	**Sig.**	**df**	**MS**	**F**	**Sig.**	**df**	**MS**	**F**	**Sig.**
1. Pathway pavement	Between Groups	1	0.060	6.992	0.012 **	1	0.030	4.518	0.040 **	1	0.102	6.334	0.016 **
2. Pathway form	Between Groups	1	0.016	1.598	0.214	1	0.033	5.090	0.030 **	1	0.005	0.257	0.615
3. Presence of Benches	Between Groups	2	0.020	2.170	0.129	2	0.011	1.579	0.220	2	0.033	1.871	0.169
4. Presence of flowers	Between Groups	1	0.001	0.056	0.814	1	0.000	0.011	0.916	1	0.002	0.080	0.779
5. Degree of shade	Between Groups	2	0.004	0.378	0.688	2	0.001	0.186	0.831	2	0.010	0.522	0.598
6. Presence of light fixtures	Between Groups	1	0.001	0.085	0.772	1	0.001	0.102	0.752	1	0.001	0.053	0.818
7. Pathway width	Between Groups	4	0.017	1.860	0.140	4	0.013	1.978	.120	4	0.034	2.081	0.105
8. Enclosure type	Between Groups	2	0.001	0.061	0.941	2	0.001	0.093	0.911	2	0.001	0.066	0.936
9. Degree of Enclosure	Between Groups	2	0.004	0.349	0.708	2	0.002	0.289	0.751	2	0.006	0.323	0.726
10. Visual connection with landmark	Between Groups	2	0.017	1.798	0.180	2	0.012	1.706	0.196	2	0.027	1.519	0.233
11. Pathway connection with activity zones	Between Groups	2	0.008	0.833	0.443	2	0.001	0.153	0.858	2	0.024	1.344	0.274

Notes. ** Sig. < 0.05.

There are no more significant associations between the number of all pedestrians (and the number of pedestrians based on age and gender) and the other physical/visual features along the pathways. Furthermore, the result of the correlational analysis shows that there is no association between the number of pedestrians (and the number of pedestrians based on age and gender) and pathway length (coefficient: 0.004; *p*: 0.983).

4.2.2. The Association between Visual Qualities and the Length of the Pathways and Walking Behavior

According to the correlational analysis (Table 7), among the visual qualities along the pathways and the length of the pathways, only legibility shows a significant correlation with the number of all pedestrians (coefficient: 0.477; *p*: 0.002). In terms of the subgroups based on age and gender, again, legibility is the only variable that shows a significant correlation with the number of pedestrians concerning adolescents (coefficient: 0.403; *p*: 0.011), adults (coefficient: 0.466; *p*: 0.003), adults (men) (coefficient: 0.475; *p*: 0.002) and adults (women) (coefficient: 0.449; *p*: 0.004).

Table 7. Correlational Analysis (N: 39) (only the factor of legibility showed significant correlations with the whole number of pedestrians and certain subgroups based on age and gender).

	Legibility Coefficient	*p*
Number of all pedestrians in each path segment	0.477 **	0.002
Number of adolescents in each path segment	0.403 *	0.011
Number of adults pedestrians in each path segment	0.466 **	0.003
Number of adult men pedestrians in each path segment	0.475 **	0.002
Number of adult women pedestrians in each path segment	0.449 **	0.004
Number of older adult pedestrians in each path segment	0.255	0.117
Number of older adult men pedestrians in each path segment	0.241	0.140
Number of older adult women pedestrians in each path segment	0.226	0.167

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

4.3. The Findings of the Qualitative Approach

4.3.1. The Associations between Tendency to Walk and Park Pathway Design Characteristics

The results of the qualitative approach added valuable insights to the findings of the quantitative approach (Table 8). The respondents included 30 males (50%) and 30 females (50%). It was found that a higher number of trees (50%), more green spaces and vegetation (43.3%), the presence of shade (31.6%), paved pathways (28.3%), connection with program and activity zones (28.3%), tranquility along the pathways especially in terms of number of people (16.6%), and presence of benches along the walkways (10%) were important for the walking of the pedestrians.

Table 8. Results of interviews based on age and gender groups in Cautin Park (Number of total interviews: 60).

Pathway Characteristics	Characteristics Preferred and Disliked	Number of Repetition						Sum (For all)	Frequency N (%) (For All)
		All Pedestrians	Adolescent	Adults		Older Adults			
				Men	Women	Men	Women		
1. Higher number of trees	Higher number of trees	25	4	7	3	7	4	30	50%
2. Green spaces (Vegetation)	More green spaces and vegetation	22	6	7	4	2	3	26	43.3%
	Low green spaces is disliked	4	1	1	1	1	-		
3. Shade	Having shade	14	3	5	1	4	1	19	31.6%
	Little shade is disliked	5	1	1	2	1	-		
4. Pathways with the pavement	Hard pavement	13	4	2	3	3	1	17	28.3%
	The unpaved pathways are disliked	4	2	1	-	-	1		
5. Connection to programs and activity zones	Connection to programs and activity zones	17	2	3	6	3	2	17	28.3%

Table 8. *Cont.*

Pathway Characteristics	Characteristics Preferred and Disliked	Number of Repetition						Sum (For all)	Frequency N (%) (For All)
		All Pedestrians	Adolescent	Adults		Older Adults			
				Men	Women	Men	Women		
6. Tranquility	Tranquility	8	2	2	2	1	1	10	16.6%
	Much people is disliked	1	-	-	-	-	1		
	Being noise is disliked	1	1	-	-	-	-		
7. Furniture, benches (the places for rest)	The pathways with more benches	5	3	1	-	1		6	10%
	Lack of benches is disliked	1	1	-	-	-	-		
8. Width of the pathway	Wider pathways	3	2	-	-	1	-	5	8.3%
	Narrow pathways are disliked	2	-	1	1	-	-		
9. More comfortable pathway environments for pets	More green spaces for pets	2	-	-	1	1	-	5	8.3%
	Less people for more comfortable walking with pets	1	1	-	-	-	-		
	Clear path to guide pets	1	-	-	1	-	-		
	More observing animals	1	-	-	1	-	-		
10. Better connection with different parts of the parks	More connection between different parts of the parks	1	-	1	-	-	-	4	6.6%
	Being far from other places in the park is disliked.	3	-	1	-	2	-		
11. Security	More security along the pathway	1	-	1	-	-	-	3	5%
	More number of people to provide security for children	1	-	-	1	-	-		
	Lack of security, especially for children, is disliked	1	-	-	1	-	-		
12. More active environments	The pathways with more number of people (more active environments)	3	3	-	-	-	-	3	5%
13. Bird sound	The pathways with more bird sounds	3	-	-	-	-	-	3	5%
14. Not visually attractive	Not visually attractive, which is disliked	3	-	2	1	-	-	3	5%
15. Places which remind the history "Memorial"	It reminds people of bad memories, especially for children	3	-	1	-	1	1	3	5%

Wider pathways (8.3%), more comfortable pathway environments for pets (8.3%), better connections with different parts of the parks (pathways that provide better connectivity) (6.6%), more security along the pathways (5%), more active environments with a greater number of people (5%), more bird sounds (5%) and not being visually attractive (5%) also showed relative importance for the walking of the pedestrians. In addition, the places that remind pedestrians of history (referring to the special design and location called the Memorial) showed confusing performance with respect to improving the attractiveness

for walking. Some people mentioned their tendency to walk there (3.3%) and some people mentioned avoiding walking in this place due to unpleasant memories that some people were killed during the dictatorship.

Furthermore, factors such as cleanliness (3.3%); light (3.3%); "not getting attention" (3.3%); uncomfortable walking due to cement, which provides more heat (3.3%); and circulation around wetlands (3.3%) could also be taken into account as relevant factors to enhance the attractiveness for walking in this urban park.

The respondents were also requested to mention if any special parts of the park are more attractive for walking. In this regard, the "plaza de infancia" (43.3%), Native Forest (31.6%), and "skatepark" (23.3%) are the locations with the highest tendency for walking. "Memorial" is the location with the medium tendency for walking (16.6%), and "wetland circulation" is among the locations with the lowest tendency for walking (5%).

4.3.2. The Associations between Pathway Characteristics and the Tendency for Walking There, Based on Age and Gender

The majority of the pathway characteristics show similarities among the different age and gender groups (Table 8). However, two differences were found. First, adolescents like to walk along the pathways with more active environments (more number of people) as compared to other age groups. Furthermore, bird sounds have a relatively important role only for older adults' walking (women) as compared with other groups. This could be related to both their gender (woman) as well as their age (older adult).

In terms of the most preferred locations in Cautin Park to walk based on age and gender, most of the adolescents (50% of adolescents) prefer to walk around the skatepark. Most adult men prefer to walk in both the Childhood Square (Plaza de la Infancia) (50% of adult men) and the Native Forest (50% of adult men). The Childhood Square is the location where most adult women prefer to walk (75% of adult women). Older adult men prefer to walk in the Native Forest (41.6% of older adult men) and the Childhood Square (33.3% of older adult men). Finally, most older adult women prefer to walk in the Childhood Square (50% of the older adult women) and the Native Forest (33.3% of older adult women).

5. Discussion

5.1. The Associations between Design Characteristics and Walking Behavior, as Well as the Tendency to Walk

The contributions of different design aspects to walking behavior were found. The pathways with pavement significantly contribute to improving walking behavior as compared to unpaved pathways. In addition, pathways wider than 2 m significantly contribute to improving the walking behavior of pedestrians. According to the results of the interviews, narrow pathways contribute to less comfortable and less expedited walking movement. These findings are supported by previous studies to improve walking behavior in urban parks [19,40]. The unpaved narrow pathway type is a common design feature in the urban parks of different cities in Chile. According to the findings of this study, such pavements are not congruent with the improvement of walking behavior in urban parks. This should be considered by urban planners while designing new parks in this context.

Other important factors to improve walking are a greater number of trees and more green spaces. These factors have been frequently mentioned in previous studies to improve walking on the neighborhood scale, as well as in the urban park setting [19,26,27]. In this park, the section of Native Forest is one of the attractive parts for walking. However, unpaved narrow pathways in this section may function negatively in improving walking behavior. Thus, while designing such spaces with dense trees and green spaces, the type of pathways should be wider (with pavement) to enhance the attractiveness for walking. This is another finding that is applicable for urban planners and designers to improve the walking behavior in urban parks. It should be noted that while defining such natural areas inside an urban park, the function changes from a native natural area to a part of the urban park that needs to attract more people to walk. In this sense, preserving the ecological aspects of such natural areas requires certain policies that are different from those with

less intervention in such natural areas. In this regard, if it is assumed that having paved pathways in these native natural places may hurt ecological values, increasing the width of the pathways is required at the very least to increase pedestrian mobility in these native natural areas.

The presence of shade is another important factor in improving walking. This is supported by a variety of studies that identified the importance of shade in improving walking behavior [19,42]. In addition, the greater presence of benches is another important factor in improving walking behavior. This is also supported by previous studies on the neighborhood scale and in the urban park setting to improve walking behavior [42].

The connection to program and activity zones is the next important factor for improving the tendency to walk in this urban park. This is supported by previous studies that showed the importance of access to activity zones in improving walking behavior in urban parks [19,49]. Temporal events such as temporary commercial ferias are also effective in enhancing park visitors' walking habits. Therefore, creating spaces that incorporate these temporal activities is crucial to the process of creating urban parks. In addition, a better connection with different parts of the parks (the pathways that provide better connectivity between different parts of the park) is another relevant factor that contributes to more attractiveness for walking. While considering and comparing this factor with more access to activity zones, it is inferred that the main activities in different parts of the park should be designed in a way that is accessible and integrated with the main pathway network of the urban park to enhance the attractiveness of walking. The circulating pathway around the wetland, for example, is one of the places with the least allure for walking, which may be related to the fact that this circulating pathway is a bit far and inaccessible compared to the main pathway network in this urban park. This could be applied by urban planners and designers to design future urban parks in this context.

Tranquility along the pathways, especially in terms of the number of people, is another important aspect to improve the attractiveness of walking in this urban park. In addition, the sense of security is another important factor that contributes to reducing the attractiveness of walking along the pathways of Cautin Park. This factor is one of the main factors that negatively influence the walking behavior of pedestrians in urban settings [37]. However, its importance in improving walking has been rarely explored in the urban park setting. The presence of other people is one of the features (found in this research) that contribute to reducing the sense of insecurity [75]. The presence of people helps to lessen the feeling of insecurity by acting as natural monitoring along the pathways [76]. Greater tranquility is also related to the lower presence of others as well. While considering and comparing tranquility with security as two relevant factors to enhance the attractiveness of walking in Cautin Park, it can be inferred that the presence of people functions positively to improve walking behavior until it generates crowded environments, in which case it becomes a barrier to walking in the urban parks. Therefore, tranquility in this context refers to less crowded areas rather than a smaller population. The wider pathways, as mentioned earlier, could help to maintain pathway environments with tolerable density for pedestrians to walk in. In addition, however, more trees are preferred for walking, but due to the importance of the sense of security, these trees should be designed in a way to reduce the sense of insecurity. For instance, the trees are to be located in a way that not provide hidden places along the urban park's pathways.

In addition, "more comfortable pathway environments for pets" was found to be one of the relevant factors in enhancing the attractiveness of walking. It contains features such as having more green spaces for pets to play and clear path to guide pets. Greater widths of the pathways also contributes to more comfortable walking with pets. Walking with dogs and its contributing factors has been mostly investigated in the urban setting (neighborhood scale) rather than in urban park environments [77]. For instance, walkability and aesthetics were positively associated with the likelihood of walking with dogs in urban settings [78]. Higher population density, more connected and integrated street layouts, and better availability of sidewalks and destinations support engaging in dog walking on

the neighborhood scale [79]. The availability of parks is also associated with dog-walking behaviors in neighborhoods [80,81]. Since considerable numbers of people usually walk with their dogs in urban parks, a better understanding of the design features that contribute to walking behavior with dogs in urban park environments seems important to improve walking behavior in this context. This could be one of the valuable lines of research in the future that could contribute to improving walking behavior and public health in this context.

Moreover, cleanliness also relates to the attractiveness of walking, according to a few respondents. This factor was removed in the quantitative approach due to not showing any variability along the different pathway segments. Cleanliness was mentioned in previous studies as one of the relevant factors to walking behavior [27].

Furthermore, the length of the pathways came up as a barrier to walking in this park. The average length of the pathway segments in this park is 91.77 m, which is almost high enough for pedestrians to walk there. Future urban park pathways are to be designed with a lower average length. Finally, a few respondents perceived that the cement, as the common pavement of the pathways, reflects the natural light and creates heat and an uncomfortable environment for walking. Regardless of how true this claim is, it is suggested that different materials be used for pathway pavements in future urban park projects.

5.2. The Associations between the Visual Qualities and Walking Behavior

Among the visual qualities, only legibility shows significant correlations with the number of pedestrians along the pathways, as well as the number of pedestrians, based on adolescents, adults, adults (men), and adults (women). The studies on visual preference also found the importance of legibility for visual preferences, especially in the natural environment [53,54]. Legibility is also an important factor in the urban design literature [82]. However, in the context of urban parks, it has rarely been taken into account. According to this finding, future park environments should be designed in a way that improves legibility among urban parks pathways. Visual access could be enhanced, and the factors that impede visual connectivity could be reduced. In addition, both the visual access and the visibility of the landmarks, as different indicators of legibility, could be improved along urban park pathways. The improvement in legibility through increased visibility of the landmarks along the pathways, however, could be more strongly emphasized in the design of future urban parks in this context due to the finding that there is a significant correlation between the number of adolescents and the visibility of the landmarks within the quantitative approach.

5.3. The Association between the Design Characteristics (as Well as the Visual Qualities) and Walking Behavior (as Well as the Tendency to Walk) Based on the Subgroups of Age and Gender

Significant variations in terms of the association between pathway characteristics and walking behavior based on age and gender were discovered for adolescents and older women compared with other subgroups when both quantitative and qualitative findings were compared.

Regarding adolescents, three design elements—degree of enclosure, visible link to landmarks, and visual connection to activity zones—also greatly influence their walking behavior. The results of the qualitative approach also highlighted the importance of pathways with more access to activity zones and more populated areas for adolescents' greater tendency to walk. Adolescents prefer to walk in more active places. This is the main difference between adolescents and other groups in terms of the association between design characteristics and walking behavior. A more active environment contributes to more active transportation among adolescents [83]. This finding—as one of the novelties of this article—is to be investigated in urban parks in future studies.

Although legibility is crucial for people of all ages and genders, it may be particularly important for adolescents, since they are more likely than people of other ages to be able to see landmarks, which is one of the indications of legibility. This demonstrates that, in

comparison to other groups, adolescents' walking ability is more dependent on the obvious landmarks along the park's routes. As a result, the pathways that are more closely tied to the activities of adolescents, like skateparks, should be structured in a way that makes it easier for them to be seen. This could be applied by the urban planners and designers of urban parks in this context.

Adolescents also walk significantly along the pathways with less enclosure and more visibility of surroundings. In this light, it is possible to understand the behavior of adolescents as an attempt to practice autonomous walking while still being controlled by their parents. As a result of their increased confidence (and decreased fear), while engaging in exploratory activities outside, they require the visibility of their surroundings while strolling. This could be more investigated in future studies.

Based on the results of the qualitative approach, birdsongs also demonstrated a relative value for the older adults' (women's) tendency to walk. This is not evident when looking at other age and gender categories. Birdsongs were found to be a type of natural sound most commonly associated with perceived stress recovery and attention restoration [84]. However, according to Franěk et al. [85], there is no evidence concerning the effect of gender on noise sensitivity. Meanwhile, natural elements play an important role in older individuals' perceptions of restorativeness and emotional well-being [86,87]. Less research has been performed on the effects of birdsong on older people's walking experiences in urban parks. Future research may look at this issue more.

6. Conclusions

The design characteristics of urban parks' pathways are important in facilitating leisure walking and maintaining the minimum rate of physical activity. This study examined and explored the relationships between design characteristics (as well as visual qualities) and walking behavior (as well as the tendency to walk) in Cautin Park, the biggest urban park in the Araucania region of Chile. These relationships were evaluated based on the differences in age and gender.

In this urban park, a number of design elements were discovered to be connected to walking propensity and behavior. Compared to walking on dirt roads, there is considerably increased walking on paved walkways. Compared to routes less than 2 m, those wider 2 m are likewise favored for walking. This demonstrates that unpaved, narrow paths that are typically seen in urban parks are not consistent with the development of walking habits in this context.

The contributions of several design attributes to the tendency for walking were also found, including a greater (denser) number of trees, more green spaces and vegetation, connections with programs and activity zones, tranquility along the pathways, more shade along the pathways, pathways that provide better connectivity between different parts of the park, and the presence of benches along the urban park's pathways. These results were reviewed, and their implications were discussed as well. These findings could be applied by urban planners and designers for the design of future urban parks in this context.

Given that activities further from the main pathway network have a lower propensity to encourage walking, one conclusion of these findings is that different areas of the parks should be built so that they connect with the main pathway network in the urban park pathway. Another implication is that the pathways in urban parks should be designed in a way that always provides the natural circulation of pedestrians to reduce the sense of insecurity. At the same time, crowded spaces contribute to lower attractiveness for walking. Thus, the flow of pedestrians should be controlled in a way that does not lead to creating overcrowded pathways.

Furthermore, another interesting finding of this study is that more comfortable pathway environments for pets correspond to the attractiveness of walking. Since many people walk with their pets along urban park pathways in this context, considering what characteristics contribute to more walking of these people is raised as an important issue. This should be surveyed in future studies to enhance walking in the urban park setting. Another aspect

is the importance of a more legible pathway to improve walking behavior. Urban park paths should be designed to provide visual connectedness to the surroundings, particularly to prominent monuments.

Adolescents showed the greatest difference from other groups when age and gender variables were taken into account. According to both qualitative and quantitative methods, adolescents are more likely to stroll in urban parks when there is a more active environment and greater access to activity areas. Less enclosure and more exposure to landmarks along pathways are also related to a higher number of adolescents using the routes in the urban park. In addition, birdsong is related to more walking among older adults (women) in urban parks. The designers of urban parks could use these findings to improve walking behavior based on the age and gender variations of users in this context.

The findings of this study could contribute to improving walking behavior and maintaining the minimum rate of physical activity for pedestrians based on age and gender differences in urban parks. These findings could therefore help to create a healthier and sustainable urban environment. In addition, the importance of evaluating both aspects of design characteristics and the visual qualities concerning walking behavior—two important aspects for designing the urban park pathways—as well as performing this evaluation based on age and gender differences, lets us state that the results of this study could be used by urban policymakers to develop urban parks, green spaces, and future sustainable development in this region.

Finally, utilizing the results from both the quantitative and qualitative methods can greatly improve the credibility of our findings. However, this study has some limitations as well. First of all, because the data are cross-sectional, causal inferences cannot be made from them. Second, the data were gathered in the spring's last weeks and early summer. Thus, it limits the generalizability of the findings to other seasons.

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Design Element Preferences in Public Facilities: An Eye Tracking Study

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Abstract: As a highly used form of architecture, public facilities are closely related to people's daily lives. The aesthetic level of their design greatly affects the quality of people's lives and interactions, as well as the appearance of the whole area. However, research on their design elements has not received enough attention, and few quantitative studies on the design of public facilities simultaneously focus on multiple influencing factors such as color and material. Therefore, this study uses eye-tracking technology and audience aesthetic preference evaluation to explore the appropriate combination of color and materials in sign design. This study found that, in the design of public facilities and in terms of aesthetic preference, firstly, color has more influence on subjective preference and objective gaze behavior than material. Secondly, men prefer technological and changeable colors and materials, and women prefer soft and uniform materials. Finally, visitors spend more time gazing at their preferred signs, which means that visitors' top-down gaze behavior and bottom-up psychological perception are highly unified. Regarding material perception, visitors' subjective preferences are influenced by the physical or cultural properties of the material itself. This study's results will provide suggestions for future urban and landscape architecture design in terms of color and material aesthetics, and the research methodology can be applied to more scenarios in environmental spaces.

Keywords: public facility; design element; environmental aesthetics preference; visual attention process; color; material

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1. Introduction

Landscape architecture aesthetics and science techniques, two hotly discussed topics in contemporary design, have long been widely discussed by architects and designers. As a discipline combining art and technology, it involves many aspects of architectural design, spatial planning, and urban and landscape architecture design [1]. In the process of small-scale urban design, after satisfying the function and the needs of users, the discussion of architectural aesthetics is conducive to enhancing the users' positive feelings towards the space and then enhancing the usage rate of the space [2].

As an important part of street-level urban design combined with infrastructure, public facilities have the potential to enhance the quality of efficient and modern services. At the same time, public facilities show the characteristic cultural landscape of the local area, and as markers of citizens' impressions of the area, they need to be both recognizable and symbolic [3], so their design aesthetics cannot be ignored. The signage system, as an important branch of public facilities, demonstrates the characteristic cultural style of the region and has a high degree of unity with the social environment and the ideology of the region [4]. It is indispensable in guiding the way and improving the quality of the tourism experience [5,6]. An excellent entrance design will greatly contribute to the revenue of the tertiary industry [7]. Consequently, the signage system has received full attention from the local community as an important promotional outlet for the area. Signage should be designed to blend in with the streetscape and make the street attractive. In contrast,

poorly designed and visually unattractive signs can discourage people from entering [8]. Whereas in designing public facilities, design factors such as color and material determine the aesthetic quality of the exterior of the building [9]. Therefore, this paper conducts a corresponding study on the design of public facilities through color and material to derive information about the visitors' aesthetic preferences for the design of public facilities and to provide a reference for the design of their appearance.

1.1. Color Research in Public Facility Design

Physically, color is the most intuitive landscape element in visual perception [10]. Due to the mechanisms of human visual perception, color contrast is considered to provide the most obvious and noticeable difference in environmental perception, especially in terms of visual detection thresholds [9]. Thus, color has a tremendous impact on the "quality of appearance" of design and even on human physiological health [11]. However, despite the increasing number of studies pointing to the importance of color in environmental perception, there is still a lack of research to support color selection in guiding design practice [12].

On a psychological level, color also has a significant impact on the subjective emotions of visitors. Red space corresponds to joy and passion and blue space corresponds to sadness, and these colors will prompt the crowd to produce corresponding behavioral feedback to the space [13]. Moreover, since environmental landscape color is a man-made product, the existing color environment not only reflects the humanistic inference of the designer, but also causes the audience to change their inner emotions and aesthetic feelings [14]. Existing studies point out that in signage design, colors are more likely to achieve visual harmony when there is little chromaticity or a large difference in luminance [11]. Brightness differences have a stronger effect on harmony and legibility, while chromaticity has a lesser effect [15]. Different gender labels affect the degree of subjective preference for color and the response to the environment [16]. In addition, extracting colors according to the local environment can help enhance the harmony of sign design [17]. The review shows that color significantly affects the visual appeal, subjective preference, and visual harmony of environmental signage design, but few articles discuss the quantitative relationship between gaze behavior and subjective preference.

1.2. Material Research in Public Facility Design

Current global research on materials focuses on physical properties, such as environmental friendliness, durability, etc. Regarding physical properties, it has been pointed out that the selection of materials should be based on the unique local ecological environment and physical facility conditions [18]. In recent years, scholars focused on the introduction of life cycle assessment into material selection began to pay attention to material sustainability [19,20], such as recyclable design, biodegradability, and disassembly design, so that economic development and the ecological environment can coexist in harmony [21,22].

In terms of emotional properties, materials possess symbolic qualities. In facility design, materials constitute people's memories of culture and place [23]. And, in the context of rapid urbanization, traditional materials are beneficial in addressing the serious homogenization and weakening of the cultural landscape in localities [24]. In addition, there are gender differences in material preferences, with women preferring recyclable and green materials [25]. Therefore, the choice of materials must fully account for users' physical and psycho-emotional needs [18]. However, there are fewer studies on subjective preferences and visual attributes due to the wide variety of materials and the difficulty in conducting a controlled variable analysis. This gap exists in the academic literature.

1.3. Application of Eye-Tracking Technology in the Design of Public Facilities

In recent years, eye tracking, a technology that records human visual data to measure human behavior and psychology, has become an integral approach for examining how people perceive their surroundings [26,27]. Quartier et al. suggest that color is an essential

element in the design of interior living spaces that impacts mood and spatial perception [28]. Bogucka researched the preferences for interior spaces with varying proportions, lighting, and color schemes and discovered that soft hues could induce favorable emotions in humans [29]. Chen et al. pointed out that people prefer to look at trees rather than buildings in outdoor activities [30]. Song investigated color preferences in dental hospitals and found that brown stabilized patients more effectively than the traditional blue [31]. Zhang discovered that subway rooms with too much or too little color saturation and brightness might be unsettling, and the most popular colors are not always the most visually pleasing for people [13].

Regarding gaze behavior, the Suarez study indicated that neither the path taken to examine the building nor the route's starting point affected the time participants spent viewing various architectural components, and those architectural components that the participants deemed aesthetically attractive were noticed for a longer duration [26]. According to the research of Li et al., most people were drawn to text in landscape photographs [32]. Rusnak assessed the visual reaction skills of experts and found that they could perform a fundamental analysis but could not predict more complex responses [9]. Regarding gender differences, Sargezeh et al. found that females exhibited more exploratory gaze behaviors, as evidenced by greater eye-hopping amplitude and longer scan paths [33]. Through the existing literature, current empirical research guided by stress recovery theory (SRT) [34] and attention restoration theory (ART) [35] has focused on stimulus-driven bottom-up processes while experiencing nature. However, a comprehensive evaluation of the signage system is based on the bottom-up visual gaze process and the top-down subjective preference factor, and the correlation between the two deserves further study [36].

Although there has been much research on color in environmental space, there is a need for additional research on elements (substance and size). Due to the limitations of research methods and the number of investigations, it is challenging to undertake variable studies on morphology, but it is easier to conduct quantitative research on the change of color and material [9]. Given the above research gaps, this paper focuses on the changes in visitors' preferences and eye-movement data for different colors and materials under the premise of fixed forms to infer the selection of design elements in environmental design. This paper also tries to deduce the general color and material selection rule in environmental signage design.

2. Materials and Methods

2.1. Conceptual Framework

Under the premise of form determination, the most important design aspects for designers to consider were color and material. Varied color and material combinations can provide different visual perception impacts, influencing the visitors' preference and interest in public facilities. Increased gaze behavior is the initial goal of sign design, which is a prerequisite for impressing visitors in sign design. Moreover, a more significant degree of preference indicates a greater readiness to travel and explore, which is beneficial to inciting further purchasing behavior [17].

On the other hand, a high level of gaze does not necessarily indicate a strong subjective preference for the entrance but also a long glance due to unpleasant emotions such as perplexity, fear, or rage [37]. Visitors may devote more time to visual perception in an unsettling color environment and have a more extended first stare [38]. Therefore, the link between gaze time and subjective preference becomes an essential criterion for determining the success of a signage's design, and an outstanding sign's design should unite gaze ability and subjective preference. Based on such arguments, this paper put forward the following four hypotheses:

Hypothesis 1. *The signage's color could affect visitors' visual attention and subjective preferences.*

Hypothesis 2. *The signage's material could affect visitors' visual attention and subjective preferences.*

Hypothesis 3. *The subjective preference was positively correlated with gaze time for signage.*

Hypothesis 4. *There are differences in the subjective preferences of men and women regarding color and material.*

2.2. Selection of Research Subjects

This study aimed to alter the color and material of the entry signs based on their fixed shape. The object of the study was the signage of Xiafang Village, Fengjing Town, Jinshan District, Shanghai, China, which arrived in 2021. Xiafang Village was successfully established as a model village of Shanghai Beautiful Village in 2021, a model-shaped epitome in rural revitalization in economically developed areas of China. Moreover, Xiafang Village represents the fusion of urban and rural styles in suburban areas of China. Therefore, the village logo of Xiafang Village was chosen as the object of this study. The signs mix traditional Chinese sloping roof components with contemporary design language, which locals and tourists highly appreciate (Figure 1).

Figure 1. Original picture.

In this work, simulation trials were conducted using photos [39]. The Lumion 11 program, often used for architectural landscape rendering, was employed to create simulations of signage to control the variables better and demonstrate a more uniform visual appearance [14]. It aided in avoiding the impact of season, weather, light, and other environmental conditions on the signage. At the end of the experimental design, eight logos from different Jiangnan regions were selected for research verification to ensure that the results of this design are generalizable for logo design in the Jiangnan cultural context.

This study focused on the logo design in the design of the entrance signage space. Our pre-experimental study found that the logo had the highest attention rate in the overall signage (Figure 2). In addition, the preference for the logo largely influenced the perception of the region [40]. Environmental identity design was closely tied to the brand concept. It can generate positive emotions and communicate brand meaning when the design helps establish an environment that provides an image and experience consistent with and appropriate for the organization's or place's goals [41,42]. A highly identifiable and effective logo can significantly enhance the brand's value [43]. This logo's design was a Chinese variant of the term "Xia fang" that uses a circle to convey its inclusive nature. The green areas in the center emphasized the indigenous traits of the tea garden's culture.

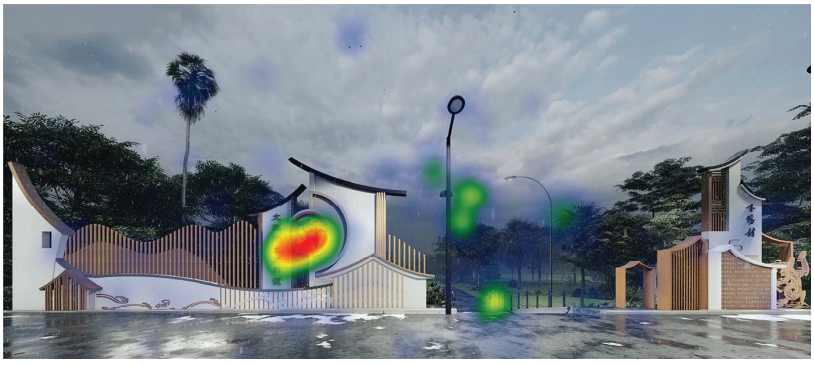

Figure 2. Heat map. (The warmer the color the longer it is watched.)

2.3. Sampling and Data Collection

2.3.1. Color Changes of the Logo

Color has three measurable attributes: hue, brightness, and saturation [44]. To better merge with the local environment, lessen the feeling of abruptness, and more easily conjure the cultural identity of local people and visitors [17], the colors used in field design are frequently derived from traditional local palettes. Consequently, in terms of color extraction, environmental color mapping (a method for objectively identifying and recording color features) [45,46] was used to extract seven local traditional representative Gangnam colors: white for exterior walls (RGB255, 255, 255), red for lanterns (RGB169, 55, 56), yellow for plaques (RGB205, 181, 141), black for the roof (RGB65, 63, 70), brown for the wall pillar (RGB84, 65, 55), brown for the gate (RGB77, 45, 45), and grey for the wall base (RGB100, 103, 108). Following preliminary research, it was determined that the yellow color of the plaque, the gray color of the wall base, the brown color of the gate, and the brown color of the wall pillar were too similar. Therefore, the most visually prominent lantern was red. The yellow color of the plaque, the white color of the exterior wall, and the black color of the roof were selected as the color variables (Figure 3).

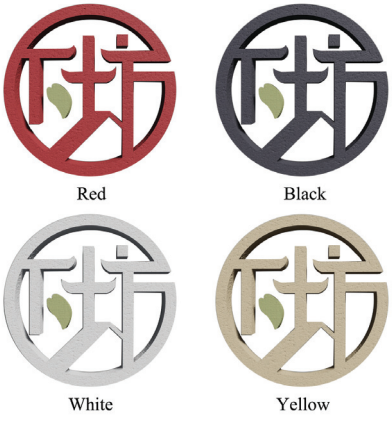

Figure 3. Color variables.

2.3.2. Material Changes to the Logo

The materials were selected from the eight materials commonly used for local logo design: brick, wood, stone, tile, concrete, metal, plaster, and glass. After preliminary research, it was found that, because some materials such as plaster, concrete, brick, and

stone present effects too close to the subjects' visual and subjective judgments that are difficult to distinguish, aluminum alloy with noticeable luster changes was chosen among metals. Therefore, acrylic, metal, wood, and plaster were finally selected as the material variables (Figure 4).

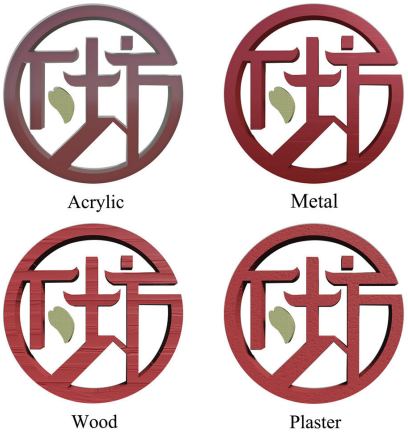

Figure 4. Material variables.

2.3.3. Crossover Effect

In the formal experiment, a full 4X4 factorial experimental design was utilized to present 16 logo forms (Figure 5).

Figure 5. Final effect.

2.4. Experimental Design

To test the hypothesis, we conducted this study in two steps: an eye movement experiment to explore physiological gaze behavior and a subjective questionnaire to explore subjective preference behavior. Based on G*Power's sample size estimation, we required at least 15 people [47]. From a demographic point of view, the eye movement experimental design was divided based on gender, professionals (design juniors and above), and non-professionals based on professional ability. There were 15 male professionals, 15 female professionals, 15 male non-professionals, and 15 female non-professionals, for 60 subjects in the four categories (each category was randomly selected while supplies lasted, and

there were no significant differences in the remaining demographic characteristics). All subjects were 18–35 years old (the subjects had a more obvious perception of color and material, and good feedback on the calibration of the eye movement experiment). A total of 123 valid questionnaires were collected, among which 81 were from design majors, 42 were from non-design majors, 44 were from males, and 79 were from females.

2.4.1. Eye Movement Experiment

The eye movement device is an SMI RED250 desktop eye-tracking device with a sampling frequency of 250 HZ and a screen resolution of 1980 × 1080. Eye-tracking sensors were used to collect information on the average gaze duration.

Subjects were instructed to sit 70 cm in front of the eye-tracking device. Before undertaking the eye movement experiment to see the photos, subjects were only instructed to relax, and the experiment's goal was not apparent [31]. Before starting the formal experiment, a five-point calibration method controlled the subject's line of sight shift to within 0.5°. In the formal experiment, an "X" image was first displayed on the screen for 6 s to determine that the subject's initial line of sight was controlled in the center of the frame. The visual in the eye movement experiment ran for 12 s and contained 16 logos. The uniform design principle was applied (Figure 6) by combining four layouts to distribute distinct logos in the image evenly and then calculating the average value of each region of interest to eliminate the influence of reading sequence in the same photo owing to visual habits. Moreover, 15 individuals were tested for each of the four types of arrangement to prevent viewing different photographs in succession from influencing the experimental results.

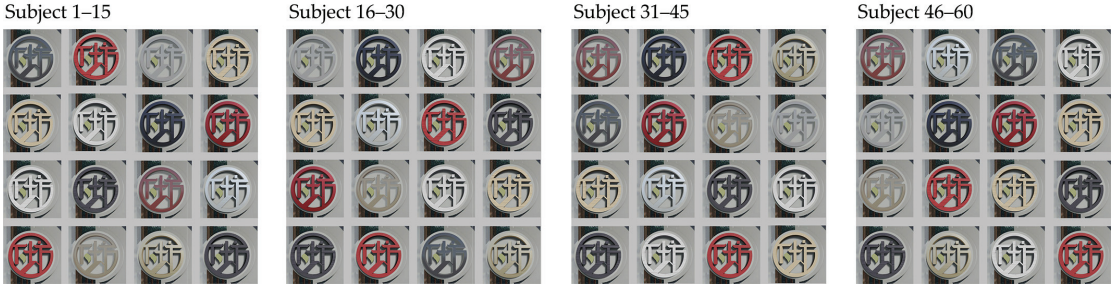

Figure 6. Schematic diagram.

2.4.2. Subjective Questionnaires

After completing the eye movement experiment, the participants were invited to complete a questionnaire regarding their preferences for 16 logos. A five-point Likert scale was utilized, with values from 1 to 5 denoting "strongly dislike" to "strongly like", respectively. This item was used to determine the visitors' preferred logos. After completing the questionnaire, the subjects were informed in detail about the study and were given a subjective evaluation of their personal preferences.

2.4.3. Data Analysis

In terms of physiological data, the eye movement data of the subjects were first analyzed. From the gaze report generated by the SMI BeGaze program, the average gaze data of 60 subjects were extracted to extract the gaze rate and gaze times of each logo to determine the relationship between logo gaze groups under different colors and material logo backgrounds. Using IBM SPSS 22 software, a multi-factor ANOVA on subjective preferences was conducted on psychological data to investigate the effect of visitors on the efficiency of the logo display under different conditions. The association between physiological and psychological impulses was determined by analyzing the correlation between objective gaze behavior and subjective preferences.

3. Results

3.1. Physiological Aspect—Objective Attention to Data

3.1.1. Attention Rate

The ease of discovery of the environmental signage system was a primary concern in the design, so the average attendance rate at each location in the experiment was concentrated. The data were obtained by dividing the number of people who gazed by the total number of subjects. From the data presented in Figure 7, against the same material background, red is the color with the highest view rate, followed by white, both of which are of high brightness, while red is relatively more saturated. Black and gold have low gaze rates, and are less saturated colors [48].

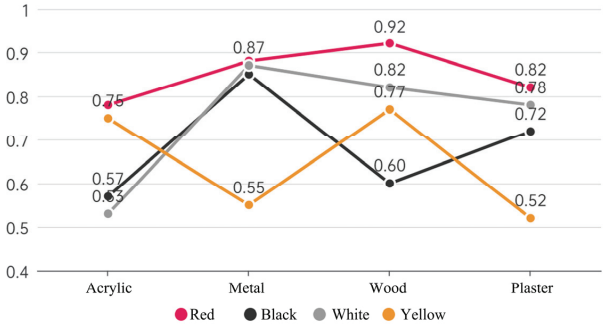

Figure 7. Attention rate.

3.1.2. Attention Time

Gaze behavior is the process through which the central open visual field focuses for a long time on a target to gain sufficient visual picture detail. According to a previous study, the fixation time (FT) can indicate a subject's familiarity and attention to a piece of information, and the total fixation time (TFT) index is essential for evaluating the user's proficiency [49]. The final attention time is obtained by calculating the average attention times for the same sign at different locations.

As shown in Figure 8, the average gaze duration for red is longer than for other colors. Red, a highly saturated color, tends to be the visual center of attention. Next is black. The lowest are white and yellow, which are similarly bright and saturated, distract attention, and attract less visual attention.

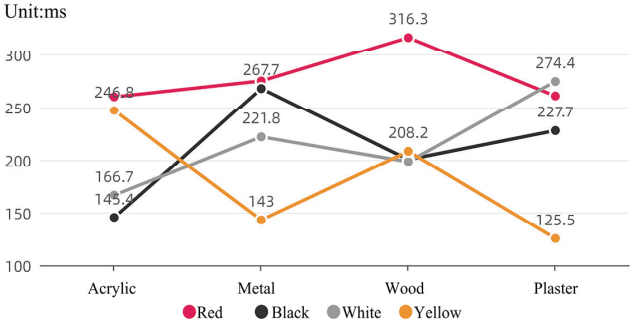

Figure 8. Gaze time for different colors.

As demonstrated in Figure 9, the eye movement indicators varied less in the background of different materials, and there was no significant variation among the materials. In comparison, wood received the most attention, and acrylic received the least gaze time. Metal and plaster had relatively stable eye movement indicators.

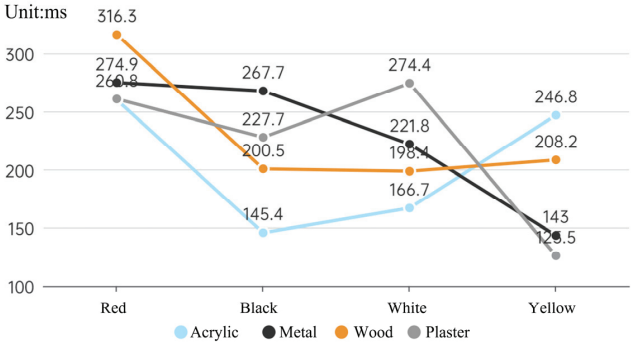

Figure 9. Gaze time for different materials.

3.2. Psychological Dimension—Subjective Evaluation Data

3.2.1. Multi-Factor Analysis of Variance

According to the scale's reliability test, the standardized Cronbach alpha coefficient was 0.839, and all reliability coefficients were more than 0.8, indicating excellent intrinsic reliability and steady test results. Both color ($F = 53.605$, $p < 0.001$; SD = 54.54) and material ($F = 10.456$, $p < 0.001$; SD = 11.307) exhibited significant differences via multi-way ANOVA. However, there was no interaction between them ($p = 0.286$). The effect of color was more substantial than the effect of material differences.

3.2.2. Color

With the same material, red scored the highest, followed by black, white, and yellow (Figure 10). Among these colors, red plaster scored the highest and yellow acrylic scored the lowest. Regarding subjective preferences, colors with high saturation scored higher than those with low saturation, and colors with high contrast with the surrounding environment scored higher than those with low contrast.

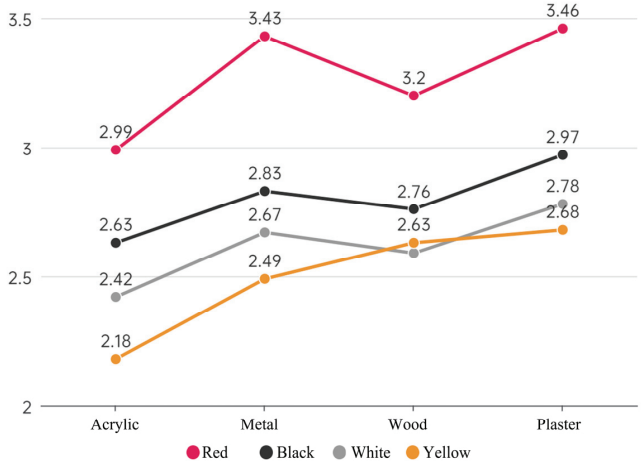

Figure 10. Average of subjective preferences under different colors.

3.2.3. Materials

As shown in Figure 11, plaster scored the highest under the same color, metal scored second, and wood scored third. The lowest score is the acrylic material, which was considered an inappropriate logo material under various colors.

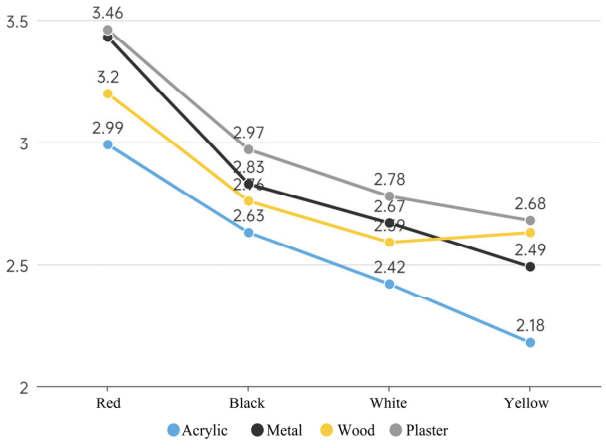

Figure 11. Average of subjective preferences under different materials.

3.3. Demographic Differences

In terms of demographics, color preferences (F = 3.221, p = 0.022; SD = 3.277) and material preferences (F = 3.419, p = 0.017; SD = 3.697) varied significantly according to gender. Regarding ratings, there was a statistically significant difference between the professional and non-professional groups (F = 9.304, p = 0.004, SD = 9.271).

3.3.1. Gender and Color

As shown in Figure 12, some differences in preferences between genders exist. Both men and women chose red as their favorite color, while the greatest difference was in white, which was significantly preferred by women than men, with smaller differences according to gender between black and yellow.

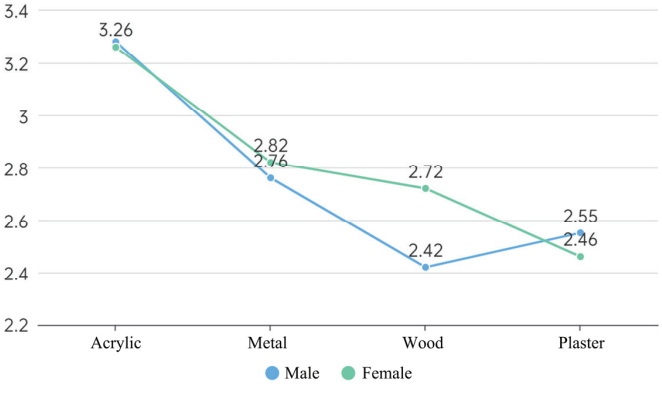

Figure 12. Gender differences in subjective preferences under different colors.

3.3.2. Gender and Material

As depicted in Figure 13, persons of different genders have distinct material preferences. Men mostly prefer metal, and women mostly prefer plaster. In addition, men have a higher preference for metal and acrylic than women, and women have a higher preference for plaster and wood than men.

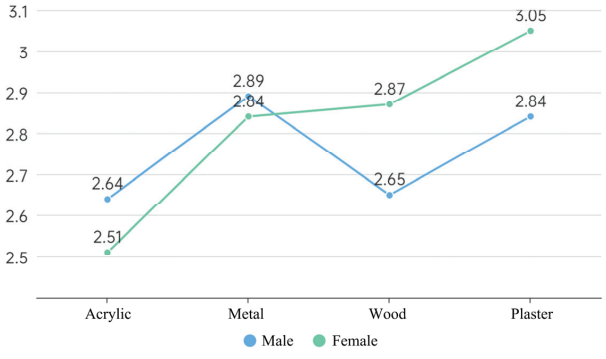

Figure 13. Gender differences in subjective preferences under different materials.

3.3.3. Professionalism

Figure 14 demonstrates that there is no significant difference in subjective preferences between the two categories, indicating that designers can judge visitors' preferences through subjective judgments and that their preferences are highly congruent with those of the non-design category (mean non-professional = 2.89, SD = 1.01, mean professional = 2.75, SD = 1.07, p = 0.004). However, non-design professionals scored their preferences slightly higher overall than design professionals, partly because designers believed that there was a best option among them, and thus the rest of the ratings were correspondingly low. In contrast, non-design professionals thought there were multiple favorites, and thus the ratings were higher overall.

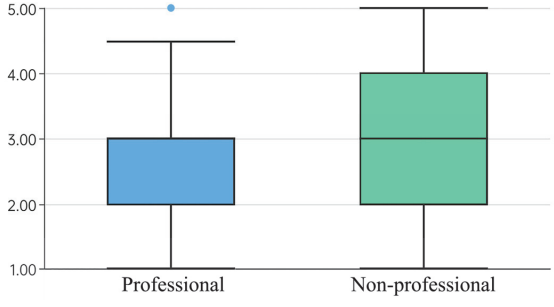

Figure 14. Professional differences in subjective preferences.

3.4. Correlation between Objective Gaze and Subjective Preferences

Pearson's correlation coefficient analysis showed a significant positive correlation between preference and gaze time (r = 0.584, p = 0.017). It showed that the sign design unified the top-down objective gaze and bottom-up subjective preference indicators. While receiving the most attention, red is also the most preferred sign color, indicating the need for a bright and traditional cultural color as the main factor in designing environmental signage systems. Therefore, there is a need to balance recognition and culture in environmental signage design to enhance visitors' satisfaction.

3.5. Verification

This study selected eight signs in the Jiangnan region to evaluate the visual comfort of color and material to verify the universality of color and material in design (Figure 15). The selected logo includes a combination of different materials, colors, and shapes commonly used in Jiangnan. A total of 60 valid questionnaires were obtained. The results show that 87.5% of tourists believe red gypsum is the most suitable color and material combination

for a logo. However, in N5, red is too close to the background color, so it is not the best choice for the logo. According to the comprehensive verification results, it was found that the subjective evaluation results are consistent with the original experimental results.

Figure 15. The 8 different logo designs for validation.

4. Discussion

This study explored the influence of color and material on the perception of design elements via subjective preferences and objective gaze indicators in the design of public sign facilities. Four hypotheses were formulated and tested in the paper. The study showed that material and color significantly differed in subjective preferences, with color having a more pronounced effect. This study validates Rusnak's conclusion that color is the most critical influence on visual response in environmental spaces [9], and the paper additionally verifies that color has a greater impact on subjective preference than material.

This study verified hypothesis 1, that color influences visual attention and subjective preferences. In the process of completing this experiment, some of the subjects answered, "The red one is the most noticeable". "The red one is the most favored." and "They will ultimately choose the red one, right?". It was determined that red was the most noticed and preferred logo color after combining the gaze and preference data. In a sense, it demonstrated that the subjects' attention and significance were unified, and it also indicated that red, a prevalent accent color in traditional Chinese culture, evoked the most intense emotions and influenced people's evaluation of cultural aesthetics [50]. Unlike the Western cultural environment where red is seen as dangerous and as a warning, the people of the East see red as a color of celebration. Red has been mostly used as a decorative accent color in space design since ancient times, such as traditional lanterns and window flowers, and its strong contrast with the saturation of the main colors of black, white, and gray in the traditional Jiangnan countryside makes it easier to become the visual center. As the colors used in a large area in the design in the Jiangnan region of China, the use of black and white in the logo has been tested. Although they can achieve the harmony of visual properties, they lack highlights and do not meet the characteristics of the visual center and cannot highlight the characteristics of the logo. The yellow is too close to the wood tone used in the design and the overall logo, and it is not distanced in brightness and lacks visual stimulation, so it also fails to gain favor. It was further supported by the fact that they chose red plaster for the logo, which was well-received by residents and tourists alike.

The study verified hypothesis 2, stating that the material influences visual attention and subjective preferences. However, few participants in the trial mentioned materials, indicating that the perception of materials is foreign to non-professional designers. Male subjects occasionally remarked, "Preferring black metal." meaning that men are more susceptible to visual aspects with a sense of technology and contrast [51]. Otherwise, it showed that the visual representation of the material still falls on the color contrast of the surrounding environment. In the interview afterward, it was found that plaster scored the highest in subjective preference, and its steady texture best fits the culture of Jiangnan and

meets the impression of tourists for the white walls in the Jiangnan area. Next is metal, whose luster will give people a bright, refreshing, and prominent intuitive feeling, full of technology and modernity, contrasting with the surrounding materials and more likely to highlight the main position of the logo. Wood has relatively more grain and raw materials, is easy to decay, has unfavorable preservation, and has a relatively low rating. The lowest rating was for acrylic gloss because the too-obvious plastic texture is often subjectively added to the "cheap" or "old" label, the visual effect is not prominent enough, and the logo design's eye-catching positioning does not match.

In addition, the experiment verified hypothesis 3, a positive relationship between subjective preference and visual gaze, indicating that visitors will look at the preferred signs longer, and those signs are more likely to leave an impression in their minds [52]. The experiment proves that the use of accent colors in the Chinese Jiangnan culture is reasonable and has developed a certain degree of recognition in the memory of contemporary people. It also proves that the colors or materials from the traditional culture can be used in the subsequent design process for secondary innovation.

Finally, the experiment partially verified hypothesis 4. Men and women are similar in color and material preferences, but some differences exist. In terms of color, Asian females seem to favor a more Western pattern of preference, while males favor a more traditional mindset regarding architectural aesthetics [53]. There are both cultural and gender-specific reasons for this. Regarding color, women's preference for white was significantly higher than men's. In the post-event survey, women thought "White is a clean and fresh color.", while men thought "White is inauspicious", "White is too rational and calm.", and from a cultural perspective, white symbolizes purity and beauty in the West, while it symbolizes death in East Asia [53]. In terms of materials, men preferred metal and acrylic, mainly because "It differentiates from the surroundings." and "The shine of metal is more eye-catching.". Women preferred plaster and wood mainly because "They are more harmonious with the overall environment.", "They use similar materials around them." and "Wood is softer.". Regarding gender characteristics of materials, men prefer hard, technological, and contrasting materials, while women prefer soft and warm materials [54] and pay more attention to the harmony of the overall environment.

4.1. Theoretical Significance

This study made a theoretical contribution to the research methodology and research content. In terms of research methods, this study increased the experiment's dimensions. Traditional eye-movement experimental research has concentrated univariately on color [13,31], but this paper used software simulation to achieve an intercomparison of various parameters to improve the experiment's dependability. Due to many tests in the experimental process, presenting each logo to the same subject could cause visual fatigue or test content awareness in the subjects, which could affect the findings. Therefore, the innovation of this experiment was to present different variables on the same effect map in a focused manner, effectively compensating for the drawbacks of existing eye movement experimental methods.

In conventional signage design, designers must balance subjective preference and recognizability in an excellent logo design. In this study, subjective preference and recognizability were researched under the premise of controlling variables, and it was determined that attention time and subjective preference had a high correlation in signage design. This article revealed that people preferred to observe the subjectively preferred signs in the signage system. The top-down attention of visitors was highly compatible with the bottom-up choice, giving a theoretical justification for the following environmental space signage design.

4.2. Practical Implications

According to the AIDA paradigm (attention, interest, desire, and action), consumers only become interested in visual materials and initiate additional responses after initially

paying attention to them [55]. In the contemporary setting of Internet-driven tourism, customers are faced with an increasing number of options. Therefore, visually arresting signage can act as a promotional point for the region and encourage tourists to spend money there. This study's findings and methodology allowed for the search for a more effective solution for signage in terms of color and material—using vibrant hues and relatively dense textures for logos to draw visitors' attention.

The study's conclusion demonstrated the significance of color and material in signage design. Furthermore, the effect of color is more than that of material, consistent with past research [9,11]. The subjects favored red as the logo's hue considering the traditional Chinese cultural components and the logo's recognizability. In terms of materials, the participants favored plaster and metal, as the plaster has the qualities of calmness and solidity, and metal has strong reflectivity, making the logo rich in light changes; therefore, these two materials can be widely used to create later logos.

In selecting experimental volunteers, eye movement tests conducted in the past have rarely compared genders. This study indicated that women were more attuned to material details than males and had color preferences that reflected this difference. For designs that demand a balance between men and women, neutral hues can be chosen. On the other hand, there was no significant difference in subjective preferences between the professional and non-professional groups, which indicates the professionalism of the designers, who can predict the subjective preferences of visitors relatively accurately to develop corresponding designs. However, the overall scoring of design practitioners was low. They usually only rated the most preferred ones the highest, presumably due to their sensitivity to design work, hence the need to classify professional and non-professional populations in subsequent design studies.

4.3. Limitations and Future Research

This study had some limitations. On the one hand, regarding demographic characteristics, the subjects were a group of university students aged 18–35 who were more sensitive to color perception. Factors such as cultural background [56], education level [57], and age [58] may affect people's visual preference evaluation, and subsequent studies can be conducted for different subject populations. On the other hand, this paper mainly focused on the color and material of logos, and the change of color and material may differ in a large spatial area. However, the influencing factors included size, shape, luminosity, and other aspects, and more factors can be investigated in subsequent research.

5. Conclusions

This study used a typical public facility in Jiangnan, China, as the research object and used eye-tracking technology to obtain data on users' physiological gaze indicators and subjective preferences for different colors and material backgrounds. The multi-factor ANOVA revealed the association between the subjective preferences of color and material in the Gangnam entry logo design to determine the optimal color and material combination scheme for the on-site entrance logo. The conclusions regarding the aesthetic design of public facilities are as follows:

1. Both color and material affect gaze behavior, and color has more influence than material. The impact of color is primarily reflected in hue. The red logo receives the most attention from the audience. It demonstrates that high-luminance and -chromaticity colors will attract greater visual attention. The effect of the material is mainly represented in its texture and contrast with the surrounding environment; the more intricate the texture and the greater the contrast with the surrounding environment, the more visual attention the material will draw.
2. Both color and material affect subjective preferences, with the influence of color being greater than that of material. Regarding color, tourists prefer red with high brightness and purity, which aligns with the traditional culture of Jiangnan, where red is used for decorative embellishments such as lanterns and window flowers. The visitor group

perceives different materials, among which metal is loved due to its luminosity and technology, and plaster is loved due to its heavy, solid texture and being in line with Jiangnan culture.

3. A considerable link exists between subjective preference and objective gaze (visitors will pay more attention to the preferred logo). It indicates that visitors prefer more visually striking colors and materials, which aligns with the need for the logo to stand out and draw attention to its function [42].
4. The overall subjective preferences of color and material are similar, but there are a few differences in terms of gender. In terms of color, Asian women are more inclined towards Western color preferences. For example, women are significantly more receptive to white than men [53]. In terms of material, men prefer acrylic and metal, while women prefer wood and plaster. It indicates that men prefer relatively technological and contrasting colors and materials with their surroundings, while women prefer relatively natural and temperate colors and materials.

In summary, this paper investigates the relationship between the two design elements of color and material in facility design. Quantitative physiological and psychological measurements are introduced in the spatial study to examine several factors simultaneously. The results can be used as a reference for optimizing the future color and material design of public facilities and provide a research paradigm and data support for the subsequent design based on street-level urban and landscape architecture design aesthetics.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land12071411/s1.

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Research on the Preference of Public Art Design in Urban Landscapes: Evidence from an Event-Related Potential Study

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Abstract: As urbanization quickens, the role of public art in urban landscape design gains prominence. Nevertheless, how stylistic characteristics of landscape public art affect aesthetic preferences remains insufficiently discussed, particularly with objective assessment methods. The use of event-related potential (ERP) can offer neurophysiological evidence to support research and practice in landscape art design. We employed a 2 (artistic features) × 2 (professional proficiency) repeated-measures design, involving abstract and figurative experimental stimuli; both experts and non-experts participated, with their aesthetic reactions and relevant electroencephalographic data recorded. Behavioral findings show a preference for figurative public artworks regardless of professional background. From neurophysiological outcomes, stimuli elicit an elevated N100 during early perceptual processing, signifying increased attentional resources. During aesthetic processing, figurative stimuli more effectively evoke positive emotions, particularly among professionals, yielding a heightened P200 response. Conversely, abstract stimuli may evoke a higher N200 amplitude, reflecting augmented negative biases. Nevertheless, non-experts exhibit no marked differences in their stimulus responses during aesthetic processing. Research indicates that low-level physical attributes of public artworks are initially noted, while the visual processing of artistic traits lies at a higher perceptual level, necessitating specialized expertise involvement. Furthermore, the complexity of visual perceptual processing plays a significant role in the assessment of landscape art preferences. This study not only offers crucial reference indices for designing urban landscapes that satisfy diverse public aesthetic needs but also lays the foundation for neural techniques to assess landscape design preferences and expands the field of landscape design research.

Keywords: urban landscape design; public art; ERP; aesthetic preferences; abstract and figurative; professional expertise

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1. Introduction

1.1. Public Art in Urban Landscapes

According to the "2022 World Cities Report" published by UN-Habitat [1], the urban population in 2021 accounted for 56% of the global population, a figure projected to rise to 68% by 2050. With the advancement of urbanization, people's aesthetic demands for urban spaces are increasing daily [2]. Public art, as a new urban norm in the cityscape, has been widely used for embellishing and beautifying urban spaces [3–5]. They not only elevate the aesthetic standards of the space but also attract people's attention to specific locations [6,7]. The unique role of public art in urban aesthetics has transcended mere visual attraction. Not only does it contribute to the improvement of life quality in urban settings, but it also acts as a catalyst in the construction of urban landscapes. Furthermore, meticulously designed public art can metamorphose undeveloped urban areas into dynamic community

hubs, thus promoting the regeneration of the city [8,9]. While a growing body of research has investigated the societal [10,11], cultural [12], and economic [13] aspects of public art, gaps still persist in the understanding of its aesthetic mechanisms. To be more specific, the majority of current studies depend on subjective methodologies like case analyses [14,15] and surveys [16,17] for measuring the aesthetics of public art. Although these conventional approaches are valuable, they are still inadequate in offering objective and measurable data. This limitation underscores the need for innovative methodological approaches. To fill this research void, our study adopts event-related potential (ERP) as an objective measure for evaluating the aesthetic mechanisms of landscape public art, a pioneering approach that blends art theory, urban landscape design, and neuroscience, representing the innovation of this research. Through the study, we can not only offer efficient guidance to designers, thereby refining the design of urban landscape art, but can also further augment the aesthetic experiences of individuals in urban public areas. Additionally, the study enriches the body of neuroaesthetic evidence within the field of public art, offering substantial reference value for directing the creation of urban landscape art.

1.2. Abstract and Figurative Stylistic Features

Public art's main goal is to meet the aesthetic demands of the general populace while concurrently serving to enhance and beautify spaces [7,8]. Therefore, the aesthetic appreciation and experience of the audience are crucial to the design of art pieces [18]. In the field of art research, how stylistic features such as those described as abstract or figurative influence the public's aesthetic perception and evaluation has been extensively studied [19,20]. The selection of these styles can profoundly impact the acceptance and interaction level of public art in urban landscapes.

People's aesthetic appreciation of urban public art falls within the realm of visual cognition, encompassing various stages of information processing. Affect accompanies cognitive processing interactively, thereby leading to corresponding aesthetic judgments and evaluations [21]. As articulated by Leder et al. [22], this includes perception, the gathering of implicit memory, explicit categorization, cognitive mastery, and evaluation. Through top–down cognitive processes, such as personal experiences and emotions, combined with bottom–up visual analyses, like color, lines, textures, and other visual attributes [23,24], temporary models of the visual world are established and validated or updated according to the information provided by sensory stimuli [25–27]. The subjective experience of artwork might involve multiple cognitive processes from perception to memory, varying with the abstractness of the art [28–30]. Figurative art often depicts true forms of life, such as humans, animals, and objects, displaying accurate proportions, dimensions, and precise details and features [31]. As a result, they frequently serve as commemorative and symbolic representations of events and individuals [32,33]. The specific information and actual events portrayed in figurative art enable viewers to rapidly process visual information, matching it with corresponding knowledge and memory, making it more readily comprehensible [34]. However, the intricate decoration and historical figures in figurative art may sometimes create impressions of elitism and political propaganda, thereby sparking controversy [35,36]. Abstract art, emphasizing elements like form, space, and material, often abandons concrete shapes and appearances, opting instead for simplified shapes, lines, and colors to convey themes and emotions [5,37]. They frequently challenge viewers' expectations, stimulate their imaginations, and invite them into more proactive and exploratory modes of artistic perception [38]. While some audiences may appreciate the ambiguity and openness of abstract artworks, the uncertainty may make it challenging to effectively link cognition with visual representation during the information processing stage, requiring further elaboration of meaning [39]. This may prove challenging for some, making abstract art confusing or inaccessible. While different styles of public art often lead to debates [40,41], these controversies further highlight the differences in aesthetic preferences between experts with professional art knowledge and training and ordinary people who, despite lacking formal education, still participate in and appreciate public

art [42,43]. To what extent do figurative and abstract artistic expressions influence people's aesthetic preferences? How do the public and artists perceive these different forms of artistic expression? Delving deep into these questions is crucial in guiding the design and creation of inclusive and attractive public spaces that cater to the varying tastes and cultural backgrounds of the audience.

1.3. Aesthetic Emotions, Fluency Theory, and Expertise

Aesthetic preference is defined as the degree of admiration and affection for visual stimuli, or the aesthetic evaluation of such stimuli [44,45], and is closely associated with factors such as aesthetic experience and emotions [46], the level of processing difficulty [47,48], and the expertise of the participants [21,49].

Researchers posit that aesthetic experience is a "perceive–feel–sense" capability, indicating the involvement of cognitive, emotional, and reward-related processes when evaluating artistic creations [24,50]. Leder et al. [22] assert that aesthetic experience initially manifests as a cognitive process, subsequently transforming into an ever-growing emotional state, ultimately culminating in aesthetic sentiment; conversely, Chatterjee and Vartanian [51] contend that aesthetic pleasure is profoundly influenced by our cognitive system. Pleasurable aesthetic emotions often correlate with positive aesthetic experiences [52]. Emotional reactions to art play a vital role in determining aesthetic preferences, as studies have shown that emotions influence the formation of preferences and decision making [53,54]. Additionally, the theory of fluency is an influential perspective, arguing that the ease or fluency of processing an artwork contributes to enhancing its aesthetic allure [48]. From this standpoint, art that is easily processed and understood is more readily favored. Moreover, the personality, training, and expertise of the viewer are also significant. A high degree of openness to experience, or a craving for novel experiences, is associated with a broader aesthetic preference and a more profound appreciation of artistic works. Research has shown that experts and non-experts differ in their aesthetic preferences and experiences, with experts exhibiting a stronger perception of unique artistic features compared to laypeople [21,49,55]. In conclusion, the emotions and expertise people engage in when appreciating and interacting with art affect their ultimate aesthetic preferences. However, these factors are subjective and dynamic, and given the complex information processing mechanisms of the audience's brain, describing these differences based on experience presents a challenge [18,47]. Therefore, scientifically measuring these disparities is a significant and difficult issue.

1.4. Aesthetic Research on Urban Public Art

Currently, aesthetic research on public art mainly focuses on areas such as questionnaire surveys [16,17] and case studies [14,15]. For instance, Peruzzi et al. [15] uncovered the presence of stereotypical impressions of female figures and the insufficiency of cultural policies in the Italian urban environment through an analysis of aesthetic and cultural aspects of 34 urban sculptures distributed across Italian territory. Meanwhile, Tang et al. [17] discussed the aesthetic experiences of tourists regarding iconic public art through a survey, finding that related aesthetic factors can serve as an indicator of the public art experience.

While these research methodologies are facile in execution and cost-effective, the data collected suffer from considerable limitations. Questionnaires, though a commonly employed quantitative research tool, are easily influenced by both external and internal factors as people respond to them. Their feelings might not correspond with actual experience, and respondents may deliberately alter their answers instead of offering their initial, unfiltered cerebral reactions [56,57]. Furthermore, numerous other elements such as rewards, time constraints, or peer pressure could lead to a distortion of the respondents' feelings, thereby possibly preventing the survey results from truly reflecting the respondents' authentic thoughts [58]. Consequently, to address these issues, explorations have begun to employ neuroscience methods to more profoundly investigate the brain's responses to art.

1.5. Aesthetic Assessment Based on Neuroscience

In recent years, the field of neuroscience has laid the physiological and methodological foundations for the study of aesthetic preferences [59,60], wherein event-related potentials (ERPs) have emerged as a complex, non-invasive method for measuring and mapping the topography of brain activity [61,62]. The experimental principle of ERPs involves recording the potential changes in the brain regions of subjects induced by specific external sensory, cognitive, or active stimuli. Through techniques such as superimposed averaging and time–frequency analysis, these subtle physiological signals are extracted from spontaneous EEG activity. ERPs are highly suited for the gathering of brain data, boasting the advantages of cost-efficient experimental design and an extraordinarily high temporal resolution [63,64]. ERPs encompass three critical metrics: amplitude, latency, and scalp distribution [65]. By determining the mean amplitude of ERP across various time segments, one can study the disparities in different environments. Latency, measured in milliseconds, refers to the time interval between the commencement of a stimulus and the attainment of its peak. Observing the ERP distribution across the entire scalp, we can identify which regions of the brain are activated when a stimulus appears. For instance, the parietal P200 refers to a positive ERP component active in the parietal lobe area of the brain, peaking approximately 200 ms after stimulus onset. Researchers typically select components and brain regions based on different experimental objectives and analyze electrode points within the chosen brain areas to obtain relevant data on ERP components. For example, in Markey et al.'s ERP study on painting semantics, the N300/400 and P600 components related to visual semantics were observed, and the midcentral region (FC1, FC2, C1, Cz, C2, CP1, CPz, CP2) in which these components are active was selected for analysis [66]. These three key factors in ERPs offer insights into human psychological activity [62]. Certain researchers have employed ERPs to explore the neural responses to various stimuli that induce users' aesthetic preferences [64,67]. Furthermore, ERPs have been utilized to study the relationship between levels of professionalism and aesthetic values [21,49,68]. Ultimately, ERP components can not only reflect human emotional activity but can also assist in understanding the complexity of cognitive functions within the brain [69,70].

The N100 is an ERP component associated with attention, typically reaching its peak within the 100–200 ms following a stimulus. As an exogenous visual element, it is related to the allocation of attentional resources elicited by the stimulus, subsequently influencing the participant's recognition of visual characteristics [71,72]. Certain studies have revealed that the N100 is sensitive to low-level visual features, and its amplitude is correlated with the physical attributes of the stimulating material [71,73]. In perceptual processing, the participant's attention and recognition handling may be influenced by physical factors such as shape and material. Notably, a higher N100 amplitude signifies a greater allocation of attentional resources to visual feature recognition [63,74]. Moreover, the aesthetic perception of artworks among different individuals has been demonstrated to have a connection with the N100 component. For instance, Else et al. [49] discovered that art experts, when engaging in the appreciation of art, elicited a greater N100 amplitude compared to non-experts. Consequently, based on the analysis, we propose Hypothesis 1 as follows:

H1: *In the face of experimental stimuli pertaining to urban public art, experts induce a greater N100 amplitude than non-experts.*

P200 is an ERP component that reaches its peak approximately 200 ms after stimulation, specifically involved in visual aesthetic processing. It is capable of reflecting the allocation of early attentional resources and emotional arousal [75,76]. Aesthetic evaluation encompasses not only attention but also an emotional experience. When exposed to positive or favored stimuli, the P200 amplitude experiences a corresponding increase [74,77,78]. For example, Fudali-Czyż et al. [78] observed that the P200 amplitude elicited when participants viewed beautiful paintings was greater than when viewing less attractive ones. Cao et al. [77] found in their study on mobile phone images that attractive anthropomorphic icons induce

larger P200 responses than their non-anthropomorphic counterparts. Based on the research, we propose the following Hypothesis 2:

H2: *People's responses to favored public art may induce a larger P200 response.*

The N200 is an ERP component that reaches its peak within a 200–350 ms time window after stimulation, is closely related to cognitive processes such as automatic stimulus recognition, selective attention, and perception, and is considered an endogenous negative component [79,80]. Moreover, existing research has affirmed that the N200 is associated with aesthetic preferences [81]. Researchers have found that individuals, when confronted with items they dislike or deem to have low aesthetic value, trigger a more substantial N200 response. For instance, Handy et al. [82] observed an increase in N200 amplitude in the central frontal area in response to disliked logos in a commercial symbol study. Similarly, Telpaz et al. [83] discovered in product preferences that products with a lower preference index elicited a greater N200 response compared to those highly favored. Therefore, in conjunction with the studies, we propose the following Hypothesis 3:

H3: *People's reactions to disliked urban art may induce a greater N200 response.*

This study aims to delve into the differences in aesthetic preferences towards urban public art under various artistic characteristics as well as the neural mechanisms underlying these differences. This paper employs the ERP research method, recording relevant brainwave data through a 2 (feature type: abstract, figurative) $\times$ 2 (group type: experts and non-experts) repeated-measures design. We propose the hypothesis that aesthetic preferences for different types of urban public art may trigger variations in the ERP amplitudes of the N100, P200, and N200. These changes can reflect the neural activities of the participants, further revealing the perceptual details in their aesthetic processing behavior. This study highlights the following innovations:

1. Utilizing ERP technology to record brain activities, we unveil the visual neural processing mechanisms during people's aesthetic appraisal of urban public art, providing objective evaluation methods and neural-level data support in the field of urban landscape design;
2. We compare the effects of abstract and figurative styles on different groups, distinguished by professional background levels, offering a new research perspective, an aspect less focused on in previous studies;
3. This study can offer insights into the design of urban public art. Understanding the preferences of the public is crucial for effective design. By considering the aesthetic needs of the public and the freedom and diversity of artists' creations, we can inspire designers and artists, promoting the creation of urban public spaces with greater artistic appeal;
4. We provide instances and support for exploring landscape aesthetic activities using cognitive neuroscience techniques, offering new evidence for the development of landscape design theory.

2. Materials and Methods

2.1. Participants

Based on previous studies and sample size estimation using G*Power 3.1 [49,78], we invited a total of 40 participants to take part in this study. However, the data of 4 subjects were excluded due to excessive artifacts caused by physical movements. Consequently, the data from the remaining 36 subjects were incorporated into the study, comprising 18 experts (mean = 26 $\pm$ 2.85 years, Min = 23, Max = 33, 9 females) and 18 non-experts (mean = 22 $\pm$ 1.88 years, Min = 20, Max = 26, 9 females). In our study, the term "expert" refers to individuals with extensive knowledge and understanding of art, including but not limited to artists. Experts hailed from the School of Design Art and the Fine Arts College of Jingdezhen Ceramic University and some were young local artists. All of them had over three years of experience in art, engaging in artistic creation and appreciation activities

weekly, with educational levels equivalent to a bachelor's degree or higher. Conversely, the non-experts were students from non-artistic design specialties at Jingdezhen Ceramic University. All participants were right-handed, possessed normal vision, and had signed written informed consent forms. No individual had a history of brain damage or a mental condition. This study received approval from the Jingdezhen Fifth People's Hospital. Upon the conclusion of the experiment, all participants were remunerated with a sum of 70 RMB.

2.2. Experimental Stimuli

Existing research has employed images of art pieces as neural experimental stimuli [76]. Building on this, researchers selected high-quality images of public sculptures as stimuli from the renowned image-sharing website www.Flickr.com (accessed on 17 August 2023). We invited professors from the Department of Sculpture and Environmental Art at Jingdezhen Ceramic University to select experimental stimuli based on the following criteria: (a) The content of the artwork typically depicts specific individuals or historical events, with proportions closely resembling those of real objects, and it possesses refined and abundant decorative techniques; (b) In terms of image specifications and scope, the selected pieces must be world-renowned public sculptures; there should not be significant discrepancies in the size and specifications of the artworks; the chosen images must be taken from similar frontal angles and must have high resolution to ensure clarity. After careful assessment by experts from Jingdezhen Ceramic University, 13 pictures were meticulously chosen from hundreds of images to serve as experimental materials for figurative public art (FPA).

Previous studies have seen scholars manipulate corresponding experimental materials through painting or technical means, such as Schwabe et al. [84], who implemented digital creation of abstract paintings by the same artist to study the aesthetic evaluation and perception of abstract art pieces. Guo et al. [85] abstracted the experimental materials within a specific framework and employed ERP methods to study the aesthetic evaluation of smartphones. In light of this, we synthesized abstract art-related descriptions within the literature and artistic experience summaries [37,84] and adhered to the following principles for artistic creation: (a) abandoning figurative forms such as realistic figures and themes; (b) simplifying or removing decorative details; and (c) utilizing abstract geometric shapes and lines to express the theme. By employing brushes and digital drawing techniques, we conducted abstract sculpture art creation using the selected 13 tangible sculptures as prototypes, thereby obtaining 29 abstract public art (APA) materials. Ultimately, 42 images were chosen for the subsequent research. Simultaneously, to minimize visual differences and eliminate the side effects brought about by irrelevant factors, all product images were preprocessed using Adobe Photoshop 2023 and converted into black-and-white high-definition images with uniform brightness, shadows, and a resolution of 2443×3338 pixels (Figure 1).

Additionally, Hou and Hu [86] employed a 5-point Likert scale to evaluate participants' familiarity with and the complexity of pictograms; similarly, Pelowski, Gerger, et al. [87] utilized a 7-point Likert scale to investigate the audience's classification of art types. Consequently, inspired by the studies, the present research also adopted a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree) and invited 28 art experts to partake in an online survey. The experts were prompted to respond to the inquiry "Do you consider the public sculpture in the picture to be abstract/figurative?" and to evaluate the photographs' degrees of abstraction and figuration online. The assessment criteria encompassed two dimensions: firstly, the average feature rating had to exceed 4; secondly, the percentage of ratings above 4 had to surpass 80%. Only if these two conditions were met could the selected public art be deemed to meet the standard in terms of their abstract and figurative levels (Table 1). Through scoring, 13 figurative sculptures and 11 abstract sculptures met the criteria. To ensure the reliability of the research data, we excluded 2 stimuli with relatively lower scores from the 13 figurative images, ensuring an equal number of experimental stimuli for both types. Ultimately, in accordance with the research objective, 11 figurative

sculptures and 11 abstract sculpture images were singled out through rating, to serve as stimuli for the ERP experiment.

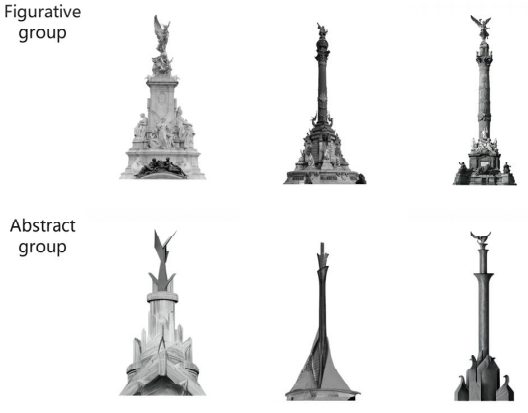

Figure 1. These are some instances of research stimuli.

Table 1. Rating table for the level of abstraction and figuration of experimental stimuli. The table includes two types of data: average feature scores and scoring percentages. Only experimental materials with an average score above 4 and a percentage over 80% meet the research standards.

Abstract Public Sculpture									
									
4.00 (60.71%)	4.21 (85.71%)	4.32 (89.28%)	3.96 (75.00%)	4.32 (89.28%)	4.00 (75.00%)	4.39 (85.37%)	4.39 (92.85%)	4.07 (78.57%)	4.14 (78.57%)
									
4.14 (71.42%)	4.11 (78.57%)	4.07 (71.42%)	4.25 (82.14%)	4.07 (85.71%)	3.86 (71.42%)	4.00 (75.00%)	4.04 (71.42%)	4.00 (75.00%)	4.00 (71.42%)
									
4.11 (78.57%)	4.36 (85.71%)	4.14 (75.00%)	4.64 (96.42%)	4.32 (82.14%)	4.25 (89.28%)	3.54 (64.28%)	4.11 (71.42%)	3.79 (60.71%)	

Table 1. *Cont.*

Figurative public sculpture									
									
4.57 (96.42%)	4.68 (96.42%)	4.39 (85.71%)	4.32 (89.28%)	4.29 (82.14%)	4.71 (100.00%)	4.75 (96.42%)	4.36 (89.28%)	4.75 (100%)	4.21 (85.71%)
									
4.36 (89.28%)	4.75 (100.00%)	4.39 (89.28%)							

2.3. Experimental Procedure

The study was carried out in a controlled environment with consistent illumination, wherein participants were instructed to assume a comfortable seated position at around 70 cm from the display, maintaining a field of view of 31.5° × 18.9° (width × height). Moreover, the monitor boasted a resolution of 1920 × 1080 and measured 24 inches in size. The task for the ERP was programmed and presented through Eprime 3.0. Participants were instructed to observe 22 images (11 abstract and 11 figurative sculptures), each photograph repeated six times, resulting in a total of 132 trials. To mitigate any sequence effect, the images were arranged in a random order. The experimental process is illustrated in Figure 2. Initially, an introductory script appeared on the screen, outlining the essential aspects of the experiment. Subsequently, during the experimental procedure, a series of images were presented, and the subjects were required to respond according to their aesthetic preferences within the stimulus's appearance time; the numeral 1 denoted liking, and the numeral 2 indicated disliking. Through script design, we assigned the keypress behaviors of number 1 and number 2, as well as abstract and figurative stimuli, to corresponding response marks and stimulus marks. When a stimulus mark appeared, a corresponding response mark would only appear after the designated key was pressed. This approach prevented errors or repeated keypresses from interfering with the data results. Participants were advised to refrain from blinking or moving their heads during stimulus presentation. After the introductory script, a brief pre-experiment occurred. Pressing the spacebar then initiated the formal experimental phase. A grey crosshair cursor appeared at the center of the screen for 2000 ms, aiding participants in focusing their attention. The stimuli were displayed at intervals of 1500–1800 ms, lasting 3000 ms. The program was set to move on from the current screen immediately upon the participant's completion of a keystroke or automatically advance to the next stage after the stimulus's display time. During the interval between stimuli, a central crosshair cursor on a grey background was shown on the screen. The stimulus images were alternately presented until the conclusion of the experiment. The entire experiment lasted 40 min, with one break included within each experimental session.

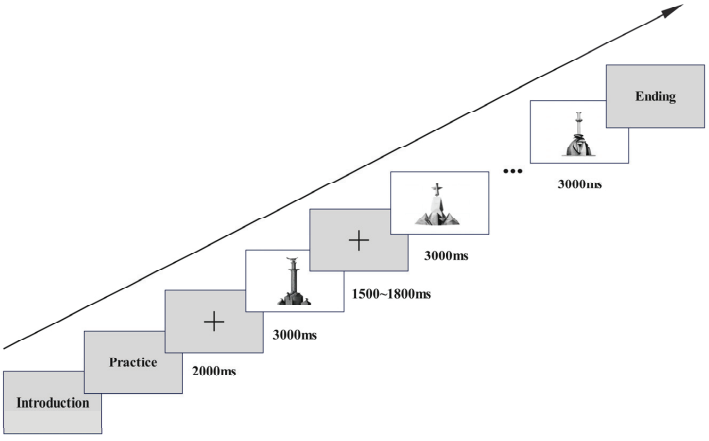

Figure 2. Experimental flow.

2.4. Data Acquisition and Analysis

According to the standard International 10–20 system, electroencephalogram (EEG) data were continuously recorded using a Neuroscan Synamp2 Amplifier coupled with an electrode cap containing 64 Ag/AgCl electrodes. Figure 3 illustrates the primary process of data collection and handling in the study. The software employed for data collection was Scan4.5, and the recording sampling rate was calibrated at 1000 MHz. The reference electrodes were assigned to the left and right mastoids (M1, M2), while a grounding electrode was placed at the FCz position. Throughout the experimental process, the resistance at each electrode was meticulously maintained below 5 kΩ.

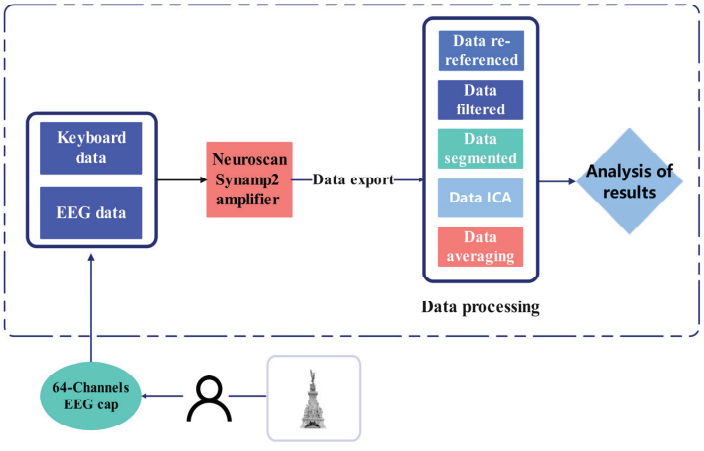

Figure 3. Data Collection and Processing Procedure.

We preprocessed the EEG data offline using the MATLAB 2023a EEGlab toolbox. The EEG data were analyzed, considering the means of the left and right mastoids, and then electronically filtered through a lowpass filter with a fixed cutoff frequency between 0.5 and 30 Hz. The first 200 ms of the EEG recordings were used as the baseline data, and sections between the 200 ms before stimulus commencement and the 1000 ms after it were recorded. Segments with a low signal-to-noise ratio were routinely eliminated through manual scanning, and ocular and electromyography (EMG) artefacts were removed using independent component analysis (ICA). Following the removal of the EEG artifacts, each

subject's data was retained with over 80 segments. Based on this, we averaged the data across subjects, channels, and conditions, culminating in the crafting of waveform graphs and topographic maps.

In accordance with the objectives of this research, previous studies [57,74,78,88], and the whole-brain topographic and waveform features within this study, we elected to conduct statistical analyses on nine electrodes situated in the frontal (FZ, F1, F2), central (CZ, C3, C4), and parietal (PZ, P1, P2) lobes. The electrode distribution is shown in Figure 4. The selection of time windows was concentrated around the peak intervals of the ERP components. In general, the frontal and central areas of the brain show a stronger N100 component during visual perception [57,88]. However, in alignment with the waveform graphs of this study, the central region displayed no conspicuous N100 component. Consequently, we selected the frontal region (FZ, F1, F2) and analyzed the mean amplitude of the N100 in the 100–170 ms time window. During aesthetic perception, the P200 is active in the parietal region [74,78], leading us to choose the parietal area (PZ, P1, P2) for the analysis of the P200 mean amplitude in the 200–240 ms time window. Research indicates that the N200 is more vigorous in the frontal and central regions [83], yet the waveforms of this study showed no evident signs of the N200 in the frontal region. Therefore, we opted for the central region (CZ, C3, C4) to analyze the mean amplitude of N200 in the 240–280 ms time window.

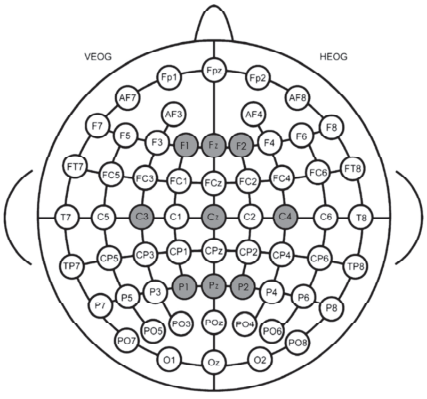

Figure 4. Selected Electrodes in the Study.

Ultimately, we extracted the mean amplitudes for all varying conditions and regions, employing IBM SPSS Statistics 26 to administer a two-way repeated-measures analysis of variance (ANOVA) on both behavioral data and ERP data, with the factors being two feature types (abstract, figurative) and two group types (experts and non-experts). In this analysis, the feature types were regarded as within-subject variables, while group types were considered as between-subject variables. Additionally, we conducted tests for normality and homogeneity of variance, describing the means and standard deviations in the descriptive statistics.

3. Results

3.1. Behavioral Results

In the collection of behavioral data, we recorded responses for both Key 1 (Like) and Key 2 (Dislike). Since the aim of this study is to investigate people's aesthetic preferences towards public art, we excluded data related to Key 2 and invalid responses (where no selection was made). We calculated the proportion of presses for Key 1 (like) relative to the total number of keypresses, treating the response time and keypress ratio as behavioral data. Following a test for normality of the behavioral data, an ANOVA test was employed

to examine the data for differences. Descriptive statistics for the response times and proportions among subjects, under varying feature-type conditions, can be found in Table 2.

Table 2. The descriptive statistics for behavioral results include the mean and standard deviation (Mean ± SD) of participants' response times and keypress ratios under different conditions. The total average (TA) of the condition categories in the table is the sum of the sub-conditional averages (SA), divided by the number of sub-conditions (*n*). The formula is $TA = (SA_1 + SA_2 + \ldots + SA_n)/n$.

Feature	Group	Response Time (ms)	Keypress Ratio (%)
Abstract	Non-expert	1185.39 ± 460.05	40.02 ± 25.02
	Expert	1157.84 ± 376.71	30.59 ± 22.13
Figurative	Non-expert	1043.19 ± 606.52	40.48 ± 31.55
	Expert	1041.07 ± 380.15	61.10 ± 25.28

In the present study, we recorded the participants' response times and conducted an analysis of the data through a two-way ANOVA. The findings revealed that there was no significant difference in the participants' response times, regardless of whether the features were abstract or figurative ($F = 2.596$, $p = 1.116$, $\eta^2_p = 0.071$). Moreover, no discernible distinction was observed between experts and non-experts in their response to the artistic features of the public art shown ($F = 0.013$, $p = 0.912$, $\eta^2_p = 0.000$), and no significant interaction between the feature variables and the between-group variables was detected ($F = 0.025$, $p = 0.875$, $\eta^2_p = 0.001$). Based on the statistical results of response times, participants across different groups bestowed equal attention to both APA and FPA.

In analyzing the participants' keypress proportions, this study conducted statistical analysis specifically focusing on the proportion of presses for Key "1" (indicating "like"). Analysis of variance (ANOVA) indicated that the feature conditions ($F = 5.393$, $p = 0.026$, $\eta^2_p = 0.137$) had a significant impact on the participants' preferences for public art. Specifically, in comparison to APA, individuals tended to favor sculptures with FPA (35.30 ± 23.77% vs. 50.79 ± 30.06%). However, the main effect between different groups was not significant ($F = 0.979$, $p = 0.329$, $\eta^2_p = 0.028$), but there was indeed an interaction between feature conditions and groups ($F = 5.080$, $p = 0.031$, $\eta^2_p = 0.130$). Further simple effect analysis revealed that experts were more inclined to appreciate FPA (61.10 ± 25.28% vs. 30.59 ± 22.13%, $p = 0.003$), while the preferences of non-experts did not exhibit significant differences ($F = 0.002$, $p = 0.962$, $\eta^2_p = 0.000$).

3.2. ERP Results

From this research, the data under each condition were separately averaged, and an analysis was conducted on the mean amplitude of the N100, P200, and N200 components through a 2 (feature type: abstract sculptures vs. figurative sculptures) × 2 (group type: experts vs. non-experts) repeated-measures ANOVA. Table 3 presents the descriptive statistics for the ERP results, while Table 4 displays the ANOVA results for the N100, P200, and N200 components.

Table 3. Descriptive statistics for the ERP results, including the time window of brain waves for each component under various conditions, the brain region involved, corresponding electrode points, and the average amplitude information (Mean ± SD).

Component	Time Window (ms)	Regions and Electrodes	Abstract (μV)		Figurative (μV)	
			Non-Expert	Expert	Non-Expert	Expert
N100	100–170	Frontal FZ,F1,F2	0.176 ± 2.32	−1.984 ± 1.88	0.476 ± 2.49	−2.361 ± 2.58
P200	200–240	Parietal PZ,P1,P2	6.056 ± 3.78	5.261 ± 2.80	5.223 ± 3.79	6.201 ± 2.73
N200	240–280	Central CZ,C3,C4	0.293 ± 2.84	0.842 ± 3.45	0.330 ± 2.76	1.912 ± 3.59

Table 4. The main effects, interaction effects, and simple effects of the ANOVA for N100, P200, and N200, incorporating variables "Feature" (Abstract and Figurative) and "Group" (Experts and Non-experts). Further simple effect analysis is conducted in cases where interaction effects are significant.

Analysis Type	Factors		N100			P200			N200		
			F	*p*	η^2_p	*F*	*p*	η^2_p	*F*	*p*	η^2_p
Main Effect	Feature		0.021	0.886	0.001	0.027	0.871	0.001	4.713	0.037	0.122
	Group		11.703	0.002	0.256	0.007	0.932	0.000	1.066	0.309	0.030
Interaction Effect	Feature × group		1.590	0.216	0.045	7.537	0.010	0.181	4.713	0.050	0.108
Simple Effect	Feature × group	Abstract × group	-	-	-	0.513	0.479	0.015	0.270	0.606	0.008
		Figurative × group	-	-	-	0.787	0.381	0.023	2.187	0.148	0.060
	Group × feature	Non-expert × feature	-	-	-	3.331	0.077	0.089	0.011	0.919	0.000
		Expert × feature	-	-	-	4.233	0.047	0.111	8.804	0.005	0.206

As illustrated in Figure 5, within the frontal region's 100–170 ms time window, we observed the N100 component, and the corresponding grand-averaged ERPs and topography map were delineated. The ANOVA results indicated a significant impact of different groups on the N100 amplitude ($F = 11.703$, $p = 0.002$, $\eta^2_p = 0.256$), where experts (−2.173 ± 2.23 μV) elicited a greater N100 amplitude than non-experts (0.326 ± 2.37 μV). However, the influence of the feature factor ($F = 0.021$, $p = 0.886$, $\eta^2_p = 0.001$) on the N100 component was not significant, and there were no meaningful interactions between features and groups ($F = 1.590$, $p = 0.216$, $\eta^2_p = 0.045$).

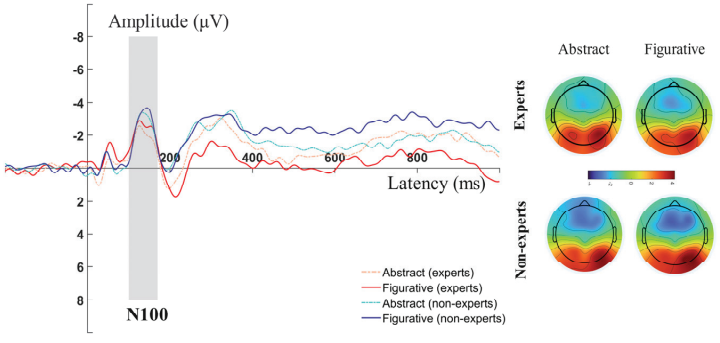

Figure 5. Under four situations, the parietal region's grand-averaged ERPs and topographical map.

Within the parietal region's 200–240 ms time window, we observed the P200 component, as depicted in Figure 6. The ANOVA analysis results indicated that the influence of the feature factor on the P200 component was not significant ($F = 0.026$, $p = 0.871$, $\eta^2_p = 0.001$),

and the different group types also failed to produce a significant effect ($F = 0.007$, $p = 0.932$, $\eta^2_p = 0.000$). However, there was indeed an interaction between the feature conditions and group types ($F = 7.537$, $p = 0.010$, $\eta^2_p = 0.181$). Further simple effect analysis revealed that experts' responses to FPA caused a higher P200 amplitude compared to responses to APA (6.201 ± 2.73 μV vs. 5.261 ± 2.80 μV, $p = 0.047$), while non-experts did not present a noticeable difference between the two ($F = 3.331$, $p = 0.077$, $\eta^2_p = 0.089$).

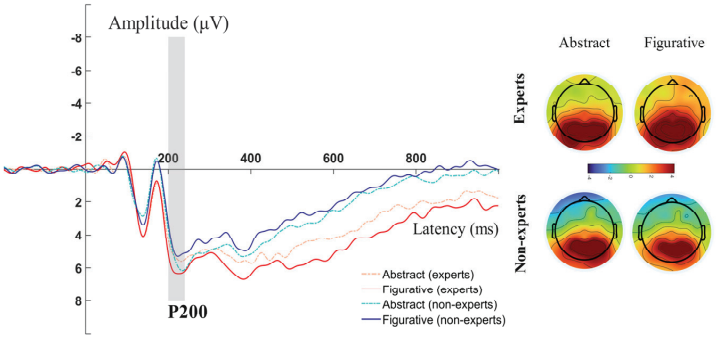

Figure 6. Under four situations, topography and grand-averaged ERPs were mapped in the parietal area.

As shown in Figure 7, we explored and extracted the average amplitude corresponding to the N200 component within the 240–280 ms time window in the central region. Through a 2 × 2 repeated-measures ANOVA, we discovered that the characteristic factor ($F = 4.713$, $p = 0.037$, $\eta^2_p = 0.122$) significantly influenced the amplitude of the N200 component, with APA (0.568 ± 3.13 μV) inducing a higher N200 amplitude relative to FPA (1.121 ± 3.26 μV). However, the main effect of group type was not significant ($F = 1.066$, $p = 0.309$, $\eta^2_p = 0.030$), although there was an interaction between characteristic condition and group type ($F = 4.102$, $p = 0.050$, $\eta^2_p = 0.108$). Further simple effect analysis revealed that experts' perception of APA elicited a higher N200 amplitude than that of FPA (0.842 ± 3.45 μV vs. 1.912 ± 3.59 μV, $p = 0.005$). Non-experts' perception of APA likewise slightly induced a higher N200 component than that of FPA (0.293 ± 2.84 μV vs. 0.330 ± 2.76 μV, $p = 0.919$), but under circumstances where $p > 0.05$, this difference did not yield statistically significant effects.

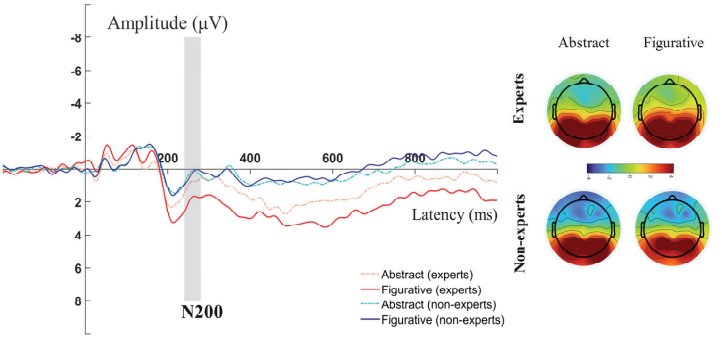

Figure 7. Grand-averaged ERPs and topography map under four conditions in the central region.

4. Discussion

This study aims to investigate the aesthetic preferences and corresponding neural responses of groups (experts and non-experts) towards different artistic characteristics of urban public art, serving as evidence of the influence of style and expertise on people's aesthetic mechanisms. By presenting participants with a series of abstract- and figurative-

style urban public art images, the behavioral data and corresponding brain signals of the subjects during the experiment were recorded, utilizing the theory and technology of event-related potentials for data analysis.

4.1. Aesthetic Preferences of Public Art

The analysis of reaction times in behavioral outcomes revealed no significant differences between experts and non-experts when viewing public art with various characteristic levels. This contrasts with the findings of Bölte et al. [21], who discerned a slower response from experts in assessing the aesthetics of web pages. This discrepancy may stem from the artistic features of the experimental materials and the distribution of attention within the stipulated time. Nevertheless, despite the absence of differences in reaction times, experts and non-experts manifested divergent aesthetic preferences when confronted with landscape art of various characteristic types. This discovery may imply that aesthetic preferences are unrelated to cognitive processing speed and are more intimately connected with an individual's artistic experience and knowledge.

In this study, we presented participants with various images of abstract and figurative urban public art, guiding them to respond with keypresses according to their personal preferences. The findings revealed a significant preference for FPA over APA ($50.79 \pm 30.06\%$ vs. $35.30 \pm 23.77\%$, $p = 0.026$). This discovery aligns with previous research, as numerous studies have already substantiated that representations of tangible entities in paintings or images elicit higher aesthetic evaluations and preferences than abstract images that do not denote any specific content [20,89,90]. We further explored the disparities in preferences between experts and non-experts, and the results disclosed a more pronounced preference among experts for different artistic characteristics. Specifically, experts exhibited a leaning towards figurative art, while non-experts manifested no significant preference between the two kinds of art pieces. However, some research has found that individuals with specialized knowledge and an artistic background tend to favor abstract art [91,92], a finding that is inconsistent with our study. This inconsistency might be attributed to the artistic features of the experimental stimuli within our research. Specifically, FPA, through its lavish decorations and intricate craftsmanship, vividly showcases more elements drawn from reality, facilitating easy comprehension and evoking a sense of familiarity among individuals. In contrast, APA necessitates a more substantial contextual and artistic emotional interpretation, which is challenging to achieve under experimental conditions [47]. Moreover, people are generally inclined towards meaningful artistic works [93], and the expertise and perceptual abilities of experts further amplify this trend [49,94]. In conclusion, preference towards urban public art is not solely related to artistic characteristics but is also influenced by level of expertise. Experts with specialized knowledge tend to appreciate the craftsmanship and decorativeness of FPA more, while non-experts are unable to make a distinct preferential choice between the two characteristics [49].

4.2. Neural Mechanisms of Aesthetic Perception in Public Art

The visual N100 is closely associated with the early visual processing stage of emotional stimuli and is considered a vital indicator of selection and resource allocation [71,95]. According to previous research, the N100 is related to the activation of early visual areas in the brain triggered by visual stimuli, an activation principally elicited by low-level properties of stimuli such as contours, shapes, and colors [71]. Moreover, the N100 is also connected to the allocation of attention in aesthetic preferences. For instance, Chen et al. [96] discovered that lighter tiles with higher preference scores could induce a larger N100 amplitude compared to darker tiles with lower preference scores. However, differing from the above studies, our statistical results demonstrate that the art's characteristic types did not induce a main effect on the frontal N100. This finding suggests that during the primary stage of perceptual processing, individuals are unable to differentiate between different feature levels of urban public art. This may be due to the specificity of the experimental material, causing participants to focus solely on low-level attributes during the

initial visual stage, without completing the mental reconstruction of APA or FPA, which requires higher-level visual processing. As Bimler et al. [89] found, the aesthetic experience is regarded as a cognitive process where objects are decomposed into lower-level features such as color, brightness, lines, light points, etc., and gradually develop into higher-level processing through the interpretation of artworks, systematically reconstructing them into intricate forms. This process might require individuals to observe for a more extended period to achieve full completion [45]. Furthermore, the statistical results also reveal that experts elicit more N100 components than non-experts, indicating that while appreciating public artworks, the brain's visual regions of experts are more active, and their professional knowledge prompts them to allocate more attentional resources [49]. This discovery aligns with prior research [49,97]. Therefore, our research results are consonant with Hypothesis 1.

According to research, the P200 functions as a neural correlate during the initial stages of processing visual aesthetics, associated with the processing of emotional stimuli, reflecting the automatic allocation process in the early stage of emotional stimulus processing [76,98]. It is well recognized that emotions (both positive and negative) constitute one of the essential elements in aesthetic preference, and both positive and negative stimuli can elicit variations in P200 amplitude [99]. According to the results of this study, people's preference for FPA leads to a greater P200 response. Existing research indicates that a larger P200 response is elicited when individuals are exposed to positive and preferred stimuli [74,77,78]. Our correlational analysis also supports this finding. The reason that FPA could elicit a larger P200 might be that, compared to the distinctive and novel APA, the FPA offering content imbued with real-life significance is more capable of resonating positively with aesthetic emotions and cultural harmony, one of the characteristics of urban public art [8,32,94]. These findings demonstrate that emotional processing has a role in the initial aesthetic assessment of urban public art, with individuals generating more positive emotions towards preferred urban sculptures, thereby inducing a greater P200 response. This study's findings concur with Hypothesis 2. Additionally, the results reveal that this preference instigated by emotional arousal appears only in the expert group, as Else et al. [49] discovered that artists, when facing figurative art, evoke more P200 responses compared to non-artists. This illustrates that experts invest more emotional resources into the aesthetic processing of art, rendering their evaluation of artworks more affirmative than novices. While the attention of non-experts wanes quickly, experts maintain a sustained sense of engagement [49].

The N200 component reflects a preferential selection of attention towards stimulus-related attributes, while also revealing differences in emotional stimuli [100,101]. Moreover, compared to stimuli with a high preference, those with a low preference have been found to evoke a greater N200 amplitude [82,83,96]. The ERP results are consistent with the aforementioned studies, demonstrating that participants exhibit a higher N200 amplitude in response to low-preference APA as opposed to FPA with a higher preference. Reber et al. [48] propounded a theory of fluency, suggesting that the aesthetic appeal of a piece of art is determined by the ease or difficulty with which it can be understood or perceived. Due to the often elusive and difficult-to-interpret content of APA [47], people tend to generate a more pronounced negative reaction to low-preference APA. This reflects a negative stimulus-driven selection of attention, and the research findings lend support to Hypothesis 3. In addition, during further analysis, experts elicited a greater N200 response to abstract art, signifying that those trained in the arts exhibit a more precise recognition and categorization of artworks. Their information processing is more profound [102], thereby enhancing their selective attention driven by emotions. In contrast, non-experts are found to be in a state where attentional resources are diffused.

4.3. Theoretical Implications and Insights into Urban Landscape Design

This study carries the following research implications: Firstly, it broadens the research methods in urban landscape aesthetics by introducing the neuroscientific approach of ERP, providing an objective assessment method and neuro-level data support for the landscape

design field. Secondly, the study also reveals the preferences and neural mechanisms of the public regarding art style and expertise, further enriching the research perspectives in landscape visual assessment. Ultimately, this study employs neuroscience theories to offer a fresh interpretation of the research on urban landscape perception, providing new evidence to foster the development of urban landscape theory.

We provide the following insights into urban landscape design:

1. This study emphasizes the potential of utilizing neurophysiological measurement methods (such as ERPs) to objectively evaluate aesthetic preferences. This approach opens the possibility for guiding urban designers in making landscape art design decisions based on objective criteria. For instance, through the analysis of different ERP components, one can understand people's attention allocation and emotional responses when facing various landscape elements. These aesthetic perception indicators can be integrated into consideration during the design process;
2. By studying abstract- and figurative-style features, urban designers can better understand preferences for different styles of landscape art, assisting designers in making the correct choices when faced with various design requirements;
3. Recognizing that the public has limited interpretation of public art can also encourage designers to adopt appropriate methods to enhance the public's appreciation ability for art aesthetics. This would help in creating urban public spaces that are both aesthetically pleasing and inclusive of different tastes.

Furthermore, we acknowledge the incredible diversity within the fields of art and design, with abstract art and various innovative styles (like the Bauhaus School) holding significant value and influence. It is crucial to note that our research findings do not advocate for a restrictive or normative approach to artistic creation. Instead, our goal is to reveal certain public preferences, providing insights for artists and designers to consider, integrate, or challenge in their work. Art styles should not merely cater to popular taste but should also attract, challenge, and expand the public's understanding and appreciation of art. Designers must consider the needs of individuals with different perceptual and cognitive conditions, ensuring that public art is experienced and appreciated by as many viewers as possible.

4.4. Limitations of the Study

This study has several limitations. Firstly, most participants were young students and artists. Future research needs to include subjects from various age groups to enhance the generalizability and representativeness of the results. Secondly, the study did not consider the impact of cultural background on the aesthetic appreciation of public art. Cross-cultural comparisons, such as those contrasting Eastern and Western cultures, can be conducted in the future. Different cultural backgrounds might foster different aesthetic patterns for public art, which is worth further exploration. Moreover, this study primarily focused on abstract- and figurative-style characteristics, potentially overlooking the influence of other style elements and artistic forms on aesthetic preferences. Future studies can undertake a broader exploration to gain a more comprehensive understanding of the aesthetic preferences for landscape public art. Lastly, to avoid data interference, this study eliminated the influence of complex variables such as the environment. In upcoming experiments, more environmental factors should be considered to restore the complexity and diversity of urban landscapes.

5. Conclusions

This study employs the event-related potential (ERP) method, aiming to examine aesthetic preferences and their neurological mechanisms in groups with diverse artistic backgrounds (experts and non-experts) while viewing abstract and figurative public art. The research findings indicate that, based on behavioral test results, people generally tend to appreciate artworks rich in concrete content. Specifically, experts tend to appreciate FPA more, but the preferences of non-experts do not show significant differences. Based on the ERP data analysis, experts generate a higher N100 amplitude when viewing stimulus

pictures of all types, indicating that they are more sensitive in allocating attention to physical properties. When experts encounter FPA, they generate a higher P200 amplitude in the parietal cortex, indicating that compared to APA, FPA more readily arouses positive emotions. In the N200 component, experts trigger more N200 responses towards disliked APA, further suggesting that APA incites more negative biases. However, non-experts exhibit almost no noticeable changes in P200 and N200 responses under various conditions. The research results demonstrate that, compared to non-experts, experts have a more intense and sensitive response to artistic stimuli in terms of aesthetic cognition and emotional experience. This difference is primarily reflected in the allocation of attentional resources, the intensity of positive emotional experiences, and negative emotional responses, but it does not alter the general tendency of people toward preferring representational art. For non-experts, their neural responses to both types of public sculptures are weaker, reflecting a slow and complex aesthetic appreciation for public art. The article concludes as follows:

1. The difficulty level of visual perceptual processing plays a significant role in the preference for landscape public art. As per the fluent processing theory, representational public art that is easy to recognize tends to be favored more by people, eliciting corresponding positive emotions. Figurative public art with rich content characteristics more readily induces positive emotional responses from individuals, whereas vague-yet-creative abstract art draws selective attention resource allocation from people, primarily due to the negative biases resulting from recognition difficulties. The present research results also highlight the importance of perceptual indicators during the aesthetic processing phase, revealing people's emotional perception and acceptance level of design features. Therefore, in subsequent related designs, designers should fully consider perceptual indicators like emotions and perceived difficulty;
2. From the perspective of the aesthetic cognitive process of landscape art, individuals first notice the low-order physical attributes of public art, and stylistic characteristics belong to a higher level of visual processing, requiring the participation of specialized knowledge. In the initial cognitive stage (N100), individuals observe primary physical attributes such as the contour and shape of objects, forming a first impression of them. In subsequent higher-order visual aesthetic processing (P200, N200), stylistic features are identified, generating corresponding emotions and aesthetic evaluations;
3. Expert knowledge plays a positive role in the aesthetic appreciation of landscape art. Professional art training allows individuals to invest more attention and positive evaluations into the allocation of attention resources, positive emotional experiences, and the intensity of negative biases. Therefore, cultivating the ability to appreciate art is also one of the aspects that designers need to focus on.

In conclusion, this study has offered insights into the aesthetic research of urban public art, enabling designers and researchers to gain a deeper understanding of the aesthetic mechanisms of landscape art, albeit with certain limitations. We hope that future studies can adopt a more enriched perspective and research paradigm to delve deeper into the relevant scientific issues. This will support the establishment of a more systematic theoretical framework in this field.

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Systematic Review

A Systematic Literature Review and Analysis of Visual Pollution

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Abstract: Rapid urbanization has introduced new pollution challenges, with visual pollution becoming particularly prominent. This type of pollution affects both the visual environment and public psychology, impairing aesthetic appreciation. Visual pollution extends beyond outdoor advertising, manifesting in various forms across urban, roadway, and natural areas. Although many studies have identified and analyzed visual pollution, there is still a lack of comprehensive knowledge and awareness of this problem. Until now, visual pollution has never been a unified and complete concept, definition, and research methodology. To address this gap, our systematic literature review examined existing literature to further explore and understand visual pollution. We systematically reviewed research articles published between 2008 and 2023, utilizing three journal databases: Web of Science, Scopus, and Google Scholar. Ultimately, 52 articles met the review criteria. The results of the study showed the types and characteristics of visual pollutants, the locations where visual pollution occurs, the various factors contributing to visual pollution, and the methodologies employed to study visual pollution. This study enhances professionals' comprehension of visual pollution and its effects on the visual environment, equipping them to implement effective measures to reduce its impact and preserve visual quality in both urban and natural areas.

Keywords: visual pollution; visual pollution's impact; visual pollution's type and characteristic; visual pollution's location; visual pollution's factors; visual pollution's method

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1. Introduction

Pollution is a pervasive issue, continuously threatening human life and the natural environment. While pollution has existed as long as human history, its detrimental effects on the world are profound and ongoing. According to [1], pollution is defined as the accumulation of contaminants or other harmful substances that have negatively affected the environment and human health. Environmental pollution has long been recognized as one of the most significant threats to humanity, alongside other factors impacting human life quality. The general understanding of environmental pollution has traditionally been primarily associated with air, water, and noise pollution. Air pollution involves harmful particles and gases in the atmosphere, such as chemicals, particulates, and biological molecules [2]. It is the world's fourth-largest fatal health risk, causing 4.8 million premature deaths annually. The trends and threats associated with water pollution have worsened, significantly impacting regions such as Europe, China, India, South America, and Africa [3]. Furthermore, the continuous development of urbanization [4], economic growth [5], and transportation systems [6] have exacerbated noise pollution. This escalation is attributed to various anthropogenic sounds and activities, as well as poor urban design and chaotic construction practices, making noise pollution increasingly difficult to control, especially in urban areas.

However, modern environmental challenges have expanded this understanding to include visual pollution [7], a relatively recent phenomenon arising from rapid urban expansion, industrialization, exploration, and insufficient regulations. Visual pollution typically involves unappealing or obtrusive elements that negatively impact the visual quality of environments [8,9]. It includes limitations on the visibility of distant objects, the subjective effects of introducing built structures in scenic landscapes, and a more expansive definition encompassing other visual disturbances [10]. The impact of visual pollution can be exacerbated when the pollutant is mobile, as it tends to attract attention and reduce feelings of tranquility [11]. This results in numerous visual stimuli competing for people's attention, making it challenging for them to concentrate on their tasks [12]. Visual pollution affects more than just aesthetics; it is closely linked to the spatial configuration of objects and can significantly alter a space's character and visual harmony [12]. Hence, the aesthetic quality of the environment is crucial in determining the overall quality of life. Visual pollution has been shown to reduce people's enjoyment of public spaces and natural landscapes, leading to dissatisfaction and a lower quality of life.

Moreover, visual pollution can also harm mental health. The proliferation of advertisements, signs, and other visual distractions creates a chaotic atmosphere that makes it difficult to relax and feel at ease [13]. Exposure to visual pollution can trigger negative psychological responses, leading to adverse moods [14–16], such as anxiety, fear, insecurity, and lethargy. Consequently, this leads to mental fatigue and cognitive decline due to the constant sensory overload. The pervasive stress on the visual senses can precipitate a decline in mental health, which in turn impairs overall well-being and life satisfaction.

Visual pollution is particularly significant in densely populated commercial centers where outdoor advertisements (OAs) are prevalent, impacting the public's visual experience of the urban landscape [17]. These OAs have also proliferated along roads in various forms, not only obstructing the sightlines of motorists [18] but also damaging the visual aesthetics of the area [19]. Although OAs are intended to inform consumers about products and services that may enhance their daily lives, their pervasive nature in everyday environments can lead to various problematic effects, such as visual pollution. Additionally, the materials used for these advertisements often contribute to environmental degradation due to their non-biodegradable nature, exacerbating landfill issues [14]. Beyond urban settings, the natural landscape areas have also become subject to the impacts of visual pollution, especially some new landscape elements and natural phenomena that modify the overall view of the natural landscape environment [20].

A study [21] has categorized visual pollution as two sides: one with tangible things that are specific objects or elements of the visual landscape that people can notice, and another one with intangible things mostly related to emotions, e.g., happiness, fear, or stress. This form of pollution not only degrades natural and built environments but also diminishes their aesthetic and potentially functional value and impacts human mental health. Therefore, understanding and addressing visual pollution is crucial to preserving urban and natural environments' visual integrity and aesthetic value and safeguarding human mental health and well-being.

The significance of visual pollution was first recognized in the mid-20th century. During that time, as automobile transportation improved and developed and car tourism increased in the United States, people became increasingly aware of the negative impacts of roadside OAs on the visual landscape [22]. Nowadays, urban environments are flooded with numerous OAs. This widespread presence often results in a cluttered and disorderly appearance, obstructing views and leading to disorientation among city dwellers [15,23]. Visual pollution has been linked to the growing number of OAs [24]. This view is supported by [25], who mentions that excessive OA contributes significantly to visual pollution, considering that more than seven OAs in a view can be problematic. Furthermore, visual pollution is said to occur when the ratio of the obstructed view to the visible view volume exceeds 4%, specifically due to OAs [26]. Frequent placement of OAs in public spaces and their long-distance visibility make them a major source of visual pollution.

While OAs are widely regarded as a significant source of visual pollution, their role is controversial. OAs are considered an effective form of communication that efficiently convey messages across diverse societies [27] and provide economic benefits by enhancing marketing efforts [28]. A study [24] has concluded that the four characteristics of OA—visibility, media effectiveness, local presence, and tangible response—define them as an effective tool for communication and a medium for information for the general public. It has also been argued that while OAs contribute to spatial disorder within urban environments, this chaos may render otherwise predictable or orderly urban spaces more intriguing [29]. Indeed, artistic advertisements can become tourist attractions, offering unique symbols and identities that may elevate locations to landmark status, as seen with New York's Times Square and Tokyo's Ginza district.

As research on visual pollution continues, the recognition of visual pollution has become more comprehensive and is not limited to OA. Visual pollution includes any material or object that causes discomfort for the visual senses [17,30]. This discomfort can stem from landscape components that are out of harmony with the surroundings [15,31,32], challenging integration into the environment. Visual pollution has been described as the loss of attractiveness and distortion of vision, resulting in diminished human perception of attractive components in all surroundings [33]. Additionally, visual pollution can result from neglect and poor management of both natural and man-made landscapes, leading to diminished area appeal [34]. It is characterized by an unregulated and disorganized diversity of colors, shapes, lights, and materials, resulting in unsightly urban environments [35].

Despite its significance, there has never been a unified and complete concept and definition of visual pollution. It is regarded as a complex phenomenon dependent on the surrounding environment and the psychology of the individual affected [36]. Unlike traditional forms of pollution, such as air and water, which have been extensively studied and defined, visual pollution presents unique challenges due to its subjective impact on environmental aesthetics and quality [31]. Although scholars have continued to explore visual pollution, visual pollution remains an under-understood and under-researched form of pollution [30]. Therefore, our review aims to systematically review the existing literature to explore and understand further visual pollution. The following section of the results presents the types and characteristics of visual pollutants, the locations where visual pollution exists, the various factors contributing to visual pollution, and the methodologies employed to study visual pollution. Understanding these factors is essential for preventing and mitigating visual pollution, thereby enhancing the visual comfort of public environments.

2. Materials and Methods

This systematic literature review utilized the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines. PRISMA offers a standardized methodology for screening and extracting literature, ensuring all relevant studies are appropriately included and appraised. This systematic literature review process was organized around precise keyword selection, well-defined inclusion and exclusion criteria, and comprehensive literature screening and selection. Subsequent stages included detailed data collection and analysis, culminating in systematically exploring the field.

2.1. Keyword Selection

In conducting this systematic literature review, keywords were strategically categorized into two primary components to cover all relevant aspects of visual pollution: visual pollution and investigations. First of all, the keyword "visual pollution or contamination" can be defined as two distinct but related concepts: visual disturbance and visual blight. These words describe disruptions that negatively impact the visual environment, potentially degrading its aesthetic quality and comfort. Secondly, "visual pollutants" and "visual contaminants" refer to the primary objects within the human environment that cause visual discomfort and contribute to the manifestation of visual pollution (Ahmed et al., 2019) [31]. Thirdly, the investigation component sought to clarify the range of topics covered by visual pollution studies by identifying the type, location, factor, and method involved. Finally, the keywords

for this systematic literature review are summarized as follows: "visual pollution" OR "visual contamination" OR "visual disturbance" OR "visual blight" AND "visual pollutants" OR "visual contaminants" AND "type" OR "location" OR "factor" OR "method".

2.2. Inclusion and Exclusion Criteria

The inclusion criteria for this study are as follows: (i) the subject of the article must be concerned with visual pollution, (ii) the article must have been published within the time frame from 2008 to 2023, and (iii) the article must be published in a peer-reviewed English-language scientific journal, including research papers, review papers, and conference papers.

The exclusion criteria for this study are as follows: (i) articles that are not relevant to the topic of visual pollution, (ii) book chapters, literature reviews, MSc and Ph.D. thesis, and government reports, and (iii) duplicate articles.

2.3. Literature Screening and Selection

Three databases—Web of Science, Scopus, and Google Scholar—were used to retrieve the initial pool of literature for this systematic literature review, shown in Table 1. Initially, a total of 15,300 articles were gathered. These articles were first filtered according to the inclusion and exclusion criteria detailed in Section 2.2, and 978 articles were finally selected. Subsequent screening removed 33 duplicates. After a detailed review of the full texts of these peer-reviewed journal articles, 52 articles (42 research papers, 9 conference papers, and 1 review paper) ultimately met all the specified requirements for inclusion in this study, as depicted in Figure 1.

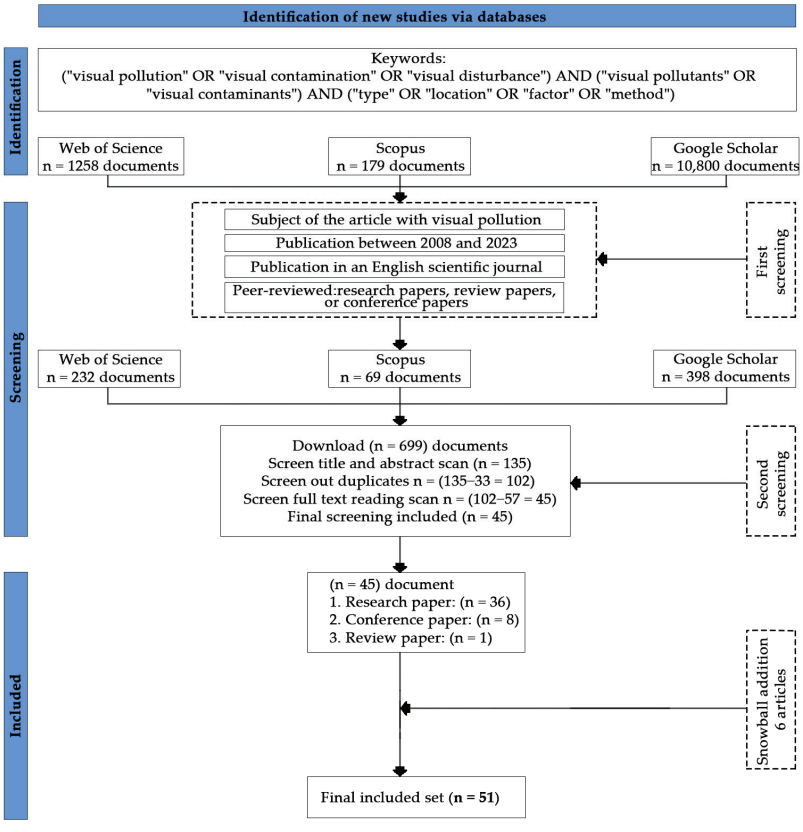

Figure 1. The PRISMA Flowchart describing the literature screening process for systematic search reviews.

Table 1. Database search strategy.

Database	Search Terms
Web of Science	"visual pollution" OR "visual contamination" OR "visual disturbance" OR "visual blight" AND "visual pollutants" OR "visual contaminants"
Scopus	"visual pollution" OR "visual contamination"
Google Scholar	"visual pollution" OR "visual contamination" AND "type" OR "location" OR "factor" OR "method"

2.4. Data Collection

In this study, a detailed examination and systematic review of the selected articles were performed to assess critical aspects of visual pollution. Relevant data extracted from these articles were organized in a Microsoft Excel spreadsheet (2020) to facilitate analysis and ensure systematic data handling. The recorded data included several detailed elements crucial for a thorough understanding of visual pollution, such as types of visual pollutants, the locations where visual pollution exists, the various factors contributing to visual pollution, and the methodologies employed to study visual pollution. The data collected in this study are presented in detail in Appendix A, Table A1.

2.5. Data Analysis

This study synthesizes the data presented in Table A1 of Appendix A, aiming to enhance the connections between existing literature. In order to fully comprehend the concept of visual pollution, it is essential to gain an understanding of various dimensions (Figure 2). Firstly, visual pollution arises through the presence of visual pollutants. Understanding the character and role of these visual pollutants could provide an overview of visual pollution. Next, the locations of these pollutants and the factors contributing to their prevalence at these sites were analyzed to provide a deeper understanding of visual pollution. Furthermore, a summary of the existing methods of identifying and measuring visual pollution was conducted, enriching the understanding of effective monitoring and management strategies. Generally speaking, this information is pivotal in effectively grasping the complexities involved in managing visual pollution.

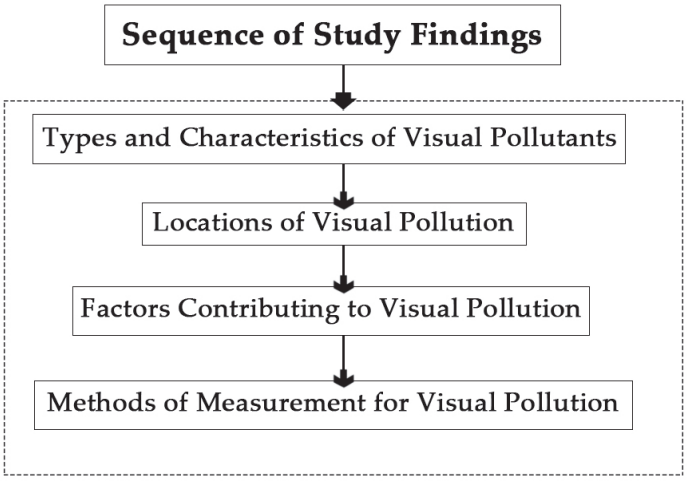

Figure 2. Sequence of study findings.

3. Results

A comprehensive count and review of the 52 articles selected for analysis revealed that these articles were published between 2008 and 2023. As shown in Figure 3, there has been a significant increase, especially after 2015. From 2019 to 2023 (July 2019, April 2020, June 2021, May 2022, August 2023), 30 articles were published, representing more than half of the articles selected. Moreover, these articles were sourced from 46 different journals. Notably, three articles were published in the IOP Conference Series: Earth and Environmental Science, three in the ISPRS International Journal of Geo-Information, and two in Land, with the remaining articles distributed across various other journals. Geographically, the regions of interest in these articles include Asia, Europe, Africa, and North America, with a predominant focus on Asia and Europe. The largest number of articles pertain to Asia, particularly the Middle East, South Asia, and Southeast Asia. Specific regions and countries studied include:

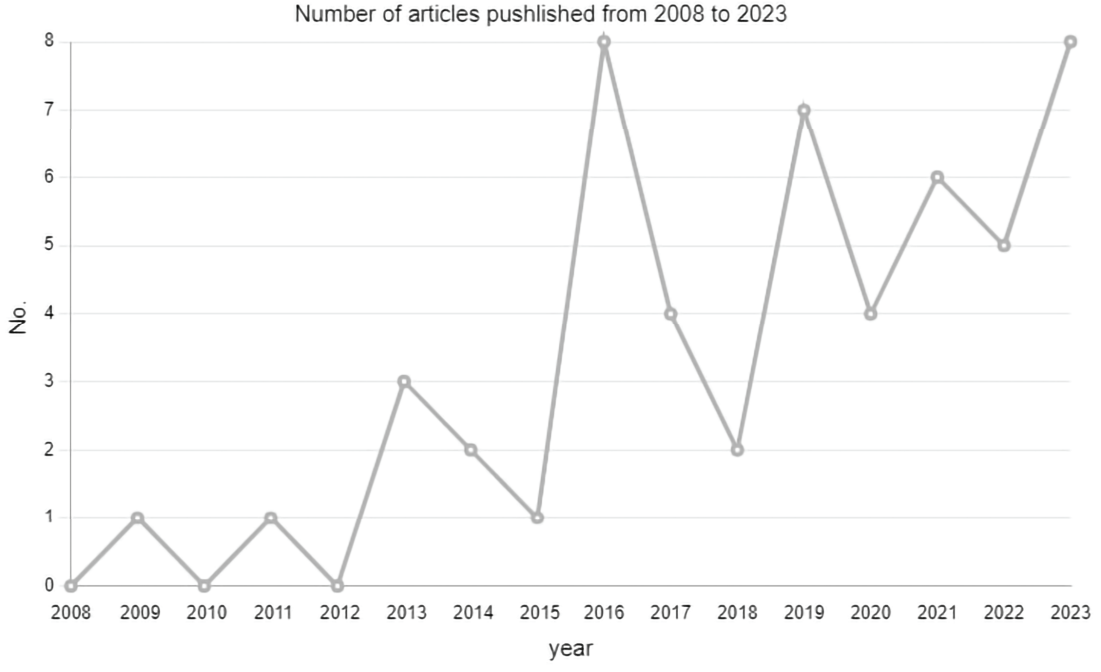

Figure 3. Number of publications from 2008 to 2023.

Middle East: Saudi Arabia (4 articles), Iraq (4 articles), Yemen, Bahrain, and Amman (1 article each).

- South Asia: Pakistan (5 articles), India (2 articles), and Bangladesh (2 articles).
- Southeast Asia: Malaysia (3 articles), the Philippines (2 articles), and Indonesia (2 articles).
- Southwest Asia: Iran (4 articles).
- In Europe, the articles cover several countries:
- Poland: 5 articles.
- Lithuania: 3 articles.
- Slovenia: 2 articles.
- Denmark, Turkey, and Romania: 1 article each.

In Africa, the research primarily focuses on Nigeria (2 articles) and Egypt (1 article). In North America, Colombia is represented by one article. Additionally, several articles do not

focus on a specific region. In general, the geographical distribution of the selected articles indicates that visual pollution is still predominantly observed in developing countries and underdeveloped regions. While developed countries are also affected by visual pollution, the number of articles on this topic is relatively low. This trend suggests that visual pollution may be a more pressing or visible issue in regions undergoing rapid urbanization and industrialization.

3.1. Types and Characteristics of Visual Pollutants

Undoubtedly, numerous studies [9,14–19,22–26,28,29,37–43] have identified OAs, including both printed and electronic billboards, as primary contributors to visual pollution in many countries across Asia, Europe, Africa, and North America mentioned in the previous Section 3.1. This pollutant detrimentally impacts ecological environments, human visual spaces, and human emotion and well-being. Key factors often attributed to this impact include billboards' size, material, appearance, and placement [17,19,28,29,44], with billboards' problematic content exacerbating this issue further [24]. Moreover, billboards' color content and cumulative area are also recognized factors that cause visual pollution [22]. Excessive proliferation of poorly designed or maintained billboards also intensifies visual pollution, detracting from the aesthetic quality of urban environments [23,45].

With the continuous expansion of the built environment, human activities introducing other forms of visual pollutants have become increasingly prevalent. The focus of attention on visual pollutants has also shifted from OA to other forms of pollutants. Such visual pollutants include other utility infrastructures and facilities almost exclusively in Asian countries—such as hanging wires, poles, broken roads, and mobile towers—adding to the landscape's visual degradation [10,12,13,16,31,32,35,44,46–52]. In particular, a study in Iraq [39] has noted that the militarization of society and the military machine has become a distinctive form of visual pollutants due to the conditions of war. Incineration facilities in Iran also disrupt urban landscapes by blocking views and degrading the aesthetic quality [48]. In addition, installing wind turbines near residential areas in Denmark has been shown to significantly detract from the visual appeal of the area and enjoyment for the residents [11]. The visual quality of roadways in Saudi Arabia is further diminished by excavation barriers, potholes, and deteriorated sidewalks [30,34]. Similarly, the accumulation of litter on the streets and the location of litter piles hurt the overall visual environment in India [50]. Interestingly, the characteristics of unmanned aerial vehicles, including dimensions, lights, color, quantity, and icons, can be perceived as visual influences and may be regarded as a form of visual pollution [53].

Building-related visual pollutants also play a crucial role in undermining urban aesthetics. Visual pollutants manifest as dilapidated or poorly managed buildings in Romania [54] and Yemen [55], façades lacking cohesion in color, material, shape, and height among adjacent structures in Middle-Eastern countries [8,33,36], and poorly planned or arranged buildings in Bahrain [13] and Turkey [7]. Moreover, new constructions that conflict with the traditional architectural character of the city and unregulated or inconsistently restored buildings exacerbate this visual disharmony [54]. It is important to acknowledge that another form of visual pollution, light pollution, is a significant issue in rapidly developing urban areas, arising from street lights, building façade lights, and billboard lights. In Egypt, light pollution manifests as sky glow, glare, and light trespass, which collectively contribute to visual problems in the nighttime environment [56].

New or modified landscape elements such as land surface mounds, excavations, structures, vegetation, water bodies, or significant increases in existing building volumes can change the landscape character in natural areas. For instance, in Lithuania, these changes have been shown to impact the visual experience of individuals who previously enjoyed the original natural scenery [20]. Similarly, in the rural areas of Malaysia, which are also more green, roadside settlements, commercial structures, mixed agricultural crops, and unmanaged vegetation are regarded as sources of visual pollution [57]. These alterations

may result in a less favorable experience for those who have previously enjoyed the original natural vision.

A study in Pakistan [44] has sought to identify types of visual pollutants based on the opinions of various experts. The majority of the visual pollutants have been discussed in previous content. It is also worth noting that some new pollutants are proposed, including graffiti/wall chalking, overflowing sewerage/drainage, and encroachments. In conclusion, visual pollutants can be defined as any elements that deviate from the established visual context, impairing the environment's overall visual appearance and quality.

3.2. Location of Visual Pollution

By the time humans became aware of visual pollution, this new pollution had silently infiltrated human and natural environments, presenting ubiquitous challenges across diverse settings—from urban landscapes to protected natural areas.

To some extent, urban areas [7,10,14,15,28,30,35,40,43–46,48,50,56,58] and their adjacent roadways [17–19,22,23,26,29,34,36,37] have become notably affected by visual pollution, impacting various zones within the city, particularly those that are developing or underdeveloped. However, Poland and Slovakia, both developed countries, also face notable instances of visual pollution. This issue is undeniable in densely populated areas where many billboards dominate the urban landscape, particularly on busy roads and intersections [18,19,25,26,34] and major city thoroughfares [17,23]. In Malaysia, commercial streets are particularly susceptible to deterioration and are often identified as hotspots for large-scale OA [22,37]. Similarly, not only do suburban areas on the outskirts encounter similar problems [24,31], but public spaces such as bus stops, schools, hospitals, and religious sites are also adversely affected by visual clutter [40,50]. These areas are typically cluttered with various forms of advertising, exacerbating the sense of visual overload and discomfort. Contemporary urban transformation along streets in Amman [33] and Romania [54] and squares in Iran [49] has also profoundly affected the visual perception of these places. Furthermore, historic districts and older urban areas suffer from visual pollution due to the deterioration of architectural integrity and the incongruent modifications within conservation areas [8,13,32,35,52,54,55,59], mainly focusing on developing or underdeveloped countries.

Highways in Lithuania represent another critical area where visual pollution is rampant [39,41], where excessive signage and advertisements detract from aesthetic appeal and pose safety risks. The construction and maintenance of these structures frequently necessitate alterations to the surrounding environment, leading to substantial ecological disturbances. Such impacts are of particular concern as they involve the modification of natural landscapes and the potential displacement of local flora and fauna.

Even protected areas in Poland and Slovakia are increasingly compromised by visual pollution stemming from tourism-related activities [9]. These OAs usually appear at major crossroads and entrances to tourism-related institutions, i.e., museums, accommodation, and catering facilities. This trend is exacerbated by the competitive placement of visually striking advertisements near businesses and tourist amenities within these areas, further disrupting the harmony and unity of the natural environment. Furthermore, natural areas are not immune to the effects of visual pollution in Lithuania [20]. These changes frequently reduce visual quality and obstruct views of valuable natural landscapes or features.

In conclusion, it can be seen that the disturbance of visual pollution is no longer restricted to any geographical area and requires comprehensive mitigation strategies to preserve both the built and natural environments effectively.

3.3. Factors Contributing to Visual Pollution

As detailed in Section 3.1, the widespread nature of OAs, characterized by their quantity, color, diverse content, and placements, significantly contributes to visual pollution. Additionally, inadequate management, maintenance, and development of utility infrastructures and buildings represent further sources of visual pollution. These elements are among

the most evident contributors to visual pollution. The underlying factors contributing to these causes can be discussed in the following areas.

First of all, economic factors could have the most significant impact on visual pollution, particularly when commercial interests prevail. Although they serve as a vital source of government revenue and alleviate financial burdens for local authorities [26], the economic benefits often present challenges in controlling visual pollution [13]. The influence of capital has propelled visual pollutants toward a state of a pollution-free environment [31]. For example, government entities often tacitly approve extensive private investments in public spaces, which results in these entities progressively dominating public spaces and reaping substantial profits by placing large volumes of their own company's OA, while neglecting the detrimental impacts on the urban environment [25]. Despite gradual improvements in regulations concerning billboard placements, the enforcement of these regulations by the relevant authorities remains inadequate. The primary reason for this shortfall is the necessity to balance the interests of multiple stakeholder groups, which can result in delays or dilution of enforcement actions [45].

Secondly, the understanding and awareness of visual pollution are critically low and are influenced by cultural and educational factors. According to Maslow's hierarchy of human needs, those fundamental to survival (physiological needs) take precedence over those more complex and abstract (cognitive and aesthetic needs) [29]. This tendency to prioritize basic needs over cognitive and aesthetic considerations leads to a general neglect of higher-order needs. For example, OA can generate income and provide information to meet people's basic needs, although acting as a form of visual pollution. In addition, studies [31] have posited that some individuals may not perceive OAs as a form of visual pollutants due to limited awareness of the concept itself. Perceptions of visual pollution are not uniform; it is a constantly changing environmental value dependent on the viewer's or perceived recipient's cultural and social context [33], underscoring the importance of aesthetic education. An interesting result from the study [37] in Malaysia has confirmed this view: even among aesthetically educated students, their sensitivity to visual pollution is very low, indicating a high tolerance.

Next, this lack of aesthetic education and awareness is also evident in the government's management practices concerning visual pollution. The reasons behind visual pollution encompass wrong decisions, lack of legal requirements, and lack of control [36,43,49]. In other words, a general lack of governmental awareness about the significance of visual pollution contributes to its persistence [16,55]. Especially in historic or old city districts, the government's indifferent, uncaring, and uninformed attitude toward visual pollution has resulted in the destruction, demolition, and alteration of ancient buildings [8,13,35,52,55]. Moreover, flawed regulations and standards within government advertising policies have led to significant visual pollution [9,14,38,39,41,50] and rapidly degrading natural landscapes and public spaces. This general lack of awareness extends to the public, who rarely communicate concerns about visual pollution to local authorities [31].

In summary, the phenomenon of visual pollution results from a complex interplay of economic constraints, cultural influences, and regulatory inefficiencies. The economic benefits of OAs frequently conflict with the necessity for visual cleanliness. Furthermore, cultural norms and educational deficiencies impede the recognition of and action against visual pollution on a broad scale. The effective management of visual pollution necessitates the robust enforcement of regulations, the promotion of public awareness, and the implementation of comprehensive educational initiatives. Therefore, it is essential to act on these factors to minimize the harmful implications of visual pollution and enhance visual ease in public settings.

3.4. Methods of Measurement for Visual Pollution

Current methods for measuring and defining visual pollution remain exploratory and lack a standardized method for effective quantification. Scholars have already tried and used various methodologies to address these challenges; however, these methods have

not been applied systematically and uniformly across studies [25]. This difficulty can be attributed to the inherent complexity of visual pollution, which requires strong background knowledge, enhanced environmental awareness, and a trained eye to identify discordant and chaotic elements that contribute to the disorder of the built environment [33]. Therefore, visual pollution assessment relies mainly on subjective evaluation [23].

Overall, methodologies for assessing visual pollution can be divided into three categories (Table 2):

- The first method is the desk-based synthesis method, which is based on examining existing literature, relevant laws, data, and regulations, supplemented by observations, photographs, and applicable software. It offers a comprehensive overview of the context within which visual pollution occurs.
- The second method is an integrated survey, interview, and analysis method, often supported by auxiliary methods to gather qualitative and quantitative data, such as photographic documentation.
- The third method is technology-based, employing specific artificial intelligence, indicators, and parameters with some software to analyze visual pollution more precisely. Utilizing technological tools could facilitate the effective quantification of visual pollution, offering objective measurements that reduce the reliance on subjective evaluation.

Table 2. The different methods that correspond to different studies.

•	**Methods**	•	**Studies**
•	Desk-based synthesis methods	•	[7–10,12,14,18,20,23,28,33,41–43,45,48,54,56]
•	Integrated survey, interview, and analysis methods	•	[9,13,15,17,19,24,25,30,35–37,40,44,46,47,49,50,53,55,57–59]
•	Technology-based methods	•	[11,26,29–31,34,38,39,60]

3.4.1. Desk-Based Synthesis Method

The desk-based synthesis method is a relatively straightforward process of analyzing visual pollution. This method is clearly and effectively illustrated in studies [8,9,12,18,33, 41,43,54,56], which comprehensively review relevant literature, documents, regulations, or data derived from fieldwork to define the concept of visual pollution and its impacts. Notably, studies [7–10,33,41,54] have further enhanced this methodology by integrating images and related data analysis.

Conversely, studies [14,42,48] have shown a different perspective by not specifying the measurement methodologies employed for assessing visual pollution. Instead, these studies mainly contribute to discussing visual pollution by exploring its impacts through document analysis that could inform the development and implementation of policy. A study [23] has also provided a comprehensive overview of the methodologies used by other researchers, offering a structured mechanism for quantifying visual pollution in a specific location.

Moreover, a study [20] has proposed a locally adapted method for the visual assessment of natural landscapes by analyzing the legal and theoretical frameworks for visual assessment and then applying logical analogies. Similarly, studies [28,45] have also suggested a spatial decision support system (SDSS) method to choose a suitable location for OA by reviewing regulatory documents and data and aided by software. Specifically, the study's methodology [28] represents further depth and refinement of the methodology employed in the study [45].

In general, the desk-based synthesis method is a more frequently employed method. This method offers a comprehensive, efficient, and adaptable framework for addressing visual pollution, particularly in the early research or policy development stages. However,

this method is inherently subjective and heavily reliant on the experience and knowledge of experts and practitioners on visual pollution. Consequently, it lacks the requisite objectivity.

3.4.2. Integrated Survey, Interview, and Analysis Methods

Surveys and interviews are frequently employed as prevalent methods for visual assessment. The assessment of visual impacts on environmental aesthetics, commonly referred to as visual pollution, is also often evaluated using these tools. Therefore, these tools are essential for a comprehensive understanding of visual pollution, given their widespread application in the field. Studies [13,17,19,24,36,40,46,50,55,58] have traditionally used single and direct surveys or interviews, often supplemented by photographs, to investigate visual pollution.

Based on these traditional methods, additional studies [9] have expanded their methodology to include both indirect and direct assessment techniques, such as landscape attribute inventories and response ratings (survey and interview). Studies [57,59] have considered using the Likert scale and heat maps to detect visual quality and identify visual elements. Moreover, a study [49] has progressed from data collection through to literature reviews and surveys. This process is further refined by applying the Analytic Hierarchy Process (AHP) for data weighting, followed by analysis using SWOT (strengths, weaknesses, opportunities, threats) and QSPM (quantitative strategic planning matrix) methods. Similarly, a study [44] has utilized a combination of methods, including a public survey, expert ranking, and the analytical hierarchy process (AHP) for the listing, classification, and weighting of visual pollution objects. Study [47] has facilitated the transition of study [44] from a paper-based visual pollution assessment tool to an online one. Study [53] has sought to ascertain public perceptions of visual pollution caused by drones in different environments and used the AHP to identify factors that may contribute to visual pollution from drones.

Further innovations have been introduced in studies [30,37], which employ systematic observation and rating of streetscapes through pictorial surveys, complemented by computer-assisted auditing and evaluation via image processing techniques. Additionally, studies [15,25,35] have integrated geographic information systems (GIS) into the survey framework, offering innovative methods to visualize and quantify visual pollution effectively. These creative methods improve the accuracy of data collection and analysis.

In the field of visual pollution research, questionnaires or interviews represent the most common and widely used method. This method offers a more reliable and quantitative means of gaining a more comprehensive understanding and explanation of visual pollution and visual pollutants. However, this method also presents certain challenges, including the necessity of collecting and processing data over a longer period.

3.4.3. Tech-Based Method

The technology-based method in visual pollution study represents a novel exploration and attempt to develop new perceptions and understandings of visual pollution. Studies [11,26] have applied modeling techniques, such as 3D isovist, voxel techniques, and digital surface models, to construct a model for assessing viewsheds and visibility to ascertain the visual impact of visual pollution. Study [29] has used raster products from aerial laser scanning data and viewshed measurements along pedestrian walkways to simulate cityscape visibility, scrutinizing landscape metrics for sensitivity to visual pollution and providing a quantifiable approach to assess the impact of billboards on landscape openness and visual character. Studies [38,39] have involved multiple phases, spatial analysis, and techniques to assess and manage visual pollution's visual and spatial impact. These studies effectively measure visual pollution spatially.

Moreover, studies [30,31,34,60] have utilized deep-learning models to train image data for the purposes of data labeling, data splitting, and the detection and classification of visual pollutants. A study [60] has used deep learning models, particularly YOLOv5, to detect and classify visual pollutants from images collected by volunteers. The collected data are analyzed to create heat maps and visual pollution indices. Study [30] has been

further deepened to fully train the prediction of visual pollution, and several emerging artificial predictors have been added and used, including MobileNetSSDv2, EfficientDet, Faster RCNN, Detectron2, YOLO-v7, and YOLOv5.

The technology-based approach is an evolving methodology aimed at understanding the impact of visual pollution on human vision through parametric and technological means to generate more precise data. At the same time, this method also seeks to develop models for identifying visual pollutants. However, the selection and recognition of visual pollutants within this framework still heavily rely on expert knowledge of visual pollution. Moreover, this method is inherently complex and detailed, necessitating a high level of expertise for successful implementation, and is often time-consuming.

4. Discussion

Visual pollution is a new environmental problem that emerges within the visual environment. The phenomenon of visual pollution has the capacity to influence how humans perceive their surroundings significantly. This study is a comprehensive and systematic literature review of 52 articles on visual pollution, focusing on four key aspects: type and characteristic, location, factors, and research methods. Analyzing these aspects can deepen the knowledge and awareness of visual pollution. Specifically, the study helps identify the various types of visual pollutants, map their locations, understand their contributing factors, and evaluate the research methods used. Ultimately, this study could help provide valuable references and assistance to policymakers to mitigate visual pollution's negative impacts on urban and natural environments, contributing to more effective environmental management and policy development.

When humans occupy more land than ever, cities and towns in developing and developed countries are strewn with undesired and unpleasant visual items called visual pollutants [31]. These pollutants are a consequence of human activities, leading to a pervasive phenomenon that affects not only the visual environment but also human experiences, daily life, and health. The type of visual pollution has significantly expanded from billboards, other structures and infrastructures, and the design problems of buildings to certain natural elements. Common visual pollutants in the urban landscape include OA, signage, and certain facilities and infrastructures, especially when they are out of character with the overall environment [22]. Additionally, visual pollutants arise from the unregulated and disorganized diversity of colors, shapes, light, and materials [26]. Accumulating disparate visual components creates unsightly and distasteful artificial environments and urban landscapes. This phenomenon means that visual pollution frequently causes landscape components to be out of harmony with their surroundings and is difficult to incorporate into the built environment.

Urban areas' rapid and uncontrolled expansion has resulted in various social issues and unregulated physical growth [17]. One notable consequence is the emergence of visual pollution, particularly in cities' commercial centers, the most popular and pervasive location for visual pollution. Visual pollution has become an integral part of the urban landscape in these areas, with some OAs even transforming specific spots into landmarks. However, a study [17] has found that OA has more negative than positive impacts as it reduces the aesthetics of urban environments, clutters public spaces, and detracts from a city's character. Furthermore, visual pollution is not confined to modern commercial areas; it is also prevalent in older urban areas, historical sites, and natural landscapes. This widespread presence underscores the far-reaching consequences of urbanization, which extend beyond a city's immediate boundaries and significantly influence human and natural environments. Visual pollution can lead to the erosion of the character and cultural identity of these places, emphasizing the urgent need for comprehensive urban planning and stringent regulatory measures.

The level of visual pollution seems to be closely linked to socio-economic status, educational and awareness level, government administration, etc. Due to the authorities' unawareness of visual pollution, the reason for economic development, and the lack of

relevant studies to mitigate this issue, visual pollution has become widespread. Vague regulations provide advertisers and business people with opportunities to install OAs indiscriminately. A surprising phenomenon demonstrates rapidly growing economies, service industries, the private sector, and the spread of consumer social models, particularly in post-communist countries, all led to the rapid deterioration of natural and landscape assets and public space, accompanied by visual pollution [9]. The economic transformation in these regions has boosted market consumption and fueled the advertising industry's fervor, resulting in the construction of numerous OAs [25]. This issue is especially pronounced in emerging capital markets, where governments have relaxed billboard restrictions and regulations. In reality, practically every business advertises its products in numerous ways, but these advertisements can easily cause visual pollution when they are not effectively controlled. Advertisers often erect more OAs in the busiest parts of town in pursuit of greater profits, further exacerbating the problem. Ultimately, to some extent, the most important cause of visual pollution is the economy.

Visual pollution is still largely dependent on public taste and culture. People have limited comprehension of visual pollution due to a lack of studies to define, analyze, and quantify it, resulting in an imprecise presentation [32]. Despite efforts to update and develop new assessment methods, limitations still exist [25]. When using quantitative methods to assess visual pollution, it is important to note that many results are subjective due to the lack of a primary assessment scale. Although a combination of subjective and objective approaches exists, the final evaluation of visual pollution consistently relies on subjective decisions [23]. Different countries have varying attitudes towards visual pollution because they attempt to develop a scientific method to identify it [28]. However, these methods often have limitations and shortcomings, such as dependence on subjective evaluations, restricted scope of visual pollution objects, lack of quantification, and inadequate planning tools [44]. The absence of relevant administrative norms and guidance exacerbates these challenges, as governments often prioritize economic interests over environmental aesthetics. Therefore, there is a growing recognition of the need for comprehensive quantitative assessment tools to evaluate visual pollution. To address these challenges effectively, comprehensive strategies must be proposed and implemented to ensure a balanced approach to measuring and managing visual pollution across diverse environments.

5. Limitations and Future Studies

Even though this study systematically reviews visual pollution research, there are some limitations. Firstly, it should be noted that the methodology employed in the literature search and the selection of databases may have omitted certain studies from the final analysis. The search was limited to English publications, thereby excluding relevant studies in other languages. In the future, we could expand literature searches to include studies published in various languages. Utilizing international databases and translating key studies could provide a more global perspective on visual pollution, enriching the overall analysis.

Secondly, the scope of the review was constrained by the selected timeframe of publications, which spanned from 2008 to 2023. The temporal limitation may result in excluding relevant studies conducted before the specified period, which could provide valuable insights into the historical context and evolution of visual pollution. In future studies, a snowballing approach could be employed to expand the existing literature that does not fall within the specified timeframe. This would entail including additional articles that have been overlooked in previous studies.

Thirdly, this study primarily employs qualitative analysis, with the absence of quantitative analysis being a notable limitation. Future studies should incorporate more sophisticated quantitative methods to provide a more comprehensive understanding of visual pollution and strengthen the findings, such as meta-analysis. Overall, it would be beneficial to address the limitations identified in future studies to gain a more comprehensive understanding of visual pollution.

In order to inform future research on visual pollution, it is recommended that empirical studies and fieldwork be conducted to collect primary data on visual pollution. This may entail administering surveys, direct observation, and using technology-based tools (e.g., GIS, remote sensing) to quantify visual pollution in diverse environmental contexts accurately. The development and utilization of advanced technological tools will facilitate the identification and measuring of visual pollutants. This may include utilizing machine learning algorithms, augmented reality (AR) applications, and virtual reality (VR) simulations to more effectively assess and visualize the impacts of visual pollution. It is necessary to review the effectiveness of existing policies and regulations related to visual pollution. Comparative studies between different regions and countries can identify best practices and areas for improvement, thereby guiding the development of more effective regulatory frameworks. Longitudinal studies should be conducted to track changes in visual pollution over time and assess mitigation strategies' effectiveness over time. Such studies assist in comprehending the dynamic nature of visual pollution and the sustainability of interventions. It is necessary to investigate the role of public awareness and education in mitigating visual pollution. It would be beneficial for research to investigate the impact of educational activities and community participation on perceptions and behaviors related to visual pollution.

6. Conclusions

In conclusion, visual pollution has emerged as a significant environmental issue due to rapid and uncontrolled urban expansion, leading to a variety of social and aesthetic challenges. It is not merely an aesthetic concern but also impacts mental health, contributing to anxiety, stress, and a reduced quality of life. This study offers a comprehensive review of 52 articles that examine the characteristics of visual pollution, its location, the factors contributing to the phenomenon, and the methodologies employed in assessing it. Key visual pollutants include outdoor advertisements, poorly maintained buildings, and unregulated utility infrastructures, which disrupt the harmony between urban and natural landscapes. The fact that busy city centers and surrounding streets, and even nature conservation, are occupied by visual pollutants indicates that there is still a lack of effective regulation and strong enforcement of the management of visual pollutants. Furthermore, the government and the public's lack of understanding of the concept of visual pollution has resulted in the emergence of visual pollution, which has been justified on the grounds of economic interests. The exploration of visual pollution is still in its infancy. The desk synthesis method represents a rapid and effective approach to defining and evaluating visual pollution from a professional perspective. However, its scope is limited. In contrast, scholars continue to favor using questionnaires as a relatively objective means of identifying visual pollution from the general public's perspective. While there are some more objective and technology-oriented methods, the majority still rely on the selection of visual pollutants by professionals, and the majority of them are also utilized in the automatic screening of visual pollutants.

Overall, by providing a comprehensive analysis of the current state of visual pollution and its impacts, this study aims to equip policymakers, urban planners, and environmental professionals with the necessary insights to develop and implement effective strategies to mitigate visual pollution. This, in turn, will help protect the visual quality of both urban and natural environments, ensuring a more aesthetically pleasing and mentally healthy living space for all.

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Appendix A

Table A1. Summary table of all 41 documents.

Ref. No. (No.)	Year	Document	Journal	Types of Visual Pollutants	Location of Visual Pollution	Factors Affecting Visual Pollution	Methods of Measurement for Visual Pollution
[7] 1	2011	Research	Asian Soc. Sci.	Buildings	City (Turkey)	Rapid and unplanned urbanization	Collecting theoretical information on the establishment and historical development of Trabzon
[8] 2	2021	Research	J. Umm Al-Qura Univ. Eng. Archit.	Poor façade design elements	Jeddah, with a specific focus on 70 streets in the northern and western zones of the city (Saudi Arabia)	A lack of detailed regulations: improper consideration of design elements among adjacent buildings, a lack of uniformity and harmony among buildings	Use of data analysis software (NVivo) to assess the implementation of design elements
[9] 3	2019	Research	Quaest. Geogr.	Large-format advertise-ments	Protected areas (Poland and Slovakia)	Presence of outdoor advertisements in settlements and at significant road points, entrances to tourism-related facilities, and the placement of advertisements in landscape areas	Field research on the number and size of advertisements, cartographic illustrations, and photographic documentation
[10] 4	2009	Research	J. Vis. Art Des.	Utility infras-tructures, graffiti, shopfront graphic designs, packaging designs, automobiles	Urban areas (Indonesia)	Lack of proper urban planning, regulation, and visual standards	Using descriptive analysis to document the presence and impact of visual pollutants, involving field observations, photographic documentation, and the analysis of design processes

Table A1. *Cont.*

Ref. No. (No.)	Year	Document	Journal	Types of Visual Pollutants	Location of Visual Pollution	Factors Affecting Visual Pollution	Methods of Measurement for Visual Pollution
[11] 5	2014	Research	Land Econ.	Wind turbines	Residential areas (Denmark)	Presence of wind turbines within a visible range of residential properties	Using high-resolution digital surface models (DSM) to construct viewsheds for wind turbines and calculate visibility from residential properties
[12] 6	2021	Research	Int. J. Adv. Appl. Sci.	Utility infrastructures, buildings, and vehicles	Related to roads (Saudi Arabia)	Lack of proper management by local administrations	Descriptive analysis
[13] 7	2019	Research	J. Contemp. Urban Aff.	Utility infrastructures	Od district (Bahrain)	Unregulated urban expansion, lack of adherence to architectural and urban planning standards, neglect of heritage buildings, and the proliferation of modern structures that clash with the historical character of the area	Theoretical background review, data collection through surveys interviewing users, residents, businessmen, and municipality officers
[14] 8	2023	Research	Pollut. Bull.	Billboards, banners, posters, and signs	Coastal cities (Colombia)	Unrestricted use of political advertisements, psychological stress from visual clutter, road safety hazards, sociocultural ramifications, and economic impacts	Not detailed specific methods of measurement for visual pollution, discussing the impact of visual pollution, and proposing mitigation strategies
[15] 9	2018	Research	Comput. Environ. Urban Syst.	Outdoor advertisements	Visual pollutants in the urban landscape (Poland)	Clustering, excess, disorder of outdoor advertising media and the lack of administrative guidance in signage control	A citizen science approach where participants use a WebGIS application to submit their observations and assessments of visual pollution due to outdoor advertising

Table A1. *Cont.*

Ref. No. (No.)	Year	Document	Journal	Types of Visual Pollutants	Location of Visual Pollution	Factors Affecting Visual Pollution	Methods of Measurement for Visual Pollution
[16] 10	2017	Research	Sch. Res. J. Interdiscip. Res.	Utility infrastructures	Urban environments where man-made elements obstruct natural views	Local authorities lack control over public displays and constructions, overcrowded advertisements that suffocate natural beauty, and individual negligence toward maintaining a natural environment	Not detailed specific methods of measurement for visual pollution
[17] 11	2023	Conference paper	IOP Conf. Ser. Earth Environ. Sci.	Advertising boards	Corridor of M.T Haryono Street in Kendari City (Indonesia)	Overlapping and unclear layout of advertising boards, the lack of communicative design, and the absence of unity with the architectural characteristics of surrounding buildings	Observations, photography, and surveys with questionnaires distributed to respondents
[18] 12	2023	Conference paper	Transp. Res. Procedia.	Large-format outdoor advertising and its impact	Four routes within the city (Slovakia)	Density of advertisements, their placement relative to drivers' viewpoints, and the content of the ads	Collecting data on the owners of advertising carriers, types of carriers, and content of advertisements
[19] 13	2016	Research	Int. J. Sci. Eng. Res.	Outdoor advertisements	Roadside (Pakistan)	Billboards, including their size, placement, and the explicit content they sometimes display	Survey exploring various aspects, such as the impact of billboards on road safety, environmental concerns, and the physical discomfort they cause
[20] 14	2016	Research	J. Sustain. Archit. Civ. Eng.	Any new or modified landscape elements	Natural areas (Lithuania)	Physical and visual characteristics of potential visual pollution objects, their function and style, and how they contrast with the existing landscape	Preparatory work to describe the observation place and landscape, photo-fixation, and a general evaluation of the landscape

Table A1. *Cont.*

Ref. No. (No.)	Year	Document	Journal	Types of Visual Pollutants	Location of Visual Pollution	Factors Affecting Visual Pollution	Methods of Measurement for Visual Pollution
[22] 15	2022	Research	ISPRS Int. J. Geo-Inf.	Outdoor advertisements	A prominent street (Malaysia)	Abundance and color content of outdoor advertisements	A user-centered assessment approach, utilizing systematic observation and rating of streetscapes through pictorial surveys, and computer-assisted auditing and evaluation through image processing techniques
[23] 16	2022	Conference paper	IOP Conf. Ser. Earth Environ. Sci.	Billboards	Urban roads	Improper planning and technical standards in billboard construction, lack of continuous maintenance and supervision during installation	Describing several methods for measuring visual pollution levels
[24] 17	2020	Research	Hum. Aff.	Outdoor billboards	Different parts of the city (city center and outskirts)	Amateur design and inauthentic content of billboards, stereotypical representations, and the overall negative portrayal of urban decay	Free associations produced by art students in response to photographs of outdoor billboards from different city areas
[25] 18	2016	Research	Geogr. Inf. Syst.	Outdoor advertisements	Busy urban streets (Poland)	Spatial properties of outdoor advertisements, such as their location, shape, and size	Creating an inventory of OAs, conducting intervisibility analysis using GIS technology, and carrying out public surveys to gather opinions on visual pollution
[26] 19	2021	Research	ISPRS Int. J. Geo-Inf.	Outdoor advertising billboards	Roads (Poland)	Location, quantity, and spatial dimensions of the billboard infrastructure	3D isovist and voxel techniques to assess the visual impact of billboard infrastructure

Table A1. *Cont.*

Ref. No. (No.)	Year	Document	Journal	Types of Visual Pollutants	Location of Visual Pollution	Factors Affecting Visual Pollution	Methods of Measurement for Visual Pollution
[28] 20	2021	Research	ISPRS Int. J. Geo-Inf.	Outdoor advertisements	Urban settings (Pakistan)	A complex interplay of legal, marketing, and ethical considerations and the need for advertisements to reach relevant community groups effectively	User-specific criteria for either multilayered query selection or a fuzzy analytic hierarchy process
[29] 21	2020	Research	Land	Outdoor advertisements	Different topographical roads (Poland)	Spatial occurrence and density of outdoor advertisements in cityscapes	Using raster products derived from aerial laser scanning data to simulate the visibility of the cityscape in motion through viewshed measurements along pedestrian walkways
[30] 22	2022	Research	Math.	Utility infrastructures	Public roads (Saudi Arabia)	Incessant construction of new buildings, the inevitable deterioration of asphalt roads and sidewalks, and even weather conditions	A deep active learning model
[31] 23	2019	Research	J. Environ. Manag.	Utility infrastructures	Urban and suburban settings (Bangladesh)	Presence of poorly designed structures, excessive and misplaced advertisements, unmanaged wires and cables, and the accumulation of street litter	A convolutional neural network (CNN), a deep learning model
[32] 24	2021	Research	J. Perlind. Tanam. Indones.	Utility infrastructures	Area of Intramuros (Philipin)	Rapid urbanization	Use of indirect and direct methods of landscape evaluation, correlation analysis

Table A1. *Cont.*

Ref. No. (No.)	Year	Document	Journal	Types of Visual Pollutants	Location of Visual Pollution	Factors Affecting Visual Pollution	Methods of Measurement for Visual Pollution
[33] 25	2018	Research	Res. J. Appl. Sci.	Discordant facades, a lack of architectural unity, and the presence of various elements that clash with each other	Al-Madina Al-Munawara Corridor (Amman)	Undefined architectural statements	A multi-disciplinary approach
[34] 26	2023	Research	DIB.	Utility infras-tructures	Urban public roads (Saudi Arabia)	Lack of consistent rules for its systematic assessment	A deep active learning strategy for automatic data annotation
[35] 27	2016	Research	Open J. Geol.	Unattractive and man-made elements that clutter urban spaces	Historical gardens (Iran)	Mismanagement of urban and public spaces	Literature review, field studies, GIS analysis, and surveys
[36] 28	2023	Conference paper	AIP Conf.	Buildings	Commercial street (Iraq)	Poor enforcement of construction laws and regulations, unauthorized building modifications, and lack of accountability for violators	A descriptive and analytical methodology, including field visits and personal interviews with specialists and residents
[37] 29	2019	Conference paper	In Proceedings of the Visual Resource Stewardship Conference, Lemont, IL, USA	Advertising boards	Jalan Tuanku Abdul Rahman (Malaysia)	Density and cumulative area of advertising boards, demographic variables, and the respondents' regular exposure to pollutants in the urban environment	Cumulative area analysis and a photo booklet survey
[38] 30	2017	Conference paper	In Proceedings of the 2017 12th International Workshop on Semantic and Social Media Adaptation and Personal-ization (SMAP), Bratislava, Slovakia	Advertising media	No details mentioned Urban environment	Weak enforcement of rules, lack of rules, low public interest, and weak involvement of authorities	Crowdsourcing and visual similarity clustering

Table A1. *Cont.*

Ref. No. (No.)	Year	Document	Journal	Types of Visual Pollutants	Location of Visual Pollution	Factors Affecting Visual Pollution	Methods of Measurement for Visual Pollution
[39] 31	2016	Research	Archit. Urban Plan.	Free-standing billboards	Main highways (Lithuania)	Lack of strict regulation and control over free-standing billboard construction	Analysis of landscape spatial structure, free-standing billboard layout possibilities, and the establishment of possible visual contrast levels of free-standing billboard
[40] 32	2014	Research	IOSR J. Humanit. Soc. Sci.	Posters, banners, and billboards	Three senatorial districts of Ondo State, Nigeria (Nigeria)	High generation of visual pollutants by politicians, religious bodies, and corporate bodies without adequate measures for their removal post-usage	Surveys using structured questionnaires to gather data on the sources of posters
[41] 33	2013	Research	Eineerinviron. Res. Eng.	Free-standing billboards	Major highways (Lithuania)	Lack of regulatory documents	Literature analysis and field surveys to inventory free-standing billboards and assess their impact on different functional and visual types of the landscape
[42] 34	2013	Research	Int. J. Educ. Res.	Signs and billboards	Urban areas (Nigeria)	Administrative negligence, economic constraints, cultural and educational levels	Surveys and reviews of urban planning and environmental beautification efforts to gather data and propose solutions
[43] 35	2016	Research	Int. J. Eng. Res. Gen. Sci.	Poorly designed and located signage, posters, billboards, and banners	Marketplaces and urban tourist attraction spots (India)	Negligence by municipal authorities, business-oriented development, lack of proper urban planning and control	Suggesting several methods to measure and mitigate visual pollution

Table A1. *Cont.*

Ref. No. (No.)	Year	Document	Journal	Types of Visual Pollutants	Location of Visual Pollution	Factors Affecting Visual Pollution	Methods of Measurement for Visual Pollution
[44] 36	2019	Research	Sustainability.	Utility infrastructures	Urban areas (Pakistan)	Physical presence and characteristics of various visual pollution objects	A combination of methods, including public opinion, expert ranking, and the analytical hierarchy process (AHP) for the listing, classification, and weighting of visual pollution objects
[45] 37	2016	Conference paper	IOP Conf. Ser. Earth Environ. Sci.	Outdoor advertisement	Urban areas (Pakistan)	Corporate pressure and the absence of spatial analysis capacity among local authorities for effective implementation of regulations	Reviewing regulatory documents for spatial provisions, preparing geo-data, and performing site suitability analysis using analytical hierarchy process (AHP) and weighted linear combination (WLC)
[46] 38	2019	Research	Anthropog. Pollut.	Utility infrastructures	Urban districts (Iran)	Incompatible buildings and lack of urban planning, unregulated advertisements and commercial signage, overcrowded areas with heavy traffic and insufficient parking, and socio-economic factors	Surveys and direct observations of visual pollutants
[47] 39	2019	Reviewed paper	In Proceedings of the Real Corp 2019 Proceedings	Utility infrastructures	Urban areas (Pakistan)	Disorderly accumulation of visual pollution object	Utilizing open data kit (ODK) for developing a mobile-based tool for data collection via Android devices

Table A1. *Cont.*

Ref. No. (No.)	Year	Document	Journal	Types of Visual Pollutants	Location of Visual Pollution	Factors Affecting Visual Pollution	Methods of Measurement for Visual Pollution
[48] 40	2017	Research	Uncertain Supply Chain Manag.	Waste collection trucks, undesirable facilities including landfills and incineration facilities, and the traffic effects	City (Iran)	Physical presence of waste management facilities and the associated traffic	Not detailed specific methods of measurement for visual pollution, the document mentions the development of a multi-objective optimization problem
[49] 41	2017	Research	Pollution.	Shadows or uniform black paintings observable as the physical structures' shadows, outdoor advertisements, cluttered street furniture, and inappropriate use of colors and lighting	Squares (Iran)	Overall messy units observed in natural or man-made environments	Use of SWOT (strengths, weaknesses, opportunities, and threats) and QSPM (quantitative strategic planning matrix)
[50] 42	2015	Research	Eur. Sci. J.	Utility infrastructures	Urban and suburban areas (India)	Administrative negligence	Documentation through photography to capture visual pollutants, surveys with structured questionnaires
[51] 43	2013	Research	J. Eng.	Utility infrastructures	Main streets (Iraq)	Administrative and management issues, economic reasons, and cultural and educational levels	Questionnaires
[52] 44	2021	Research	Int. J. Manag. Rev.	Utility infrastructures	Roads (Philipin)	Lack of proper urban planning, the commercial-ization of public spaces, and inadequate enforcement of city ordinances	Indirect and direct assessments, which included surveys, landscape attribute inventories, response ratings, and interviews

Table A1. *Cont.*

Ref. No. (No.)	Year	Document	Journal	Types of Visual Pollutants	Location of Visual Pollution	Factors Affecting Visual Pollution	Methods of Measurement for Visual Pollution
[53] 45	2023	Research	Drones	Unmanned aerial vehicles	Observable characteristics of unmanned aerial vehicles, such as dimensions, lights, color, and icons	Number, distance, purpose of unmanned aerial vehicles, and awareness of unmanned aerial vehicles' route	An image-based questionnaire to gather data on public perceptions of visual pollution from unmanned aerial vehicles
[54] 46	2016	Research	Procedia Environ. Sci.	Abandoned buildings	Bucharest's Old City (Romania)	Urban transformations during the communist period, lack of authorities' involvement post-1990 in preserving buildings, illegal demolitions, incorrect restorations, and the gradual degradation of buildings	Historical and legislative research, field research, economic data analysis, and classification of creative industries
[55] 47	2020	Conference paper	In Proceedings of the International Workshop on Green Energy, Environment and Sustainable Develop-ment, Weihai, China	New constructions	Historical city (Yemen)	Use of modern building materials and techniques, lack of awareness and supervision by competent authorities, economic constraints, and the cultural and social disposition towards historical preservation vs. modernization needs	Surveys for direct observation and classification of visual distortions and interviews with residents, visitors, and officials
[56] 48	2020	Conference paper	Springer	Sky glow, glare, light trespass	Light pollution (Egypt)	Urbanization and economic development	Literature review, satellite imagery, GIS models, comparative analysis
[57] 49	2023	Research	Land	Roadside settlements, commercial structures, mixed agricultural crops, and unmanaged vegetation	Rural road (Malaysia)	Human-made structures	A combination of public preference surveys and heatmap analysis

Table A1. *Cont.*

Ref. No. (No.)	Year	Document	Journal	Types of Visual Pollutants	Location of Visual Pollution	Factors Affecting Visual Pollution	Methods of Measurement for Visual Pollution
[58] 50	2022	Research	Anfusina	Utility infrastructures	City (Iraq)	Lack of proper urban planning and regulatory enforcement, economic constraints leading to unregulated and poorly managed constructions, and public negligence and lack of environmental awareness	Descriptive and field studies to document and analyze the presence of visual pollutants
[59] 51	2022	Research	Heritage	Historical building	Baghdad's historical old town (Iraq)	Not mentioned	Heatmap analysis

Notes: The name of the journal is an ISO4 abbreviation.

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Identifying Visual Quality of Rural Road Landscape Character by Using Public Preference and Heatmap Analysis in Sabak Bernam, Malaysia

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Abstract: The rural road landscape is crucial in forming rural areas' landscape character (LC). As a platform for portraying the rural landscape, the rural roads demonstrate the area's unique natural and cultural characteristics to visitors. However, with the continuous development of rural areas, the rural LC has been severely impacted, thus impacting visitors' visual experience. In order to preserve and protect the rural landscape, this study aims to assess the visual quality of rural road landscapes based on public preference and heatmap analysis. The results indicated that most of the participants had a higher level of preference for rural landscapes with open horizontal views represented by agricultural areas, such as paddy fields. It was also found that different paddy field characters based on their planting stages can also positively affect the visual quality of rural road landscapes. The study also revealed that rural LCs with roadside settlements, commercial structures, mixed agricultural crops, and vegetation received low preference ratings. These characters negatively impact the visual quality of the rural road landscape. These findings provide significant insight for planners and decision-makers regarding protecting and preserving the essential rural road landscapes for the rural tourism experience.

Keywords: rural road landscape; landscape character; landscape visual quality; rural tourism experience

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1. Introduction

Rural regions have very distinct landscape patterns due to the effect of the region's natural beauty, the style and form of the local architecture, and local cultural aspects [1]. In other words, the rural landscape is a particular sort of landscape that uses the countryside as the focal point and is characterized by a unique landscape [2]. The rural roads' landscape characteristics typically consist of various land cover types, landforms, land use, rural historical sites, and artistic features [3]. As an essential component of the rural road, the rural plays a crucial role in the scenic experience in the local tourism industry [4]. Rural roads not only serve as vital connectors between communities but also as potential tourist routes for rural life experiences, scenic landscapes tours, and other relevant tourist attractions [5]. To some extent, the rural road landscape could be considered a valuable resource that can be used to promote and enhance local tourism activities. It can provide visitors a quick, easy, safe, and scenic experience to explore the countryside. Studies have shown that the rural roads' landscapes could provide travelers with a positive experience through rural scenery and local cultural engagement [6–8].

However, in recent decades, rapid development and urban sprawl have changed and threatened the landscape's appearance in rural areas [9,10]. Although the modernization processes have improved the living quality and enhanced basic facilities in the

rural environment, they have also altered the appearance of the rural landscape [11,12]. Primdahl et al. [13] have identified that these changes are perceived as a threat, a harmful development that could damage the richness and distinctiveness of the original landscape. Changes in nature and the original appearance of the landscape in rural areas, without reasonable control, may lead to a decrease in the visual quality of the rural landscape [1,14]. Meanwhile, the change of land in rural areas has accelerated the process of fragmentation of the rural landscape, further generating negative impacts on the characteristics and affecting visual comfort in rural areas [15,16]. These changes may also decrease rural population satisfaction and a reduction in the usefulness of the landscape [17]. Many countries also emphasize the significance of protecting cultural and natural landscapes in response to development pressure [18]. Because of the numerous environmental changes related to these pressures, the idea of LC has been expanded to embrace not just extraordinary landscapes but also typical daily landscapes [19]. Therefore, nowadays, it can be seen that the awareness in the preservation of the original form of the landscape has received more attention and become particularly important.

Literature Review

Landscape character (LC) is defined as "a distinct, recognizable, and consistent pattern of elements in the landscape that makes one landscape different from another, rather than better or worse" [20]. The physical elements of the scene vary from one another, and bringing them together in one distinctive scene is known as "character" [21]. Koç and Yılmaz [22] have highlighted that LC could be seen as a notion and a process of differentiation based on its diversity, organization, and layout, ultimately providing each area a distinct personality that distinguishes it from the surrounding landscape. Each LC area is made up of a unique set of variables that reflect the landscape's overall characteristics. LC may be defined as the landscape's overall expression, which is reflected in several features, such as natural, cultural, visual, or symbolic. The quantification of LC as an indicator could describe and identify the scene, further measuring human preferences using visual quality [23]. Nonetheless, nature and culture are the most fundamental in defining LC. For instance, Simensen et al. [24] pointed out that the natural and cultural character of the landscapes has been included as an essential factor within the landscape character assessment (LCA) framework. LCA is a collection of tools and processes used to classify and describe landscapes, as well as to comprehend and convert the evolution of their physical and cultural traits into the development of the related management or planning policy [25]. As a result, LCA lays the groundwork for several policies to balance the contradictions that arise when multiple sectors use landscape resources [26].

Landscapes' visual quality is determined by how an observer values the elements of the surrounding environment through their perception, emotional and psychological processes [27]. The landscape's visual quality is based on the perceptual interaction between visitors and the landscape; hence, it can be subjectively quantified [28,29]. In contrast, some studies consider the landscape's visual quality as dependent on the intrinsic characteristics of the environment [30]. Therefore, the visual quality of a landscape could be seen as coming from two primary sources: one is the elements and combinations of the landscape itself, while the other is the observer's perception and perception of the landscape [14]. The first approach evaluates both the intensity of the characteristics and the objective and inherent beauty of the landscape itself [31,32]. These aspects can be evaluated quantitatively based on their physical or aesthetic components or other factors [33]. However, this approach ignores the observer's subjective feelings, personal preferences, and psychological components, i.e., it leaves out the underlying hidden qualities of the landscape [34]. The second is a more intuitive way of assessing the landscape, using respondents' preferences for the landscape, which means that each person needs to incorporate their understanding of the landscape into the assessment to reach a consensus [35]. Furthermore, certain authors have proposed a fusion of the two approaches [36,37], modifying the emphasis on integrating them based on practical considerations and aiming to establish a clearer relationship be-

tween landscape elements and the observer [38–41]. Therefore, landscape character and visual quality are essential to comprehending and assessing landscapes. However, their application requires careful consideration of the integration of objective and subjective assessments and the incorporation of different dimensions. Adopting a multidisciplinary approach encompassing diverse perspectives and disciplines can contribute to a more comprehensive and robust understanding of landscapes.

In Malaysia, rural-tourism-related projects have been progressing in recent years, with predominantly agricultural and agrarian tourism becoming popular, and the revenue from tourism gradually increasing [1]. However, along with development and other influences, the visual experience of Malaysia's rural landscape has declined [42]. During this time, large portions of the rural population migrated to the city, resulting in a loss of cultural identity that may impact how the rural LC develops [13]. Hence, Malaysia's rural visual experience and quality have become increasingly bleak. As mentioned earlier, the rural road is a significant component of rural areas and could indicate a place's identity. It not only provides visitors with a taste of the local conditions or culture as they pass through but could also allow emotional attachment to the rural landscapes. Hence, the rural road landscapes' visual quality has become a significant factor that can impact people's experience. However, in Malaysia, only a few studies have focused on the visual aspect of rural road landscapes, leading to poor understanding among the decision-makers regarding its importance and future protection. Therefore, this study has three aims:

1. To classify and identify types of rural road LCs in Sabak Bernam in Malaysia;
2. To identify public preferences towards the visual quality based on rural road LCs in Sabak Bernam in Malaysia;
3. To identify preferred rural road landscape elements and socio-demographic factors that affect the preferences of rural road landscapes in Sabak Bernam, Malaysia.

2. Materials and Methods

2.1. Study Area

The proposed study area is located within the Sabak Bernam district on the Malaysian Peninsula's west coast. It borders Lower Perak District, Perak, to the north, the District of Kuala Selangor to the south, and the upper Hulu District to the east. It takes approximately 2 h of travel from Kuala Lumpur, the capital of Malaysia, to the study area. The majority of the district land areas are occupied by agriculture (47%) and forestry (40.18%), with less than 5% of the land being settlements and known as one of Malaysia's major rice producer areas. Ibrahim et al. [43] mention that the road from Kuala Selangor to Sabak Bernam in the Malaysian government's planning could be an attractive tourism route demonstrating the local rural landscape, such as culture, heritage, paddy fields, rural settlements, and tourist attractions. In addition to this, the related tourist services are relatively well equipped within the area. However, due to the conversion of paddy fields into commodity crops, housing, commercial and industrial, the acreage of paddy fields in Sabak Bernam has decreased over the past ten years, dropping from 26,645 hectares in 2000 to 13,375 hectares in 2013. Fortunately, due to food security and supply concerns, the government has recently started adopting measures and policies to protect the paddy field areas.

As one of the small towns in the district of Sabak Bernam, Sungai Besar, an area that retains its charms of rural character with traditional Malay architecture of "kampung houses", vast areas of paddy fields and coconut plantations [44]. Sungai Besar is also well renowned for its homestay programs, which continue to preserve the rural way of life for tourists to enjoy. This study was specifically conducted on the rural road in Sungai Besar, starting from the junction of Jalan Sungai Panjang and Jalan Parit Cabang until the junction of Jalan Sungai Panjang and the rural path near Maktab Rendah Sains Mara Sungai Besar (Figure 1). This rural road is approximately 18.0 km (11.18 mi) long and is rich in scenic views of the rural landscape on both sides of the road.

Figure 1. The location of the study area.

2.2. Methods of the Study

Studies examining visual aesthetics have asserted that public preference for a landscape is an interactive phenomenon that results from the interplay between the physical attributes of the landscape and the psychological responses of individuals who observe it [45,46]. This study proposes a user-centered evaluation method based on a public understanding of landscape preferences using the Likert scale technique. The Likert scale, widely employed in educational and social science research, is one of the most basic and extensively utilized instruments in psychological measurement [47]. In general, using the Likert scale often balances both positive and negative items, aiming to mitigate bias in the response set [48]. The participants utilize a bipolar scale, consisting of options such as, "strongly disagree, disagree, neutral, agree, strongly agree", to express their sentiments towards each item.

Furthermore, the photo survey method is one of the most direct approaches to assessing visual quality in the rural landscape [14]. The photo survey visually shows the scenic beauty of the landscape and allows the observer to assess its aesthetic appeal. Google Street View (https://www.google.com/maps, accessed on 1 February 2023) provided the photos for this investigation because it employs more comprehensive and high-resolution panoramic photographs and could be more effective, quicker, and more convenient than field-based techniques [49]. Besides, the heatmap analysis allows respondents to understand which LCs and elements are preferred. Today, heatmaps have gained popularity as a prevalent method of presenting information-rich data in 2D and 3D space. In terms of visualization, the graphical depiction of a heatmap provides a means of revealing coherent patterns within data by compressing a large amount of information into a small space [50]. Typically, two main categories of heatmaps exist the image-based heatmap and the data matrix heatmap [51]. The former refers to numerical data overlaid with an image, object, or geographic location, enabling visual information representation. The latter shows numerical information using a pseudo-color table or matrix format, presenting the information in a visual representation with specific color coding. Matrix heatmap finds extensive usage in the natural and biological sciences [52]. For this study, image-based heatmaps are an appropriate means of demonstrating data visualization and emphasizing the visual impact of specific landscape elements.

2.3. The First Phase

- Collection of Photos

Photos along the rural road were captured through Google Street View at every 250 m interval to cover the selected rural road (approximately 18.0 km long, Figure 2). The interval was decided based on the rural roads' 60 km/h speed restriction, equating to 60,000 m in 60 min. A vehicle traveling at this speed would cover a distance of 250 m in 15 s. The 15 s interval was chosen assuming that it would be a reasonable duration for a visitor to experience the totality of the landscape offered by driving through the rural road. Based on this approach, 72 photos were captured. The details of capturing and classifying photos were be explained in the next section.

Figure 2. Examples of photos taken at a distance of approximately 250 m.

- Landscape Character Identification

This study classified the LCs in the collected photographs based on land use, landform, land cover, vegetation, and human-made structures. Twelve categories of LCs were eventually identified, each including at least four images of the same LC. There were 12 groups, from A to L, using upper case letters in sequential sequence as a code. Each group was labeled based on a particular LC, such as Group A: "Barren paddy fields with roadside vegetation". To ensure that only dominant LC groups were selected for the survey, each group must have at least four photos. Based on this selection criteria, only 48 images were selected for this study after classification (Appendix A). Table 1 shows the code and label for each group with one photo.

Table 1. Each group with their LCs.

Group	Landscape Character	Code	Photo Example
A	Barren paddy fields with roadside vegetation	A1	
B	Semi-barren paddy fields with irrigation canals	B1	

Table 1. *Cont.*

Group	Landscape Character	Code	Photo Example
C	Roadside oil palm vegetation	C1	
D	Semi-barren paddy fields with open horizon view	D1	
E	Roadside banana tree vegetation	E1	
F	A dense mix of roadside vegetation	F1	
G	Mix vegetation with settlements	G1	
H	Partial oil palm roadside vegetation	H1	

Table 1. *Cont.*

Group	Landscape Character	Code	Photo Example
I	Green paddy fields with irrigation canals	I1	
J	Partially grown paddy fields with roadside vegetation	J1	
K	Partially grown paddy fields and roadside vegetation with irrigation canals	K1	
L	Roadside settlements and commercial structures	L1	

2.4. The Second Phase

- Survey

This study's survey was administered and distributed online using a platform called Qualtrics. To avoid repetition of survey respondents' responses, the images were randomly organized, and no images from the same group were allowed to be placed consecutively. Besides, two additional images were added (one at the beginning and another at the end) to allow respondents to familiarize themselves s with the survey procedures and to avoid having a misled result. However, results from these two additional images were excluded from the analysis.

This online preference survey has two sections: (A) the demographic and (B) the photo survey. Section (A) contains 11 general questions: age, gender, income, educational background, experience with rural road landscapes, and other questions that are also important to the study. Section (B) contains two parts. One is the use of a five-point Likert scale from 1 (least preferred) to 5 (highly preferred). Participants were asked to view and evaluate a rural road landscape scene in the photo. Each photo was given a visual

quality score ranging from −2 (least preferred scene) to +2 (highly preferred scene), where 0 value means it is a moderate scene. Positive scores represent positive visual quality and vice versa. Using this categorization of the Likert scale, Wartmann et al. [53] successfully identified what the public considered an influential visual quality. Mundher et al. [54] successfully utilized this Likert scale to classify landscape characters into negative and positive visual quality categories. Another section is to allow respondents to click and identify two elements of photos that they like the most in the rural road landscape. Heatmap analysis will be automatically generated based on the recorded clicks' intensity. The Qualtrics heatmap analysis was utilized to identify the LC that impacts the visual quality.

The final survey was distributed through social media using purposive sampling, limiting people living in Malaysia as participants. The survey data were collected over 30 days beginning 25 February 2023. The SPSS V26 program was used to analyze the survey results and identify the variables that influence visual quality evaluation. Figure 3 provides an overview of the research methodology employed in this study.

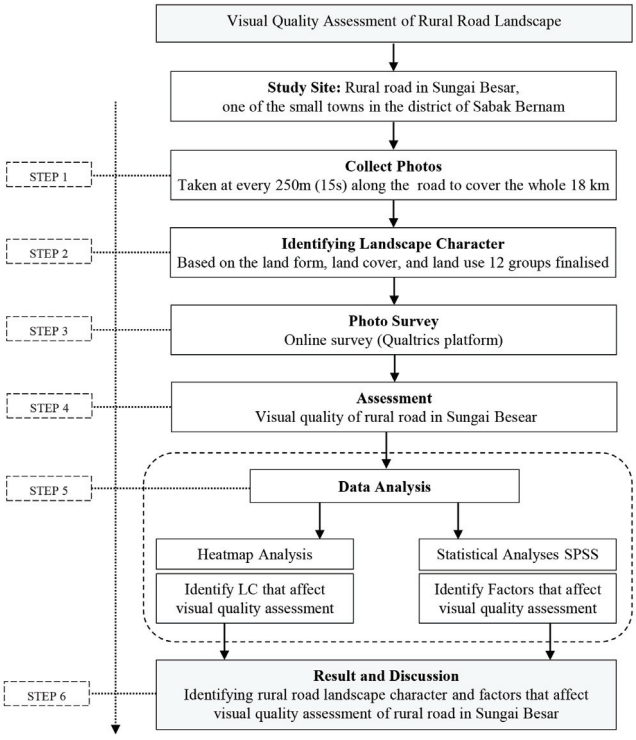


Figure 3. Overview of the research methodology.

3. Results

3.1. Demographic Statistics Description

As shown in Table 2, 250 respondents out of 282 completed the survey, with more females (N = 155, 62%) than males (N = 95, 38%). A majority of the respondents (45.6%, N = 114) fell within the age group of 26 to 35 years old, while a significant portion (42%, N=105) belonged to the age group 18 to 25 years old. The remaining respondents (N = 31, 12.4%) were over 36 years old. Additionally, 108 respondents were foreigners, making up 43.2% of the total respondents, while 142 were Malaysians. Among Malaysians, the majority were Malays (N = 65, 26%) and Chinese (N = 67, 26.8%), while Indians were the minority (N = 10, 4%). On the other hand, among the international respondents, there were significantly more Chinese respondents (N = 97, 38.8%) than respondents from other

nations (N = 11, 4.4%). More than half of the respondents were students (N = 131, 52.4%), which may indicate that their average monthly income was less than RM 2500 (N = 148, 48%). Moreover, over 80% of respondents (N = 222, 88%) in this group were educated higher than the high school level. Almost two-thirds of the (N = 160, 64%) respondents had a home in an urban area, while 35.2% (N = 88) reported visiting rural areas less than once a year. When the respondents were asked about the type of transportation they use when traveling to rural areas, the majority commented that the primary means of transport when traveling to rural areas was by car (N = 216, 86.4%). However, only a relatively small number of respondents stated that they have been to Sungai Besar. This accounted for 47 samples, representing 18.8% of the total respondents. Based on the results, it can be concluded that the respondents are predominantly female, students, and local; have a good education level; and are relatively familiar with rural areas but have limited information about the study area.

Table 2. The overall data of the demographic survey.

Variable	Category	Frequency N	Valid Percent %
Gender	Male	95	49.6
	Female	126	50.4
Age	18 to 25	105	42.0
	26 to 35	114	45.6
	36 to 45	29	11.6
	46 to 55	2	0.8
	Above 55	0	0
Malaysian citizen	Yes	142	56.8
	No	108	43.2
Ethnicity	Malay	65	26.0
	Chinese	164	65.6
	Indian	10	4.0
	Others	11	4.4
Monthly income	Below RM 2500	120	48.0
	RM 2500 to 5000	66	26.4
	RM 5000 to 7500	38	15.2
	Above RM 7500	26	10.4
Type of work	Student	131	52.4
	Self-employed	24	9.6
	Private	73	29.2
	Government	22	8.8
Educational level	High school	28	11.2
	Diploma or bachelor's degree	114	45.6
	Master's degree	70	28.0
	Ph.D. or higher	38	15.2
Hometown	Urban area	160	64.0
	Suburban area	53	21.2
	Rural area	37	14.8
Frequency of visits to the rural area	Less than one a year	88	35.2
	2 to 4 times a year	95	38
	5 to 8 times a year	23	9.2
	More than 8 times a year	44	17.6
Type of transportation for the rural area	Train	18	7.2
	Bus	12	4.8
	Car	216	86.4
	Motorcycle	4	1.6
Visiting Sungai Besar or not	Yes	47	18.8
	No	203	81.2

- Statistics Description of Landscape Experience in Demographic Survey

This part depicted the extent to which respondents were intrigued by the experience of the rural environment (Table 3). In general, respondents exhibited a higher interest in the natural landscape (AM = 3.75) compared to cultural ones (AM = 3.288), particularly demonstrating the highest interest in the hills and mountains (IM = 3.83) in the natural landscape. However, traditional houses (IM = 3.67) and orchards (IM = 3.56) had a much higher average individual value in the cultural group than other LCs. Interestingly, the individual mean value for traditional houses (IM = 3.67) in the cultural LC variable was even higher than the forests (IM = 3.63) in the natural landscape variable. This result suggested that traditional rural houses could be of interest to some respondents because of their specific memories of their hometowns and their preference for traditional heritage. Paddy fields, mixed agricultural crops, and oil palm plantations were comparable within the cultural landscape, with oil palm plantations being the lowest at 2.94. This may be because planting large areas of oil palm has reduced respondents' experience of the diversity of the rural landscape.

Table 3. The respondent's landscape experience within the rural area.

Variable/Landscape Experience	Landscape Character	Individual Mean Value	Average Mean Value
Culture	Paddy field	3.12	3.288
	Mix agricultural crops	3.15	
	Traditional houses	3.67	
	Oil palm plantations	2.94	
	Orchard	3.56	
Nature	River	3.78	3.75
	Hill/Mountain	3.83	
	Forest	3.63	

3.2. Photo Survey

- Rating of Each Photo Survey

The Likert scale used in this visual photo survey ranged from negative two to positive two. According to this criterion, the mean value from the respondents' survey was analyzed for all 48 photos and ranked (refer to Table 4). The number of photos with positive visual quality was slightly less (N = 21) than those with negative (N = 27). Surprisingly, neither the positive nor the negative visual quality photos had a mean value greater than +1 or −1, with the highest mean value of +0.74 for positive visual quality and the lowest mean value of −0.53 for negative visual quality. These results could indicate that respondents for the rural road landscape were within their acceptable range. No specific landscape elements significantly influenced respondents' visual preferences as either exceptionally good or bad. Instead, the overall landscape of the rural road was perceived to be in relatively good condition and maintenance, suggesting a general satisfaction with the overall rural road landscape. Next, six images from the highest positive and lowest negative visual quality values were selected to provide a general overview of the visual quality trends (Table 5).

Table 4. The ranking of each photo's mean values.

Positive Visual Quality			Negative Visual Quality		
No.	**Photos Codes**	**Mean Value**	**No.**	**Photos Codes**	**Mean Value**
1	I3	+0.74	1	L3	−0.53
2	K2	+0.64	2	F4	−0.35
3	I1	+0.62	3	G2	−0.24
4	I4	+0.59	4	E2	−0.14
5	I2	+0.54	5	H3	−0.13
6	K4	+0.51	6	F2	−0.12

Table 4. *Cont.*

Positive Visual Quality			Negative Visual Quality		
No.	**Photos Codes**	**Mean Value**	**No.**	**Photos Codes**	**Mean Value**
7	K3	+0.37	7	F3	−0.12
8	B4	+0.35	8	H1	−0.12
9	B1	+0.33	9	J4	−0.12
10	D3	+0.31	10	L1	−0.12
11	B3	+0.28	11	F1	−0.11
12	A4	+0.26	12	E1	−0.10
13	B2	+0.24	13	G3	−0.10
14	J3	+0.17	14	L2	−0.07
15	D4	+0.14	15	E3	−0.06
16	A1	+0.14	16	A3	−0.05
17	J1	+0.08	17	H4	−0.05
18	H2	+0.07	18	C3	−0.04
19	J2	+0.06	19	C4	−0.04
20	K1	+0.05	20	L4	−0.04
21	D1	+0.01	21	C2	−0.02
			22	G1	−0.02
			23	A2	−0.01
			24	C1	−0.01
			25	D2	−0.01
			26	E4	−0.01
			27	G4	−0.01

Table 5. The top six photos based on the highest value in positive and the lowest in negative visual quality.

	Photos	
Positive Visual Quality Photos		
	1. Mean = +0.74 (I3)	2. Mean = +0.64 (K2)
		
	3. Mean = +0.62 (I1)	4. Mean = +0.59 (I4)
		
	5. Mean = +0.54 (I2)	6. Mean = +0.51 (K4)

Table 5. *Cont.*

	Photos	
Negative Visual Quality Photos		
	1. Mean = −0.53 (L3)	2. Mean = −0.35 (F4)
		
	3. Mean = −0.24 (G2)	4. Mean = −0.14 (E2)
		
	5. Mean = −0.13(H3)	6. Mean = −0.12 (F2)

Positive visual quality photos: The mean value is greater than 0. Negative visual quality photos: The mean value is less than 0.

Based on Table 5, notably in the positive visual quality category, four of the six photos were from group I (I3 M = +0.74; I1 M = +0.62; I4 M = +0.59; I2 M = +0.54), which predominantly displayed the view with "green paddy fields with irrigation canals". Other photos were from group K (K2 M = +0.64; K4 M = +0.51), featuring "partially grown paddy fields" and "roadside vegetation with irrigation canals". It can be seen that the entire top six is only from groups I and K. These photos showed most likely similar LCs and elements that contribute to high visual quality and overall popularity among the survey respondents. Even the top 11 images fit this pattern (Table 4). However, the presence of water significantly enhanced the visual appeal to a certain degree, which has been consistently proven in many studies. Table 3 indicates that water experience was highly preferred in rural areas, while the experience of paddy fields was only the second least preferred among all the LCs. Thus, the element of water and its role can be considered vital in rural areas. However, most of the photos in the negative visual quality group also shared a similar LC of vegetation (F4 M = −0.35; G2 M = −0.24; E2 M = −0.14; H3 M = −0.13; F2 M = −0.12) except for L3 (M = −0.53), which had the poorest visual quality with "roadside settlements and commercial structures". The top four photos of the negative visual quality group showed a lack of coherence and a higher sense of complexity among elements within the scenes. In particular, L3, "human-made elements" without proper management, as the main LC, were more likely to result in the lowest preference for landscapes. The remaining two showed a slightly more orderly coherence, but the overall scene gave a sense of being enclosed, causing respondents to prefer this scene less.

Average values of visual quality across different groups are presented in Table 6. A surprising finding is that groups having paddy fields as a main LC were classified in the positive visual group. In contrast, groups characterized by mixed vegetation as the dominant LC were classified as the negative visual group. In the positive LC groups, the top three (I M = +0.6625; K M = +0.3925; B M= +0.3) featured "paddy fields and irrigation canals", with the only differentiating factor being the phases of paddy plantation observed in the fields. The higher the maturity from semi-barren to green, the higher the respondent's preference. Next, in fourth place was group D (M = +0.3), which provided a complete view of the paddy field landscape. The last two groups (A M = +0.11, J M = +0.085) featured "paddy fields and vegetation". The value of visual quality for group D is lower than the first three groups, mainly due to the absence of a water landscape, which confirms that the existence of a water character in the landscape improves its visual appeal. However, group D has a higher visual quality rating than the other two (A and J) mainly because of its broader field of view. Group A and J, with a limited line of sight due to vegetation obstruction, received a lower rating.

Table 6. The ranking of group photo mean values.

	Group	Landscape Character	Code	Individual Mean Value	Average Value
Positive Visual Quality	I	Green paddy fields with irrigation canals	I1	+0.62	+0.6225
			I2	+0.54	
			I3	+0.74	
			I4	+0.59	
	K	Partially grown paddy fields and roadside vegetation with irrigation canals	K1	+0.05	+0.3925
			K2	+0.64	
			K3	+0.37	
			K4	+0.51	
	B	Semi-barren paddy fields with irrigation canals	B1	+0.33	+0.3
			B2	+0.24	
			B3	+0.28	
			B4	+0.35	
	D	Semi-barren paddy fields with open horizon view	D1	+0.01	+0.1125
			D2	−0.01	
			D3	+0.31	
			D4	+0.14	
	A	Barren paddy fields with roadside vegetation	A1	+0.14	+0.085
			A2	−0.01	
			A3	−0.05	
			A4	+0.26	
	J	Partially grown paddy fields with roadside vegetation	J1	+0.08	+0.045
			J2	+0.06	
			J3	+0.16	
			J4	−0.12	
Moderate Visual Quality (M = 0)					
Negative Visual Quality	C	Roadside oil palm vegetation	C1	−0.01	−0.0275
			C2	−0.02	
			C3	−0.04	
			C4	−0.04	
	H	Partial oil palm roadside vegetation	H1	−0.12	−0.0575
			H2	+0.07	
			H3	−0.13	
			H4	−0.05	

Table 6. *Cont.*

	Group	Landscape Character	Code	Individual Mean Value	Average Value
Negative Visual Quality	E	Roadside banana tree vegetation	E1 E2 E3 E4	−0.1 −0.14 −0.06 −0.01	−0.0775
	G	Mix vegetation with settlements	G1 G2 G3 G4	−0.02 −0.24 −0.10 −0.01	−0.0925
	F	A dense mix of roadside vegetation	F1 F2 F3 F4	−0.11 −0.12 −0.12 −0.35	−0.175
	L	Roadside settlements and commercial structures	L1 L2 L3 L4	−0.12 −0.07 −0.53 −0.04	−0.19

Subsequently, in the negative visual group, nearly all groups, except for group L (M = −0.19), which had the lowest preference for "roadside settlements and commercial structures", showed a landscape mostly covered in vegetation. Essentially, the top three views (C M = −0.0275; H M = −0.0575; E M = −0.0775) were simple plant-based views, with the oil palm (group C and group H) slightly more popular than the banana tree (E). The following three views showed a slightly more varied LC: group G (M = −0.0925) with "a mix of vegetation with settlements"; group F (M = −0.175) with "dense roadside vegetation"; and group L (M = −0.19) with "roadside settlements and commercial structures", causing those surveyed to feel confused, disordered, and complex. Notably, Groups G and F with vegetation were better than Group L, in which artificial landscapes dominate. Hence, the preference for vegetation landscapes is generally better than artificial ones in the negative visual group. In comparing vegetation landscape groups only in this group, visual quality in vegetation landscapes can be changed by specific characters or elements.

3.3. Heatmap and Landscape Characters Effect on Visual Quality Assessment

This study used heatmap analysis on specific landscape elements that affect the overall visual quality of the rural areas. Heatmap analysis relied on respondents' click density, with areas shaded in red indicating the most clicks, while those in blue representing the fewest clicks (Table 7). The focal concentration of red areas suggested a greater preference among the respondents towards specific or dominant elements, while scattered and lighter red areas indicated the opposite. Thus, photos and heatmap analysis provided a more accurate indication of the landscape elements that the respondents preferred. Table 7 provides examples of heatmap analysis based on positive and negative visual groups presented in Table 6. In the positive group, the red zones are more concentrated mainly towards paddy fields or irrigation canals, indicating a strong preference for these two specific characters among respondents. Despite some clusters of red regions on the vegetation, the red intensity was notably lesser than in the paddy fields and irrigation canals. This suggests that the visual appeal of paddy fields accompanied by irrigation canals is superior to the combination of paddy fields with roadside vegetation. Furthermore, the photographs belonging to the positive group depicted a scene with an open or semi-open view. The arrangement and integration of the landscape elements in the scene also appear coherent and harmonious, which may be attributed to the paddy field dominating a more significant portion of the scene, creating a sense of unity and order.

Table 7. A heatmap analysis identifying the key characters and elements for visual quality.

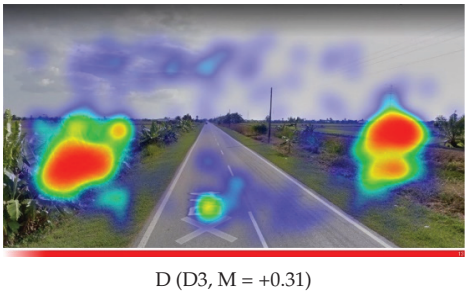
	Before Heatmap Analysis	After Heatmap Analysis
Positive Visual Quality		
	1. Group (Mean) Landscape Character	I (I3, M = +0.74) Green paddy fields with irrigation canals
		
	2. Group (Mean) Landscape Character	K (K2, M = +0.64) Partially grown paddy fields and roadside vegetation with irrigation canals
		
	3. Group (Mean) Landscape Character	B (B4, M = +0.35) Semi-barren paddy fields with irrigation canals
		
	4. Group (Mean) Landscape Character	D (D3, M = +0.31) Semi-barren paddy fields with open horizon view

Table 7. *Cont.*

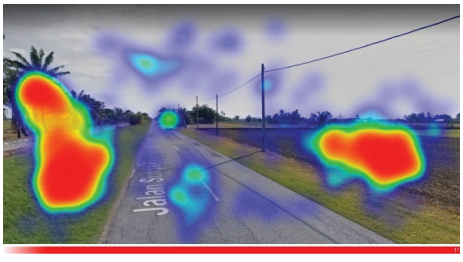
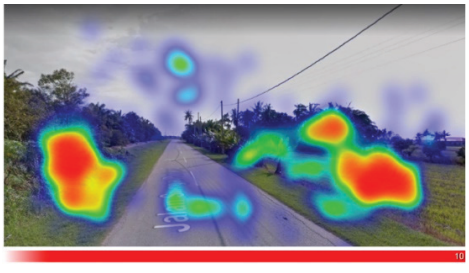
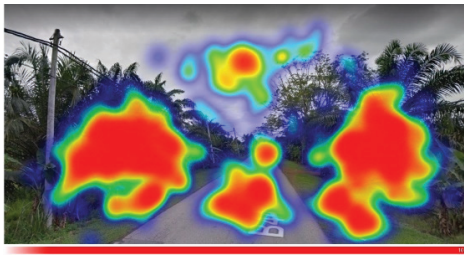
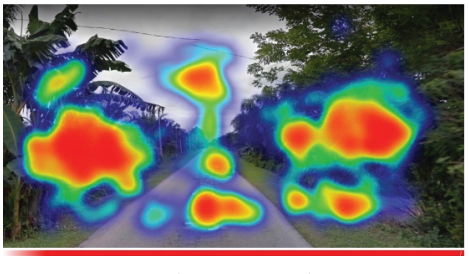
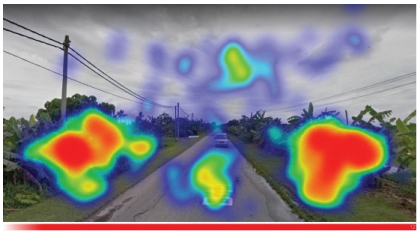
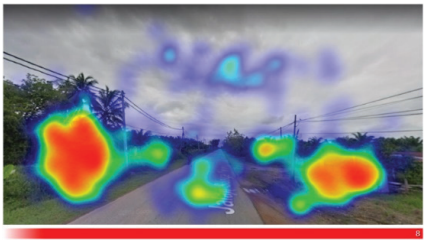
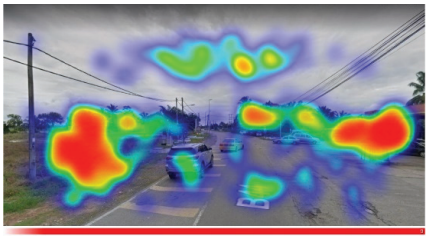
	Before Heatmap Analysis	After Heatmap Analysis
Positive Visual Quality		
	5. Group (Mean) Landscape Character	A (A4, M = +0.26) Barren paddy fields with roadside vegetation
		
	6. Group (Mean) Landscape Character	J (J2, M = +0.16) Partially grown paddy fields with roadside vegetation
	Moderate Visual Quality (M = 0)	
Negative Visual Quality		
	1. Group (Mean) Landscape Character	C (C3, M = −0.04) Roadside oil palm vegetation
		
	2. Group (Mean) Landscape Character	H (H3, M = −0.13) Partial oil palm roadside vegetation

Table 7. *Cont.*

	Before Heatmap Analysis	After Heatmap Analysis
Negative Visual Quality		
	3. Group (Mean) Landscape Character	E (E2, M = −0.14) Roadside banana tree vegetation
		
	4. Group (Mean) Landscape Character	G (G2, M = −0.24) Mix vegetation with settlements
		
	5. Group (Mean) Landscape Character	F (F4, M = −0.35) A dense mix of roadside vegetation
		
	6. Group (Mean) Landscape Character	L (L3, M = −0.53) Roadside settlements and commercial structures

However, in the negative group, the absence of paddy fields and irrigation canals as dominating elements resulted in more scattered clusters of red areas. Notably, in the negative group, the preference for the view with enclosed horizons was higher than that with partially open horizons. The initial two scenes within the negative group exhibited a relatively uniform arrangement of the oil palm, albeit with a narrower field of enclosed view. The LCs maintained relatively high coherence in the scenes, with the oil palm dominating. However, these two groups caused negative visual quality probably because

the vegetation created a more enclosed visual space. Next, although Group E was also a relatively homogeneous vegetation landscape (banana tree), the unity and integrity of the scene were less than that of the previous two groups. The subsequent scenes depicted diverse landscape elements; the overall scenery lacked more coherence and was abundant in human-made characters, causing the respondents to dislike it more. Hence, the scene's complexity and coherence could impact the respondent's visual preference. To some extent, it could be contended that the tidiness and coherence of the scenery hold greater significance than the openness of the scenery in terms of rural negative visual quality.

3.4. Factors Affecting Visual Quality on Rural Road Landscape

This section has focused on the influence of different respondents' demographic factors on the visual quality of rural road LCs. Following the previous grouping of means, the reliability of the two groups of positive and negative visual quality was examined separately. The reliability test indicated that the result is greater than 0.7 (PVQ Cronbach's Alpha = 0.969, NVQ Cronbach's Alpha = 0.961, total Cronbach's Alpha = 0.976), which is within the acceptable range, as shown in Table 8. Additionally, the normality of the survey sample was also tested to determine the appropriate analysis. Based on the results indicated in Table 9, the Kolmogorov–Smirnov and Shapiro–Wilk significant values for the positive and negative groups were greater than 0.05 ($p > 0.05$), meaning the null hypothesis should be accepted. The results satisfied a normal distribution.

Table 8. The results of the statistical analysis of reliability.

Visual Quality	Valid (N)	N of Items	Reliability Cronbach's Alpha
Positive visual quality (PVQ)	250	24	0.969
Negative visual quality (NVQ)	250	24	0.961
Total reliability (Cronbach's Alpha) for 48 photos			0.976

Table 9. The results of the normality tests.

Visual Quality	Kolmogorov–Smirnov [a]			Shapiro–Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Positive	0.44	250	0.200 *	0.992	250	0.158
Negative	0.55	250	0.069	0.991	250	0.128

*, This is a lower bound of the true significance. [a], Lilliefors significance correction.

Parametric analytical tests, such as *t*-tests and one-way ANOVA, were used in the following analysis with results that only presented significant differences ($p < 0.05$) listed. The independent *t*-test, as shown in Table 10, shows two factors influencing the positive visual quality: the respondents' citizenship and previous experience visiting Sungai Besar. However, these effects were limited to some specific LCs.

The factor "Local or Foreigner" influenced Group D, "Semi-barren paddy fields with open horizon view"; Group A, "Barren paddy fields with roadside vegetation"; and Group J, "Partially grown paddy fields with roadside vegetation", indicating there was a significant difference in the perception of these landscapes between locals and foreigners, with higher mean scores for these LCs in locals than foreigners. This difference may be attributed to Malaysians' familiarity with similar landscapes in real life, leading to a more pronounced perception of local landscapes. In contrast, non-Malaysians may have viewed the landscapes as unremarkable paddy fields without personal interaction, causing lower mean scores. Similarly, the factor "With or without experience" affecting the LC groups was almost the same as the previous one. Respondents who were familiar with and had visited the study area provided higher mean scores than those who had not been there. It is implied that respondents who have visited the study area may have had more associations with the local landscape, which influenced their visual judgments. Conversely, respondents

who had not been there could only rate by visual impression in photos, resulting in lower average scores. These findings indicated that familiarity with specific local landscapes and the associated local landscape could influence respondents' visual judgments in rural road landscapes.

Table 10. The results of the *t*-test in the positive group.

Visual Quality	Variable	Group	N		Mean	F	Sig.	*t*	Sig. (2-Tailed)
Positive Visual Quality	Local or Foreigner	D	Yes	142	3.2535	1.037	0.309	2.819	0.005
			No	108	2.9190				
		A	Yes	142	3.2183	0.884	0.348	2.697	0.007
			No	108	2.9097				
		J	Yes	142	3.1373	3.529	0.061	2.031	0.043
			No	108	2.9168				
	With or Without Experience	B	Yes	47	3.6277	1.217	0.271	2.626	0.009
			No	203	3.226				
		D	Yes	47	3.3670	0.753	0.386	2.097	0.037
			No	203	3.0493				
		A	Yes	47	3.3404	0.023	0.879	2.157	0.032
			No	203	3.0259				
Negative Visual Quality	Local or Foreigner	L	Yes	142	2.9595	3.848	0.051	3.256	0.001
			No	108	2.6134				

Significant at $p < 0.05$.

In the negative group, the factor "Local or Foreigner" only exhibited a significant difference in influencing group L's LC. Group L, "Roadside settlements and commercial structures", was the last one among the negative groups. The Malaysians rated this group better than the foreigners, indicating that they might have had prior exposure to this landscape and found it more familiar. On the other hand, non-Malaysians were less familiar with this type of landscape, leading to a more intuitive judgment with a lower mean score. Therefore, the degree of familiarity with some particular landscape could significantly affect people's visual experience, as evidenced by the results of these factors.

Next, the one-way ANOVA analysis data are presented. The age groups of 46–55 and over 55 were merged into the 36–45 age range due to limited respondents. This new age range was then adjusted to above 36. After analyzing the socio-demographic data for all options equal to or greater than 3, it was discovered that only the age factor displayed a statistically significant difference ($p < 0.05$) in some positive groups (B, "Semi-barren paddy fields with irrigation canals"; D, "Semi-barren paddy fields with open horizon view"; A, "Barren paddy fields with roadside vegetation"; J, "Partially grown paddy fields with roadside vegetation"), as demonstrated in Tables 11 and 12. The data presented in Table 11 only show significant differences, with significant values below 0.05, indicating a significant difference among at least one pair of the three age options. Next, Table 12 presents comparative data for these positive groups. Notably, the average scores for the photos provided to the 18–25 age group were higher than those for the 26–35 age group across all four groups. This suggests that younger respondents were more drawn to these LCs. However, there were no significant differences between those aged 18–25 and 26–35 to those aged 36 and above. This may be due to the small sample size of those aged 36 and above compared to the larger sample sizes of the 18–25 and 26–35 age groups.

Table 11. The results of the ANOVA test in the positive group.

Positive Group	(18–25, 26–35, Above 36) Group	F	Sig.
B	Between Groups Within Groups Total	3.259	0.040

Table 11. *Cont.*

Positive Group	(18–25, 26–35, Above 36) Group	F	Sig.
D	Between Groups Within Groups Total	3.902	0.021
A	Between Groups Within Groups Total	3.612	0.028
J	Between Groups Within Groups Total	3.621	0.028

Significant at $p < 0.05$.

Table 12. The results of the comparisons in the positive group.

Positive Group	(I) Age	(J) Age	Mean Difference (I-J)	Sig.
B	18–25	26–35	0.32669 *	0.040
D	18–25	26–35	0.33528 *	0.030
A	18–25	26–35	0.31253 *	0.038
J	18–25	26–35	0.30382 *	0.031

*. The mean difference is significant at the 0.05 level.

4. Discussion

4.1. The Impact of Landscape Elements on Visual Quality

This study shows that the rural road landscape elements play a significant role in terms of influencing public preferences toward determining visual quality. The overall results show a distinct shift in the landscape's visual quality, transitioning from a predominantly paddy fields with a positive visual quality to predominantly mixed vegetation or human-made structures with a negative visual quality. Within the positive visual group, the landscape elements paddy field is a critical determinant of visual quality. The paddy field not only provides economic value but also plays a crucial role in preserving local traditions and culture, protecting the environment, and offering educational and recreational opportunities [55]. When investigating rural tourism routes in a similar area, Sungai Besar, it is discovered that tourists are also intensely interested in the paddy fields that typify the scenery along those rural routes [43]. The preference for paddy fields is consistent with findings from studies on highway landscapes in Malaysia [56]. Paddy fields have the highest preferences compared to other landscape elements. Hence, it can be seen that paddy fields are an irreplaceable part of a scenic drive in Malaysia.

Additionally, other landscape elements alongside the paddy field can affect the visual quality of the paddy field, such as water-related elements or vegetation. Landscapes containing water-related elements are the most preferred by the public in rural areas, contributing to a positive emotion and higher perceived recuperation [57,58]. The presence of water-related elements in the scene positively impacts human preference. As the proportion of water in the scene increases, so does the degree of human preference [57]. However, the excessive addition of elements are added to the paddy field landscape could result in a decline in its visual quality [59]. For example, abundant vegetation elements in paddy fields could result in a lower overall visual quality than in paddy fields with water-related elements. Hence, the visual quality of the groups with "paddy fields with irrigation canals" is better than groups with "paddy fields with vegetation".

Within the negative visual group, vegetation or human-made structure landscape elements become the main character. These landscape elements, especially scenes dominated by the human-made landscape, are unpopular in the Malaysian road landscape, offering the most unpleasant visual experience [56]. Similarly, Akbar et al. [60] found that most respondents regarded roadside vegetation as unpleasant and monotonous in their study. Besides, when visibly distinct and incongruous with the surrounding environment, human-made structures and elements such as electricity poles and settlements

result in a lower public preference. Without proper management and maintenance, these elements could be perceived as visual pollutants [61]. Hence, the public's perception of these visual qualities is negative. Among the negative visual group, the visual quality of the group focusing on vegetation alone is better than the others, likely because, to some extent, road users consider roadside vegetation to be the primary aspect of scenic beauty on the road [62]. However, vegetation leading to the negative visual quality in this study may be specifically the excessive density of vegetation, which creates a more confined environment. On the other hand, the groups in which human-made landscape elements are distinctive and dominant are often perceived as a type of visual pollution, causing more visual discomfort and emotional disgust, further lowering public preference for such landscapes. Hence, these landscape elements are in the last group within the negative visual group, representing the poorest visual experience.

4.2. The Impact of Visual Character on Visual Quality

Visual characters are also a key factor affecting visual quality [63]. Each concept comes with its description and attributes; scholars only choose the corresponding concept to access based on the current context [64]. Given the landscape scenes presented in this study, we have further identified four key characteristics—visual scale, coherence, complexity, and disturbance—to provide a more detailed visual quality analysis.

For the positive visual group, the combination of unified and orderly landscape elements, paddy fields with water-related or vegetation elements, and the presence of more open views contribute to the public an excellent visual experience. The unified and orderly environmental components could be attributed to the coherence [65]. In other words, coherence, the degree to which scenes are put together using organized materials, textures, structures, repetition, and continuity, could be seen as unity [66]. The concept of unity in aesthetics results in a harmonious and balanced composition, allowing the various elements of the scene to be integrated cohesively [67]. The unity, in turn, creates an orderly arrangement of spaces and plants. Hence, there is connectivity with coherence, which pertains to the extent of association between perceivable features or elements within the environment and their potential significance in the broader context [68]. Landscapes with a more organized visual appearance are preferred over those that appear disorderly [69]. Additionally, there is a direct correlation between the extent of openness in a landscape and individuals' preferences [70]. This implies that landscape scenes characterized by a high degree of openness and a high sense of order are preferred by more respondents [71]. Hence, the landscape elements of the predominantly paddy fields, combined with other complementary landscape elements, present a more harmonious and comfortable composition, providing visual enjoyment for the public.

Conversely, within the negative visual group, a mixture of diverse, intricate, and disorderly landscape elements, vegetation and human-made elements, and a relatively closed view gives the public a negative visual experience. The entire negative visual group has a slightly worse field of view than the positive visual group. Since this degree of openness is generally low, the public's preference for such landscapes is also diminished. Furthermore, the concepts of diversity, intricacy, and disorder can be summarized as complexity in the visual LC [63,72]. Kaplan et al. [66] have subsequently mentioned that complexity could serve as a representation of both order and disorder. An orderly complexity contributes to the visual richness of a setting, whereas a disorganized complexity may be regarded as a chaotic element [73]. Therefore, the visual quality of a single-vegetation-dominated landscape is better than others in this negative visual group. The disturbance in the landscape's visual character is also a factor causing negative visual quality. The disturbance is generally the absence of contextual suitability and coherence in the scene of the landscape [64]. In some negative visual groups, the main distracting elements are the human-made landscape elements that do not harmonize with the surroundings and indirectly become visual pollution. Hence, the presence of such elements can distract and lead to an unpleasant visual experience for the public.

4.3. Respondent Background and Its Influence on Preference

This study reveals that only a limited number of specific landscape characteristics are impacted by demographics, such as citizenship, experience in Sungai Besar, and age. These factors are primarily related to specific positive visual groups. Citizenship or experience in Sungai Besar could be seen as a familiarity. Previous studies have demonstrated the significance of familiarity in the visual assessment of landscapes, where familiarity mainly refers to the place of presence and current residence [74]. The relationship between people and place appears to be an essential element influencing visual landscape preferences [6]. Familiarity with landscape type is an important factor in preference for visual landscapes [75]. However, the impact of familiarity on preference is not always clear-cut [76], which may explain why citizenship or experience in Sungai Besar have little effect on the rest of the LCs. Other familiarity-related factors, such as hometown, are also found to have no relationship with LCs in this study. Besides, regarding age, some research has discovered that landscape preferences change with age [77,78]. The main differences in preference are typically observed between children and adults or young and elderly individuals [58]. However, in this study, the observed difference in preference is primarily between two closely related age groups, namely 18–25 and 26–35, which is very different from the results of previous studies. Hence, there is a lack of relevant evidence to explain the difference between these two age groups.

5. Limitations and Future Studies

This study provides valuable information about people's preferences and the visual quality of rural roads. However, it is crucial to acknowledge its limitation. Firstly, most respondents were ethnic Chinese, while other ethnicities were under-represented. The high number of Chinese participants may be because there are more links to the surveys distributed through WeChat, a popular social media platform widely used by the Chinese population. There were also many other social media, but a large number of people were still in the process of completing the survey by the deadline. However, this imbalance in the proportions may have potentially influenced the results. Future research should strive to establish a more equal representation of different ethnicities in order to provide more inclusive and representative outcomes.

The second limitation is related to the difficulty in ensuring the seriousness of some respondents while answering the questionnaires. As most surveys were distributed through online links or QR codes, controlling the respondents' level of attentiveness and engagement was challenging. For example, the number of respondents who completed the survey was higher among younger respondents and students, probably because they have more time and are rarely interrupted by other things. It is also possible that older people were less familiar with the QR code and online survey links, leading to concerns about potential scams and subsequently abandoning the survey quickly. Hence, to improve this limitation, it is recommended to consider incorporating measures to assess and ensure the seriousness and attentiveness of respondents, such as conducting in-person interviews or implementing validation techniques.

Next, the study relied mainly on Google Street View images as the source of the landscape scenes. However, these images may not wholly reflect the actual visual experience due to the limitations of uploading and updating images. Hence, to guarantee that the sceneries are as accurate and realistic as possible, it is recommended to validate the visual data by visiting the actual locations and confirming the accuracy of the photographs. This is crucial for research or decision-making processes when visual data are used. Doing so can avoid biases and inaccuracies from relying solely on images from platforms, such as Google Street View.

Lastly, it is proposed to include both qualitative interviews and quantitative questionnaires in future studies. This mixed-methods approach can provide a more comprehensive understanding of the visual quality of the rural road landscape and other related information. By integrating qualitative and quantitative data, researchers can discover more

about the respondent's perceptions and preferences and capture subtle characteristics that quantitative measures alone may miss.

6. Conclusions

This study examined the visual quality of rural road LCs in Sabak Bernam, Malaysia, through a combination of heatmap analysis and public preference surveys. The findings emphasized the significance of preserving the original appearance and scenery of the rural landscape in the face of rapid rural development. The study indicated that paddy fields hold a very high status in the Malaysian rural landscape and contribute significantly to enhancing the overall visual quality of the area. Although the public did not prefer the vegetation-based LC regarding visual quality, it was still essential in the rural road landscape. On the other hand, human-made elements in the rural road LC have significantly negatively impacted the landscape's visual experience and original appearance. It is essential to integrate human-made elements thoughtfully into the rural landscape to complement and enhance the rural environment rather than detract from it. This research contributes to valuable knowledge about the visual quality of rural road landscapes and offers the groundwork for future landscape planning and conservation initiatives in Sabak Bernam and surrounding areas. Moreover, by taking the public's preferences into account, stakeholders may make well-informed decisions to maintain and enhance the visual quality of rural road landscapes. The study also emphasizes the necessity of sustainable development strategies that preserve the rural regions' unique natural beauty, cultural diversity, and customs. Overall, the results of this study can provide valuable insights for decision-makers, landscape architects, and planners, enabling them to make informed decisions regarding future landscape conservation and planning, particularly in rural tourism and preservation.

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Appendix A

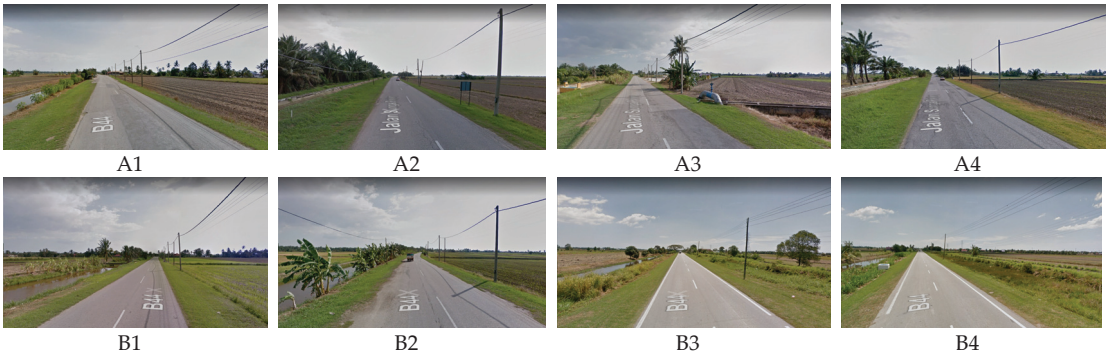

Figure A1. *Cont.*

Figure A1. *Cont*.

Figure A1. The group of landscape characters.

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The Lawn as a Social and Cultural Phenomenon in Perth, Western Australia

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Abstract: Lawns, introduced in Australia through English colonial heritage, dominate public spaces in cities, serving various ecosystem functions. Australian lawns consist of non-native grasses that differ from native original vegetation and require intensive management and maintenance. This study explores public perspectives on urban lawns in Perth, Western Australia, an area largely overlooked in ecological and social research in the context of Australia compared to Europe and North America. This paper presents empirical research on public perceptions of urban lawns and alternatives in Perth, Western Australia. The study explores social values and preferences regarding traditional lawns and new options, considering visual appearance, uses, and maintenance. Findings from an online questionnaire, involving 171 respondents, identified seven categories based on a content analysis of lawn definitions: flat area; ground covered by grass; maintained; non-native vegetation; open space; recreational space; and turf grass. The results revealed that respondents most value lawns for aesthetics, cooling and recreation (exercises, walking pets, as a transit area, passive recreation, and social gatherings). At the same time, participants demonstrated an environmental awareness of lawns and the necessity of revisiting the existing planning and maintenance routine based on irrigation and intensive mowing by considering several alternative solutions. While valuing new solutions such as Scaevola patches in dedicated areas and "weedy lawns", participants still preferred alternatives closest in appearance to a conventional lawn (e.g., lawn grass with Dichondra and lawn grass with clover). The study emphasizes the need for a 'blended model' of urban lawns, combining durability with heat-resistant, biodiverse vegetation to address social values and environmental concerns.

Keywords: lawns as a social phenomenon; definitions; public views and values; purpose and use of lawns; alternative solutions; Western Australia; Perth

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1. Introduction

The lawn is one of the most common and familiar elements of urban green spaces in cities around the globe and is an integral part of public parks and private gardens, roadsides, industrial areas and sports grounds. Lawns originated in Europe from managed meadows and pasturelands during the medieval period. From the middle of the 19th century, lawns turned into the most desirable and fundamental feature within both public and private gardens in the United Kingdom, Europe and European colonies. By the beginning of the 21st century, lawns had become synonymous with urban landscapes globally, despite differences in climatic and socio-economic conditions [1].

There are many different definitions of a "lawn", but we define a lawn as an intentionally established "plant community consisted of predominantly grass species (cultivars), which are sown by seeds or planted using vegetative parts and could contain spontaneously occurring (unwanted) herbaceous species ("lawn weeds")" [1] (p. 5) and which are the

subject of constant ongoing maintenance. Lawns serve multiple ecosystem services and are used for different recreation activities. One of the most important aesthetical features that make lawns attractive to urban citizens is the green colour and its beauty. The lawn is an important element of landscape designs and is used as a green carpet for displaying feature plants (trees, shrubs and flowerbeds) and decorative elements such as pieces of sculpture, fountains and benches [1].

One of the main distinctive characteristics of lawns is turf/sod which is a complex entity consisting of dense intertwined grass shoots above ground and a mesh of bounded living stolons and roots that are in symbiosis with soil fauna below ground. Lawns require specific establishment techniques (the preparation of soil and seed mixtures or specially prepared rolled turf in turf farms) and management regimes (mowing, herbicide application, aeration, fertilising and watering). These techniques are aimed at maintaining targeted grass species, controlling weeds and mosses, and keeping a desirable grass height to create a walkable surface.

Over the past 30 years, research has explored the ecosystem service functions provided by lawns including their aesthetical function, cooling effect, heat island effect mitigation via transpiration and evaporation, carbon sequestration, regulation of the water cycle, habitat provision, enhancing private property values, and offering social, recreation activities and even therapeutical values such as tranquillity. Furthermore, analyses have been conducted on ecological components such as biodiversity, the role of lawns in urban planning and landscape design, and people's perceptions (e.g., an analysis of socio-cultural reasons of public attachment to lawns) in European countries and the USA [2–5].

However, growing concerns have arisen about the urbanisation process that has led to the visual and biological homogenisation of urban green spaces globally. In particular, there is a growing worry about the loss of biodiversity and the increasing pressures associated with climate change. This concern has drawn attention to the issue of urban lawns and the associated requirement for intensive management and the use of significant amounts of water and energy. These issues have encouraged the development of alternative sustainable solutions to conventional lawns that require less intensive management and fewer resources. Examples of alternative solutions such as naturalistic plantings, pictorial meadows, grass-free lawns, and transformation of conventional lawns into meadows or pastures can be seen in the urban areas of the United Kingdom, Germany, Sweden, France, Spain, Portugal, and the USA [1,6–9] (Figure 1).

(**a**) (**b**) (**c**) (**d**)

Figure 1. Conventional smooth green carpet in Augsburg, Germany (**a**) versus alternatives: pictorial meadow from annual plants in Malmö, Sweden (**b**), urban meadow in English Garden, Munich, Germany (**c**) and grass-free lawn in Uppsala, Sweden (**d**). Photos: M. Ignatieva.

Lawns in Australia

Lawns were introduced to Australia by European colonists at the end of the 18th century. Despite the popularity and wide use of lawns for 200 years, there are only a few sources on the cultural and social history of the use of lawns in Australia. Butler-Bowdon [10] discussed the development of lawns in Australian cities, from the middle-class houses' patches of front and back lawns in mixed-use gardens of the late 19th century to

minimalist manicured lawns in Australian modernist gardens of the 1920–1930s which aimed to be an exterior room of a family house and demonstrated the social norms of the society. Particularly for the first European settlers who resided in dry and hot places of Australia such as Perth, lawns were an important tool for "civilising" towns as an opposition to the unfamiliar and very alien-looking native environment, "the bush" [11]. For the successful establishment of lawns, Australian settlers had to find appropriate grass species and employ effective techniques. They used grass species from South Africa, Asia, America and Europe to create turf/sod, enabling its use for recreational and sport purposes. The introduced lawn species needed new soils, the application of fertilisers, and the use of herbicides to successfully grow. Unlike Europe, where both grass species and weeds are native and thus considered to be a part of urban nature, lawns in Australia were used to delineate "civilised" urban areas from native vegetation ("native nature") and to create spaces with short cut grass, specifically designed for recreation and sports [12] (Figure 2).

(**a**) (**b**)

Figure 2. Lawn in a public park in Perth (**a**) and remnant of native "bush" (*Eucalyptus* woodland) within Perth metropolitan area (**b**). Photos: M. Ignatieva.

By the middle of the 20th century, lawns in Australian cities dominated public open spaces (POS) including parks and recreational reserves, foreshores, public gardens, nature reserves, civic areas and promenades. Thus, lawns in Australia are the subject of built infrastructure and designed landscapes [12]. There is a growing number of studies on the role of public open spaces and their benefits for human well-being. For instance, parks are assessed for their usage and activities [13]. Another example is a study conducted by Dickinson [14], which examined the overall non-material benefits of urban green spaces in Perth without specifying the typology of green spaces. There have been several studies on Australian lawns as an agricultural crop, e.g., how to prepare soils, grow lawn grass species and maintain a good lawn that provides a green smooth surface for play and joy [15]. While lawns in Australia face growing challenges to uphold a high-quality surface in an increasingly dry climate with a decreasing water supply, there is a lack of research dedicated exclusively to understanding lawns as an ecological and social phenomenon.

Growing urbanisation and the creation of cultivated and irrigated green spaces by replacing native forests and wetlands resulted in the dramatic loss of unique Australian ecosystems. That pushed to the development of a strong environmental movement aimed at conserving, protecting and restoring unique native biodiversity. Regarding growing climate change impacts, including a drying climate, higher temperatures, increased water scarcity and pollution due to herbicide and fertiliser use, the use of native plants and the rewilding of urban green spaces have gained more support. The main arguments for using native vegetation to replace lawns are to reduce water demand, improve the sense of local identity, enhance biodiversity and improve associated ecosystem services in urban environments. However, there are very few studies on the theoretical as well as practical application of potential alternative lawns. Grose [16] was one of the first who argued for a

rethink of the use and purpose of lawns in Perth's open spaces and argued for the necessity to establish lawns only in designated areas where grassed areas provide amenities and require less maintenance. One of the main arguments for the call to use native vegetation is that the local vegetation can reduce water demand and return native biodiversity to the urban environment. The reduction of water use is the red thread of new studies on public preferences for different landscape design scenarios that could decrease the irrigation needs in public parks. One example is redesigning park grounds and substituting some watered lawn areas with draught-tolerant native vegetation, groundcovers and mulch [17]. One particular type of lawn in Perth has received more attention as a potential for alternative solutions. These are lawns located on verges (areas between streetscapes and private property boundaries) [18].

In Australia, "true" alternative solutions to lawns (surfaces that are like lawns, e.g., grass-dominated communities that can accommodate trampling and regular mowing) could be inspired by different local grassy ecosystems and even by "hybrid" models where native herbaceous species are blended with the lawn's grasses. This approach could be similar to northern hemisphere countries such as Germany, Sweden, and France mimicking native meadows, pastureland, or open margins of temperate forests, which support grasses and low-growing vegetation [1,6,8]. Some Australian native grasses can be recommended as an alternative to classic lawn grasses, for example, *Microlaena stipoides*, *Danthonia* spp. and *Themeda triandra* [19], but they are not often used in the landscape design of urban public open spaces and need further studies.

Most existing lawn alternatives (especially in areas lacking native grassland biomes such as Western Australia) may be designed using perennial groundcovers and low-growing shrubs. The purpose of alternative solutions is to reduce the number of unused lawn surfaces, thus decreasing the use of water and avoiding ecological homogeneity by employing different landscape design patterns (colour and texture) as well as providing more biodiversity and ecologically friendly wildlife habitats [1]. However, compared to Europe, these alternatives in Australia do not provide an equivalent to conventional lawns.

Compared to Europe, lawns in Australia have never been an object of a separate scientific study, neither as a specific urban biotope or social phenomenon nor as an aesthetical element of public and private green spaces. This study aims to fill this gap in recognising lawns as complex socio-cultural and ecological entities in Australia. The main research question is as follows: "How do the people of Perth, Western Australia, define and use private and public lawns as well as understand their role in an urban environment?" Another research question is the following: "What are the current social values and preferences of different socio-economic groups of people toward existing traditional lawns and lawn alternatives that introduce new species, designs and management strategies?" One subquestion of this study is the following: "What is the current maintenance and perceived quality of local lawns in Perth?" This question aims to reveal the existing maintenance routine of urban lawns and, in perspective, suggest more sustainable and economical approaches. This particular question was included due to the recent decision to change the sprinkler roster for scheme water users in Perth and Mandurah, reducing from three days per week to two days per week [20].

This research is a part of a large interdisciplinary research project investigating the phenomenon of lawns in Perth from environmental (biodiversity), social (perceptions and attitudes), and design and planning perspectives to test alternative sustainable design solutions for urban lawns in a drying climate using empirical data and innovative technologies.

2. Materials and Methods

2.1. Study Area: Perth, Western Australia

Perth is the sprawling capital city of Western Australia founded by British colonists in 1829, appropriating the territory of the Wadjuk Noongar people. Perth is situated on a coastal plain, a narrow strip between the Darling Range and the Indian Ocean. The Wadjuk Noongar nation has occupied Perth and surrounding areas and managed the landscape for

at least 40,000 years. The city is located within what is known as the Southwest Australian Floristic Region (SWAFR), which is one of 35 biodiversity hotspots worldwide. The remnant native vegetation in the region is characterised by the richness of exceptional plant species, with about 8000 species, and high endemism [21]. Perth experiences a Mediterranean type of climate with hot dry summers (24.6 °C is the mean max temperature) and warm wet winters (12.7 °C is the mean minimum). The city has the highest level of daily sunshine among all Australian capital cities [22] which allows people to develop a year-round outdoor lifestyle. The annual rainfall is 850 mm of which about 90% occurs between April and October.

Perth's climate is different from the climates of major cities on the east coast of Australia. For example, Sydney is located in a humid subtropical climate with mild and cool winters, warm and hot summers, and no dry seasons, with an average rainfall of around 1175 mm a year. Melbourne is located in a temperate oceanic climate with an average rainfall of around 650 mm a year and even a rain distribution pattern throughout the year. The closest climate among Australian cities is Adelaide in South Australia which is also located in a Mediterranean type of climate with an average rainfall around 550 mm a year. However, Perth is hotter than Adelaide in the summer, and Adelaide is cooler in winter.

Below Perth, there are three layers of aquafers: superficial, the deeper Leederville Aquifer, and the lower Yarragadee Aquifer with ancient waters that are 40,000 years old and with an extraordinary capacity of water (1000 cubic kilometres of water). No other Australian city and not many cities around the globe have such extensive aquafers. This unique hydrological system supports Perth's rivers, wetlands, minor waterways, and diverse native vegetation. It supplies an important part of potable scheme water [23]. For many decades, Perth's green spaces, including lawns, had the privilege of being watered several times a week. However, the mean annual rainfall in Perth has declined significantly since the 1970s with a 30% reduction in stream flow. While Perth is located in a relatively wetter area of Western Australia, the reduction in rainfall and stream flow means there is a strong reliance on subterranean aquifers and the desalination of sea water to supply potable water for the growing population of Perth [24]. The mixture of groundwater (47%) and desalinated water (53%) makes Perth unique compared to other state capitals in Australia that are highly dependent upon surface water [23].

The Perth metropolitan area covers about 1640 km^2 and extends 150 km north–south along the Swan Coastal Plain confined between the Indian Ocean to the west and a scarp (the Darling Scarp) on the eastern boundary that restricts the east–west urban sprawl to about 50 km wide. The most recent census, conducted in 2021, indicated there were nearly 2.1 million residents living in the greater Perth area [25] (Figure 3). Perth's urban planning structure is based on the classic colonial grid that was subsequently transformed into a downtown low-density suburbia pattern in the 20th century. The city is dominated by single-story, owner-occupied homes with small gardens. Green and blue spaces within the city mainly consist of publicly accessible nature reserves based on remnants of native vegetation and designed urban public parks, including pocket parks planted with mainly exotic plants or a mixture of native and exotic species.

Lawns are a prominent feature of Perth's landscapes. In Perth's 'Urban Zone' (as defined by the Metropolitan Region Scheme or MRS), 7% is covered by lawns, 12% is made up of tree canopies and the remaining 81% is impervious or built areas (buildings, roads, pavements). Public open spaces (POS), water bodies and industrial zones are separate types of land use in the MRS. Within areas zoned public open space (including regionally significant parks and recreational reserves, foreshores, public gardens, nature reserves, civic areas and promenades), lawns cover 26% of the total area. Lawns in private gardens and verges (areas in the public road reserve between the carriageway and the boundary of property) are the leading category (53%), followed by lawns in smaller local parks (37%). The domination of lawns in public parks and gardens reflected the accepted picturesque–gardenesque landscape design "formula" where tree belts, tree groves and single trees are scattered on short-cut lawns [1].

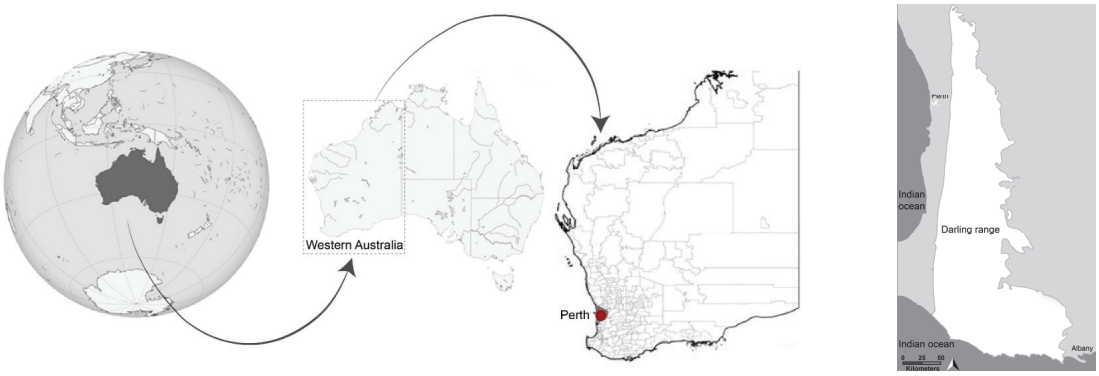


Figure 3. Map location of Perth, Western Australia. Map produced by authors based on the figures sourced and adapted from Wikimedia. CC BY 3.0 https://commons.wikimedia.org/wiki/File:Australia_on_the_globe_(Australia_centered).svg accessed on 7 December 2023 (**left image**) and https://creativecommons.org/licenses/by-sa/3.0/deed.en accessed on 7 December 2023 (**right image**).

2.2. Online Questionnaire

An online questionnaire was developed to ascertain Perth's residents' perceptions and preferences associated with lawn alternatives, using the Qualtrics online survey tool [26]. The questionnaire included a total of 37 open and multiple-choice questions about different aspects of urban lawns (Table S1) with four major themes related to the research questions:

1. General understanding of what a lawn is and its main purpose;
2. Uses of a lawn (human and non-human);
3. Maintenance and perceived quality of local lawns;
4. Perceptions and preferences associated with lawn alternatives.

The general understanding of what a lawn is, and its main purpose, was ascertained by asking respondents to write a brief definition and then a brief comment about the main purpose of urban lawns. To measure lawn and lawn alternative preferences, respondents rated and then ranked a series of five images of lawn alternatives (Figure 4). The images were selected based on an analysis of existing experimental lawn alternatives of living labs in Perth [27]. An experimental trial in Perth, "Lawn as an Ecological and Cultural Phenomenon", was designed in 2021. We also analysed existing alternatives in Europe and Australia including pictorial meadows, naturalistic plantings, grass-free lawns, weedy lawns and woody meadows. Our vision of alternative solutions is based on understanding the essence of lawns as durable surfaces that can endure a certain amount of trampling and other kinds of human activity.

(**a**) (**b**) (**c**) (**d**) (**e**)

Figure 4. Lawn alternative images used in the questionnaire. Lawn with turf grasses and Dichondra (**a**); lawn with turf grasses and clover (**b**); Scaevola patches in dedicated spaces (**c**); 'old' uncut high grass lawn (**d**); biodiverse lawn with turf grasses and flowering weeds (**e**). Photos: M. Ignatieva.

While there are some limitations in using photographs to depict an image to the survey participants [28,29], photo survey remains the most commonly used and reliable methodology for the aesthetic evaluation of a landscape that includes a variety of environmental contexts including urban environments, agricultural fields, and wilderness [30–33]. The value of using images in the questionnaires for a better understanding and visualisation of ecological information in urban landscapes has also been acknowledged by American [34], English [35] and Australian [17] scholars. The most recent example of using direct photographs in existing demonstration lawn trials in a questionnaire related to residents' perceptions of and preference for the lawn alternative was conducted in the city of Xianyang, China [36].

The questions were related to private lawns as well as to lawns in the nearest public parks.

The survey was distributed online using a snowball sampling method. An invitation to complete the questionnaire was sent via email to the researchers' professional and social network residents in the Perth metropolitan area. The email invitation asked participants to forward the questionnaire to others in their own social networks. This snowball sampling approach extended the sample to a broader pool of participants. The respondent sample included participants from across the Perth metropolitan area.

2.3. Data Analysis

The data analysis included a content analysis, descriptive statistics and modelling to explain the effects between respondent characteristics and other survey responses. Written responses to open-ended questions ascertaining the respondents' general understanding of what a lawn is and its main purpose were analysed using inductive content analysis [37]. The responses were manually coded to identify common terms, which were grouped by similar meaning to identify key response categories. Coding was conducted independently by the researchers and then compared and discussed to resolve any discrepancies. Descriptive statistics were used to describe respondent demographics, uses and management of lawns and lawn preferences. Finally, a logit model was used to estimate the effects of explanatory variables on lawn use, management, perceptions and preferences (Table 1).

Table 1. Description of dependent and independent variables for logit model.

Variable Name	Description
Private/or public	Dependent variable: Value 1 if respondent had private lawn, 0 otherwise
Age group	Value 1 if age of the respondent between 18–24 years, 2 if 25–34 years, 3 if 35–44 years, 4 if 45–54 years, 5 if 55–64 years, 6 if 65 years or above
Identity	Value 1 if male, 2 if female, 3 if third gender, 4 if prefer to self-describe, 5 if prefer not to say
Dwelling	Value 1 if detached house, 2 if flat or apartment or townhouse, 3 if others
Residence	Value 1 if Australian, 2 if non-Australian
Employment	Value 1 if full-time, 2 if part-time, 3 if home duties, 4 if unemployed, 5 if retired, 6 if student, 7 if others
Education	Value 1 if primary, 2 if secondary, 3 if university graduate, 4 if university postgraduate, 5 if other, 6 if vocational training

Logit models are commonly used to examine factors influencing preferences, perceptions and behaviours such as the adoption of agroforestry practices [38–40], slash and burn agriculture [41], REDD+ [42] and composting [43]. For this study, the logit model is specified as follows:

$$logit\ (Y) = \ln\left[\frac{p_i}{1-p_i}\right] = \alpha + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \cdots + \beta_k X_{ki} \quad (1)$$

where Y represents a private lawn ($Y = 1$ if respondents have a private lawn and $Y = 0$ if respondents have no private lawns), subscript i refers to the i-th observation in the sample, p is the probability of the adoption of a private lawn. α is the intercept term, X_1, X_2, X_3, . . ., X_k are explanatory variables and β_1, β_2, β_3, . . ., β_k are coefficients of explanatory variables. These coefficients were estimated using the maximum likelihood method.

2.4. Respondent Demographics

The majority of respondents were females (53%) aged between 35 and 64 years of age (55%) (Table 2). Most respondents had a university-level education (81%). They worked full-time (61%) and lived in a detached house (82%) with a private lawn, as shown in Table 2. These data generally align with the census data for the Perth region, where 51% of the population is female, the median age is 37 years, 57% work full-time and 79% live in a detached house [25]. The level of education is notably higher for our survey sample when compared with the greater Perth population (26% with a university degree). Analysis indicated that age generally did not influence the responses to the survey.

Table 2. Socio-demographics characteristics of respondents.

Identity	**n**	**%**	**Age Group**	**n**	**%**
Male	61	41.78%	18–24	14	9.52%
Female	78	53.42%	25–34	25	17.01%
Non-binary/third gender	1	0.68%	35–44	38	25.85%
Prefer to self-describe	2	1.37%	45–54	42	28.57%
Prefer not to say	4	2.74%	55–64	15	10.20%
Total responses	146	100%	65 or older	13	8.84%
Place of residence			Total responses	147	100%
Australia	144	97.96%	Employment type		
Outside Australia	3	2.04%	Working full-time	89	60.54%
Total responses	147	100%	Working part-time/casual	25	17.01%
Type of dwelling			Home duties	5	3.40%
Detached house	120	82.19%	Unemployed	0	0.00%
Flat/apartment/townhouse	22	15.07%	Retired	8	5.44%
Other (please specify)	4	2.74%	Student	20	13.61%
Total responses	146	100%	Other	0	0.00%
Education			Total responses	147	100%
Primary school	0	0.00%			
Secondary school (high school)	13	8.90%			
University graduate	54	36.99%			
University higher degree (postgraduate)	65	44.52%			
Other	3	2.05%			
Vocational training	11	7.53%			
Total responses	146	100%			

3. Results

3.1. General Understanding of What a Lawn Is and the Purpose of Lawns

There were a variety of different lawn definitions. For example, participants described lawns such as "A flat green groundcover popular in urban areas. Various types of turf"; "An area of maintained grass around a house or park"; "Urban green, well main-

tained turf represents wealth"; "Grass, turf, green non-native soft ground cover often used on verges. Takes a lot of water and mowing and edging"; "A green expanse of turf"; "A specific irrigated green space installed for fit for purpose uses such as play or wellness areas in both residential and non- residential areas"; "I consider lawn to be a space of grass used for ornamental purposes or various activities including, sports, social interactions and personal recreation"; "Tended turf grass that is mown and provides amenity for humans and pets and can be found in public spaces and homes".

Through coding, we generated seven categories identified based on a content analysis of lawn definitions: flat area; ground cover by grass; maintained; non-native vegetation; open space; recreational space; and turf grass (Figure 5). The most common definition related to a lawn was "a ground cover by grass".

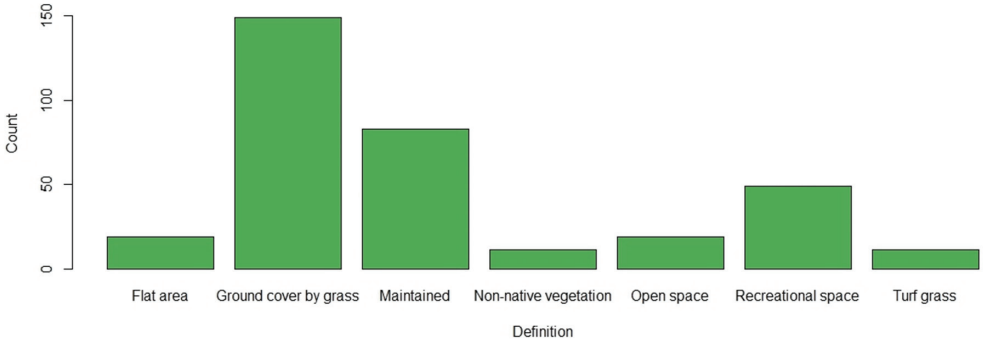


Figure 5. Categories identified based on content analysis of lawn definitions.

The other common definitions included concepts associated with a lawn being a surface that is "maintained" and used as a "recreational space" which demonstrates an understanding of the ecological and social essence (maintained grassy surface for recreation) of lawns by Perth dwellers. The common appearance of the words "non-native vegetation" in the definition also indicates an awareness about the origin of urban lawns in Australia (an introduced element from Europe).

The respondents most commonly identified the purpose of lawns as being for "recreational use", "aesthetics", "cooling effect", "ecosystem support" and "social status" (Figure 6).

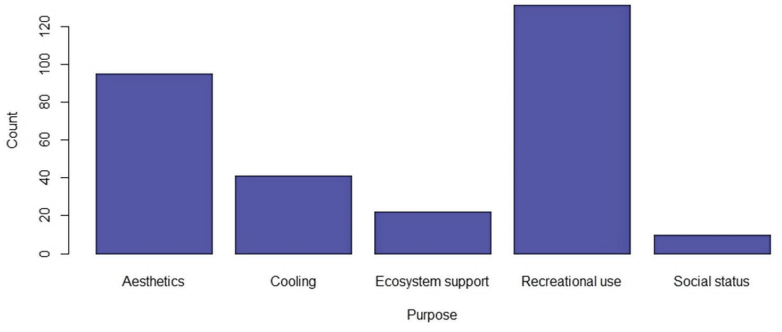


Figure 6. Purpose of lawns categories.

3.2. Uses of Lawn (Human and Non-Human)

3.2.1. Respondent's Use of Private Lawns

Around 49% of respondents often used their private lawns for passive recreation (sitting, socialising) followed by playing games (32%) and light exercise (26%), while only

7% of respondents used private lawns for vigorous exercise. More than 35% of respondents reported sometimes using their private lawns for light exercise, vigorous exercise, playing games and passive recreation (Table S2 and Figure 7).

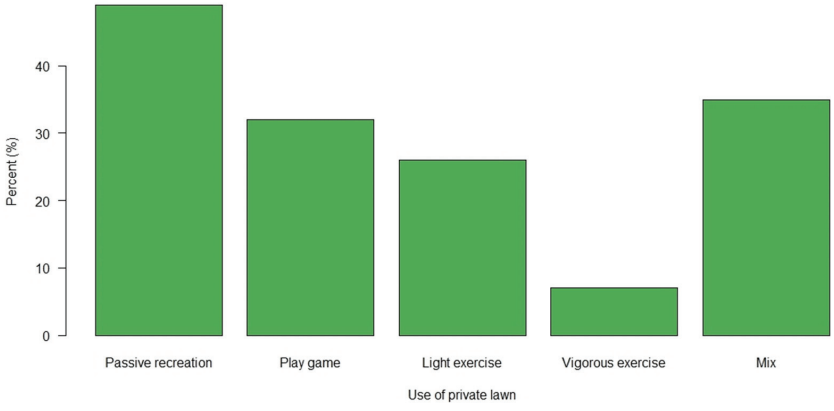


Figure 7. 'Often'-reported uses of private lawns for various activities.

3.2.2. Use of Public Lawns

Around 52% of respondents often used public parks for light exercise, 49% for walking pets, 41% for a transit area, 24% for passive recreation, 20% for vigorous exercise, 18% for social gatherings and 14% for sports (Table S3 and Figure 8).

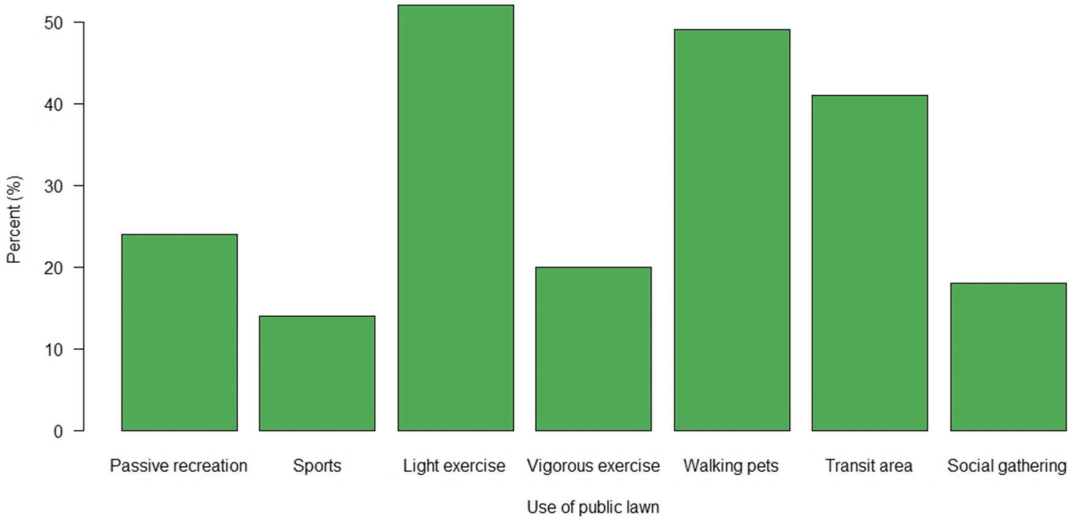
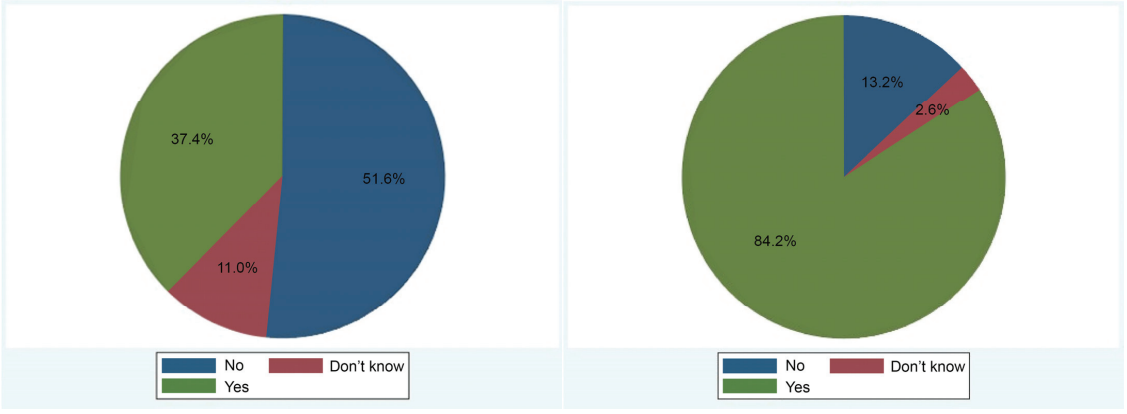


Figure 8. 'Often'-reported uses of public parks for various activities.

3.3. Lawn Use (Habitat) for Animals

Figure 9a represents respondent perceptions about whether the lawn is a good habitat for animals. About 37% of respondents reported that lawns are good habitats for animals, whilst more than half of the respondents reported that lawns are not good habitats for animals. Figure 9b shows that 84% of respondents reported that public and private lawns were also used by animals.



(**a**) (**b**)

Figure 9. Perception about the lawn as a good habitat for animals (**a**) and animals using public or private lawns (**b**).

Respondents most often mentioned dogs, birds (ibis, magpie, willy wagtail, pink galah, corella, and Australian wood ducks) and sometimes kangaroos foraging on lawns (Figure 10). One of the respondents noticed "Native bees, particularly where clover is present".

(**a**) (**b**)

Figure 10. Magpies (**a**) and ibises (**b**) use public park lawns to forage in Perth.

3.4. Maintenance and Perceived Quality of Local Lawns

Private Lawn Maintenance

Around 39% of respondents mowed their private lawns once per fortnight followed by 37% of respondents who mowed their lawns once every month, whilst 3% of respondents had never mowed their private lawns since their establishment (Figure 11).

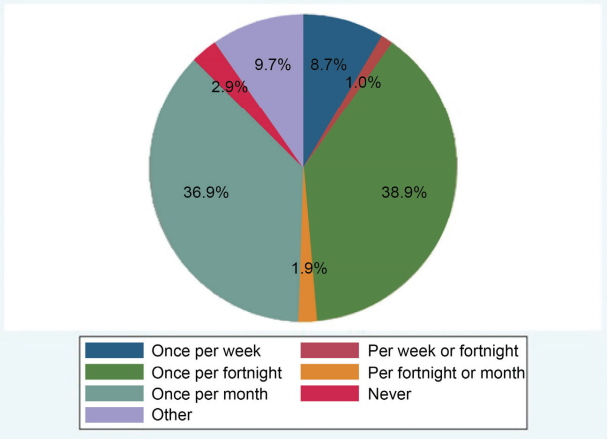


Figure 11. Frequency of mowing private lawns.

Around 45% of respondents preferred 3 to 5 cm tall lawns, and 40% of respondents preferred short lawns (less than 3 cm tall) (Figure 12).

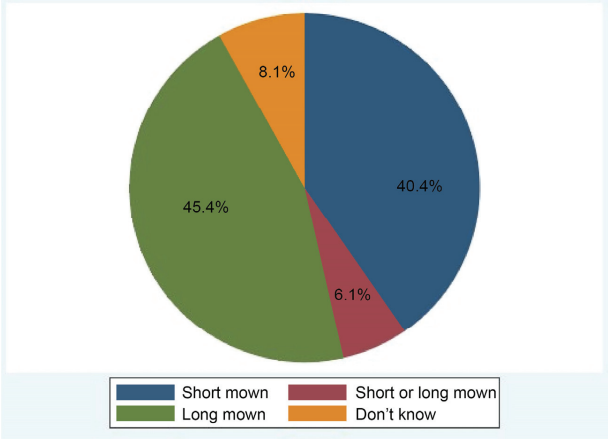


Figure 12. Height of private lawn.

Table 3 shows various lawn management techniques used by the respondents, and we found that 92 respondents used mowing methods followed by fertilisers (73 respondents), removed mown grass clippings (69 respondents) and added soil wetting agents (69 respondents as well).

Table 3. Summary of various lawn management techniques.

Lawn Management Techniques	**Obs.**
Removing mown grass clippings	69
Fertilising	73
Applying herbicides	32
Adding soil wetting agent	69
Mowing	92

Around 93% of respondents regularly watered their private lawns (Figure 13).

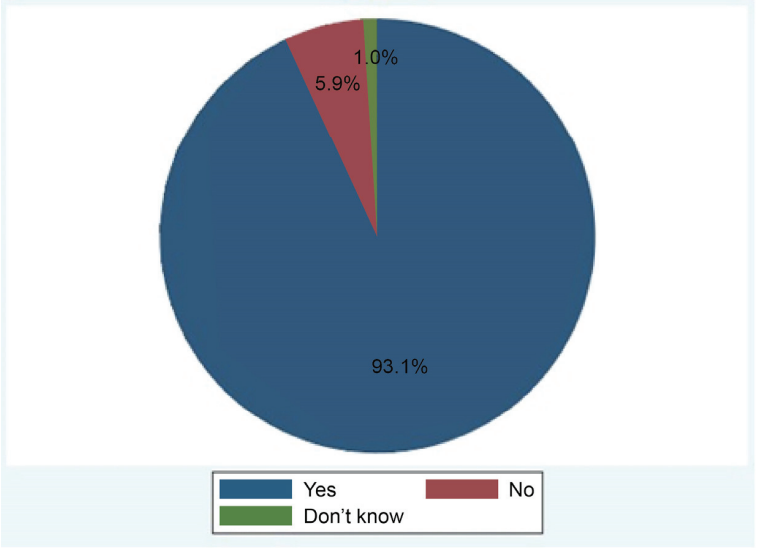


Figure 13. Regular watering of private lawns.

Only three respondents did not regularly water their private lawns because they thought lawns survive without watering (Table 4). These people mentioned the reasons why they do not irrigate lawns. For some, it was okay if the lawn died during dry summer months, while others believed that watering the lawn is a waste of water and that lawns survive without watering.

Table 4. Reasons for not watering private lawn.

Reason for Not Watering Lawn	Obs.
No reticulation system	0
No time to hand water	0
Lawn survives without watering	3
Watering the lawn is a waste of water	1
OK if the lawn dies during dry months	2
Other	3
No sprinkler	0
I don't know how to keep my lawn healthy and green during summer	1

3.5. Perceived Quality of Lawns

Around 37% of respondents were very satisfied with the quality of private and public lawns, which was followed by 33% of respondents who were somewhat satisfied and 16% of respondents neither satisfied nor dissatisfied. In addition, only 2% of respondents were very dissatisfied with the condition of private and public lawns (Figure 14).

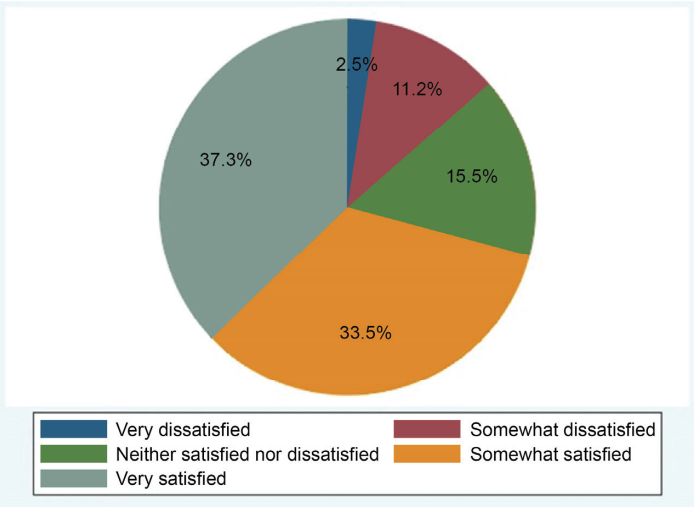


Figure 14. General impression about the quality of private and public lawns.

3.6. Perceptions and Preferences Associated with Lawn Alternatives

Most respondents indicated that Scaevola patches were good (61%), while lawns with turf grasses and Dichondra were the second most commonly positively rated image (57%). The least positively rated image was the old uncut high grass lawn (15%) (Table S4 and Figure 15).

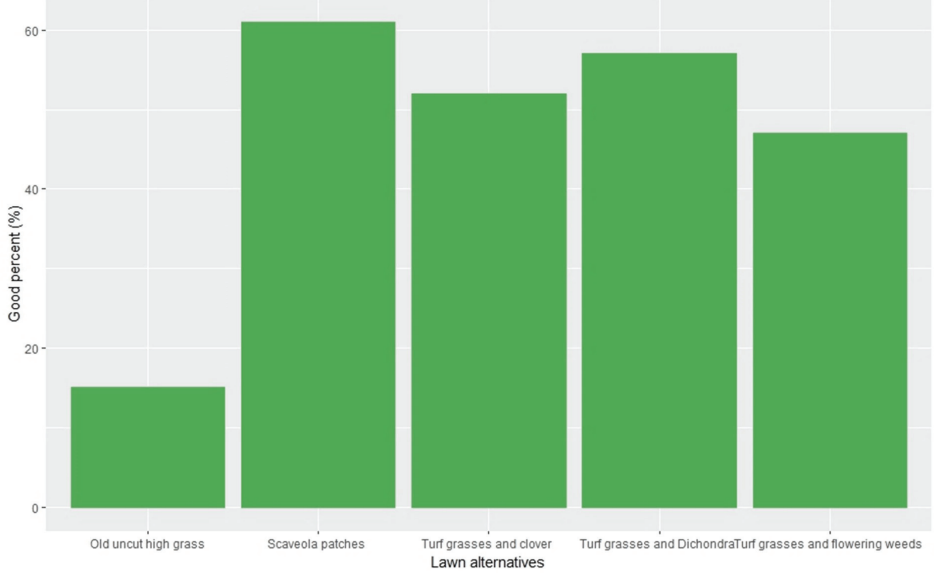


Figure 15. Positive rating of lawn alternatives.

Figure 16, Tables S5 and S6 present the ranking of five lawn alternatives that could be used in urban public parks. Around 35% of respondents ranked lawns with turf grasses and Dichondra above the other lawn alternatives. In contrast, old uncut high grass was ranked the lowest by 56% of respondents.

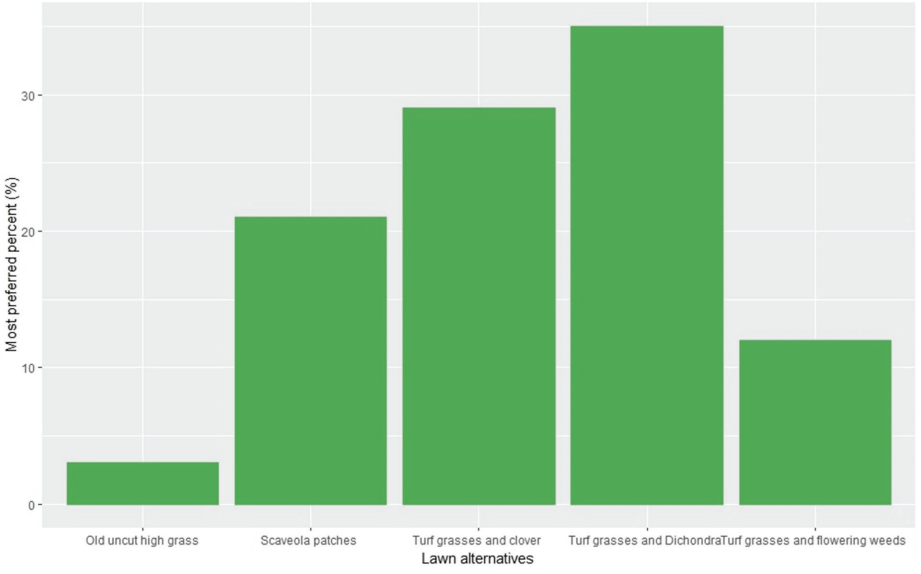


Figure 16. Comparative ranking of five lawn alternatives that could be used in public parks.

3.7. Summary of Logit Model Results

Our results show that the majority of respondents have private lawns. The age of the respondent, the type of house they live in, their education level, and retirement status had a significant effect on the ownership of private lawns (Table 5). Older respondents (aged 35–44, 45–54 and 55–64) had an increased log of odds for owning private lawns, respectively, compared to younger age groups (18–24). The age groups 25–34 and over 65 years had no significant effect on the ownership of private lawns (Figure 17).

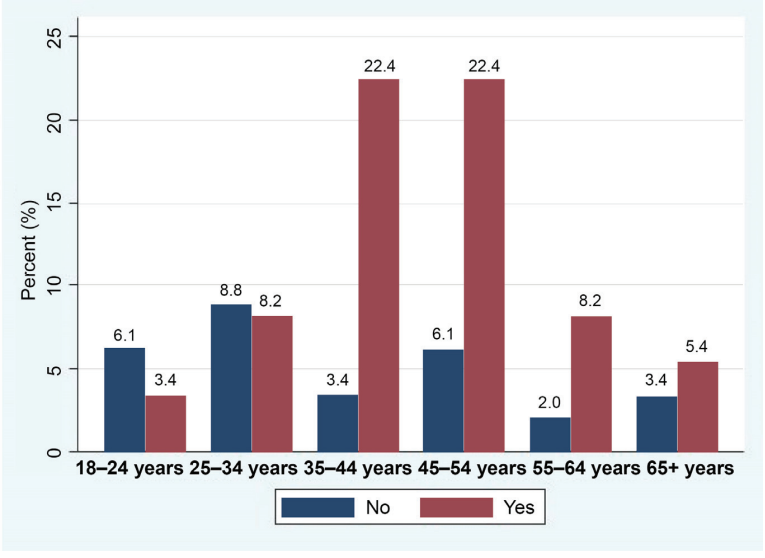


Figure 17. Ownership of private lawn by age group.

Table 5. Effect of socioeconomic variables on use of private lawn using a logit model.

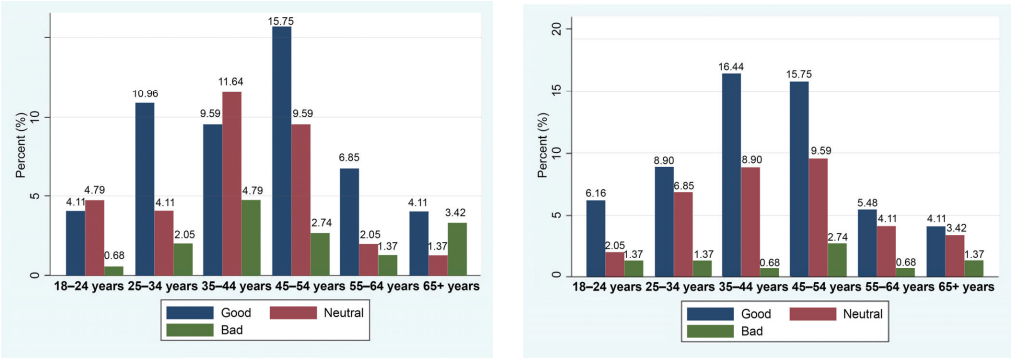
Variables	Coefficients
25–34 years old	0.474
	(0.855)
35–44 years old	2.202 **
	(1.078)
45–54 years old	1.863 *
	(0.981)
55–64 years old	2.612 **
	(1.057)
65+ years old	1.003
	(1.252)
Female	−0.724
	(0.552)
Prefer not to say	−3.325 ***
	(1.276)
Flat/apartment/townhouse	−2.521 ***
	(0.658)
Other (please specify)	−0.570
	(1.398)
Outside Australia	0.643
	(1.312)
Working part-time/casual	−0.211
	(0.728)
Home duties	−0.512
	(1.079)
Retired	−2.188 *
	(1.238)
Student	−0.623
	(0.865)
University graduate	−1.291
	(0.967)
University higher degree (postgraduate)	−1.215
	(0.949)
Other	−4.388 **
	(1.835)
Vocational training	−0.499
	(1.335)
Constant	1.893
	(1.242)
Observations	141

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

3.8. Preferences for Lawn Alternatives by Age Group

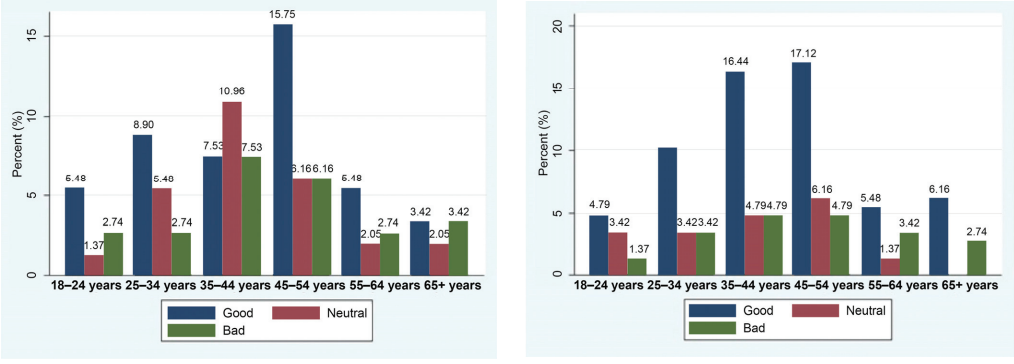
Figure 18a shows that at least 10% of the respondents from the age groups 25–34 years, 35–44 years and 45–54 years were more likely to prefer lawns with turf grasses and clover in our study. In addition, at least 9% of the respondents from the age groups 25–34 years, 35–44 years and 45–54 years preferred lawns with turf grasses and Dichondra (Figure 18b).

Around 16% of the respondents from the age group of 45–54 years preferred a biodiverse lawn with turf grasses and flowering weeds, followed by 9% for the age group of 25–34 years and the least (3%) for the older age group (Figure 19a). But for Scaevola flowering patches in dedicated spaces, around 17% of respondents from the age group of 45–54 years considered that it is a good idea, followed by 16% of respondents from the age group of 35–44 years, whilst younger respondents appreciated Scaevola patches the least (Figure 19b). The old uncut lawn option was unpopular among all age groups (Figure 20).



(**a**) (**b**)

Figure 18. Preference for lawn alternative with turf grasses and clover (**a**) and preference for lawn alternative with turf grasses and Dichondra (**b**).



(**a**) (**b**)

Figure 19. Biodiverse lawn with turf grasses and flowering weeds (**a**) and Scaevola patches in dedicated spaces (**b**).

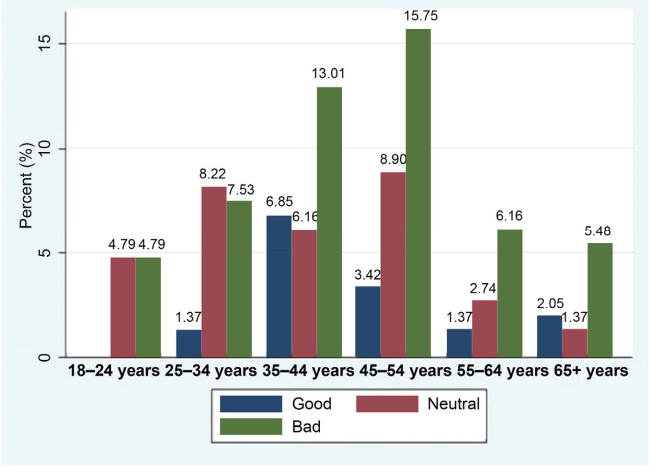


Figure 20. Old uncut high grass lawn.

3.9. Preferences for Lawn Alternatives by Lawn Definition and Purpose

The results showed no significant effect of lawn definition or purpose on lawn preferences (bad, neutral and good) of lawn alternatives (Figure 21).

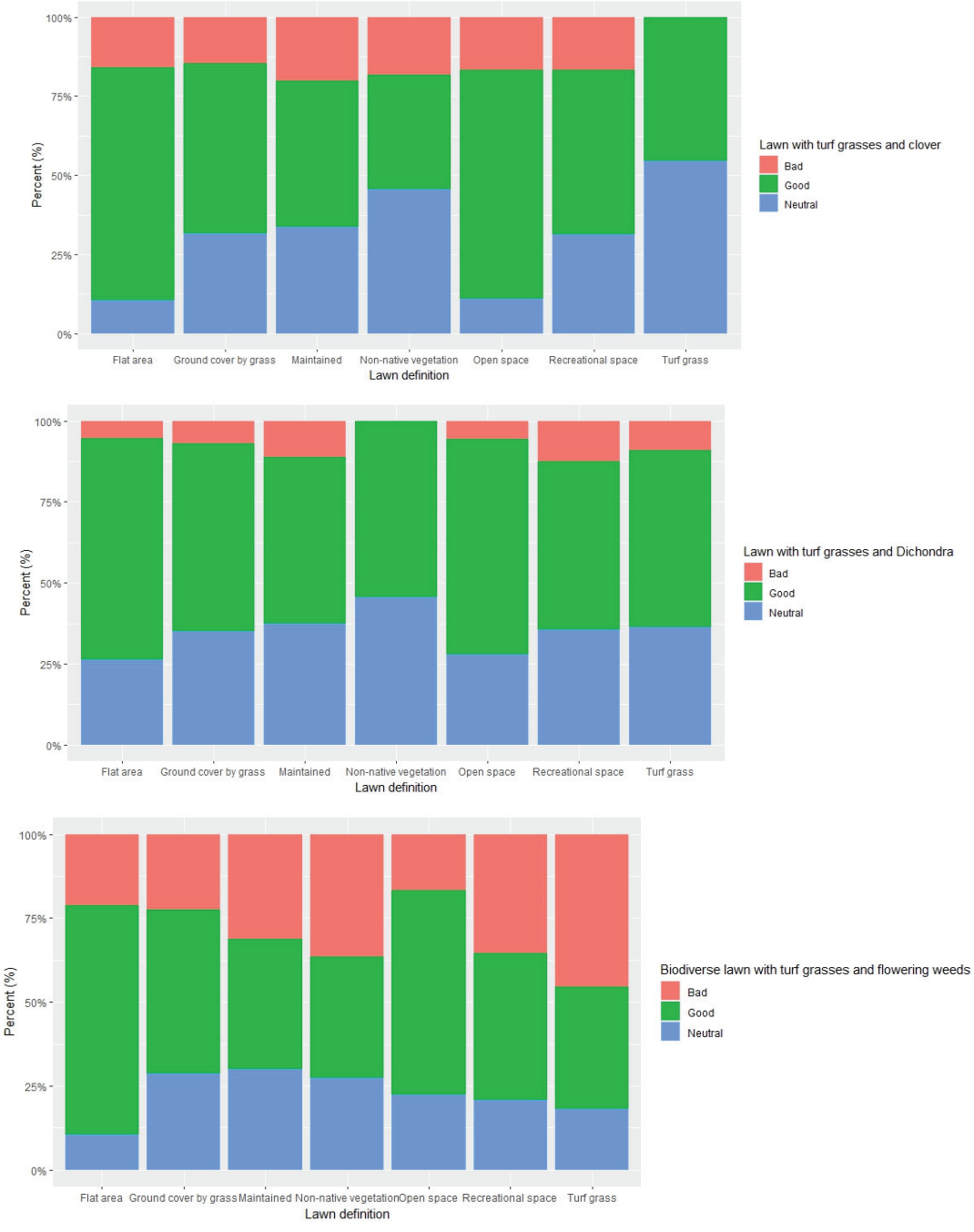


Figure 21. *Cont.*

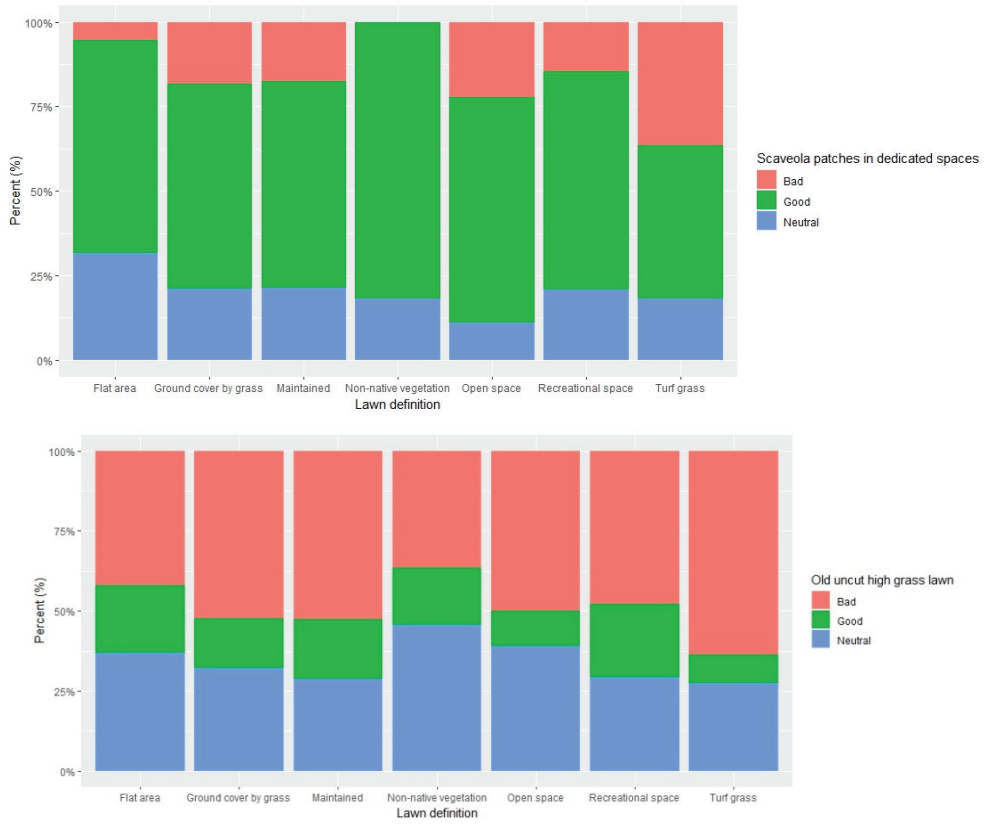


Figure 21. Definition of lawn groups combined with the alternative preferences for lawn alternatives.

Respondents who indicated the primary purpose of lawns being for social status (classical lawn) also positively rated lawns with turf grasses and clover. Turf grasses and clover were also highly rated among respondents, as it was the closest to the conventional lawn alternative option "turf grasses with Dichondra" (Figure 22).

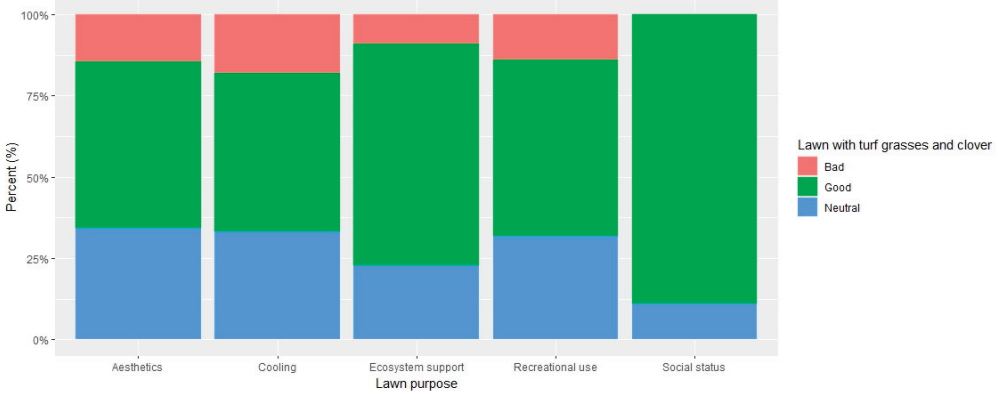


Figure 22. *Cont.*

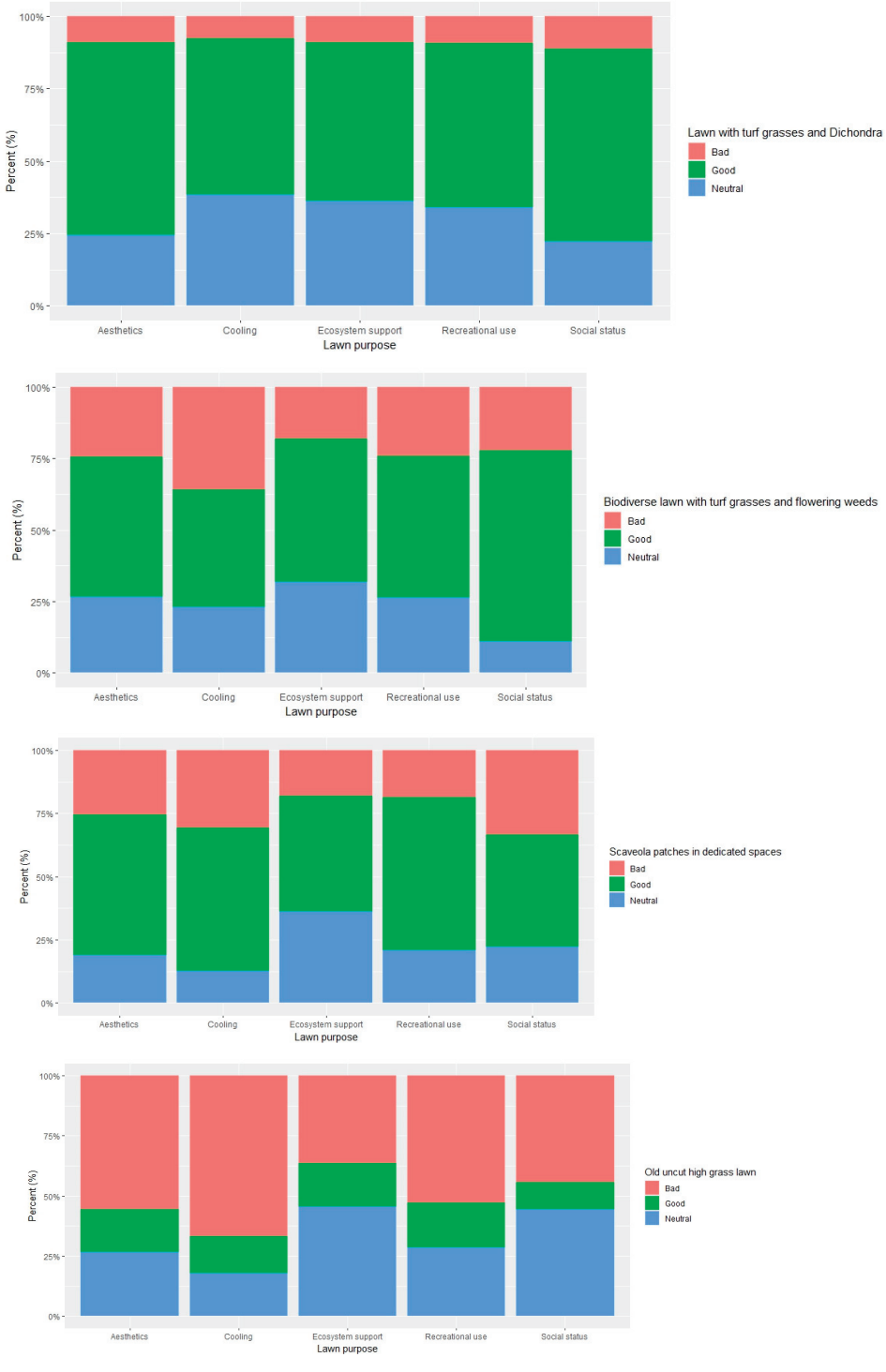


Figure 22. Purpose of lawns (overall) combined with the alternative preferences.

4. Discussion

4.1. Understanding of What a Lawn Is and Its Main Purpose and Use

The analysis of lawn definitions demonstrated that Perth's residents understand the ecological essence of a lawn, which is a ground covered by grasses that requires constant maintenance (irrigation, mowing, fertilising and weeding). Irrigation is one of the most important maintenance operations for Perth lawns because of long, dry and hot summers. Significant maintenance is required to create the desired grass-dominated plant community all year round. The use of terms such "non-native vegetation" and "open" spaces in the definitions also demonstrates the familiarity of some respondents with the environmental peculiarity of Australian urban spaces where all lawn grasses have been introduced from other parts of the world. The "public open spaces" (POS) is widely used in Australian governmental documents such as city masterplans and strategies [12], and knowledge of this term was indicated by many participants.

Some respondents provided quite detailed answers where they demonstrated knowledge of horticulture, landscape design and environmental sciences (e.g., "intensively managed area of turf grass and in between of hardscape and softscape"; "a variety of monocot cultured for its consistent pleasing green appearance" and "invasive species of grass"). This can be explained by the level of education of the respondents which is notably higher than the general population for our survey sample (81% university graduates and postgraduates). Other than the response to this question, the level of education generally did not have a significant effect on responses.

Another important term commonly used to define lawns was "turf grass". This corresponds with the overall tendency in Australia to use the term "turf" instead of "lawns". The term "turf" but not "lawn" dominates in all governmental documents (masterplans and urban development strategies) and landscape architecture and horticulture publications. The turf industry grows turf that is installed in public and private spaces. In Australia, the terms "turf" and "lawn" are synonymous. Even from an ecological point of view, turf is "the surface layer of soil with its matted, dense vegetation, usually grasses grown for ornamental or recreational use" [44]. Once turf (sod) is installed on the ground, it becomes a lawn—a particular grass-dominated plant community which is regularly maintained and which is "the issue of natural processes such as climate, growing of other species from existing seed banks, competition between species, developing of the microbial communities" [27] (p. 419). In the world's scientific and popular literature related to urban grass-dominated surfaces, "lawn" is the most commonly used term. In Australia, it was not until 1930 when turf farmers, who grow grass for dairy pastures, started to cut grass into strips and then sell them. Since that moment, the turf industry has developed, and an 'instant lawn' has become available for private homeowners and public green managers [45].

The association of lawns as a "recreation space" was among the most often mentioned categories. It also corresponded with the results of the use (purpose) of Perth lawns where "recreation" was the dominant category. From the very beginning, the lawn in Australia was designed to be a special amenity for sport and leisure.

The analysis of "purpose of lawn" answers demonstrated that respondents identified categories similar to the ecosystem services typology indicated in recent lawn research [3,5]. Recreational activity was most common, followed by the aesthetic qualities of lawns (both belong to cultural service), then cooling effect (regulating service), ecosystem support and social status. The appearance of "Ecosystem support" in participants' answers also indicated the respondents' awareness of environmental issues in urban environments such as urban heat and increasing dryness. The dominance of recreational use can be also explained by the climatic reasons and lifestyle of the people of Perth who are using the advantage of sunny and warm climates for recreational activities and can use lawns throughout the year. The positive effect of lawns for cooling urban spaces during the summer months in the Mediterranean climate has been indicated also for Santiago de Chile [46].

The high appreciation of the aesthetic value of lawns in Perth is connected to colonial heritage and nostalgia for the green colour of the British countryside. Urban "lawnscapes" were used in the battle against dust, sand and heat and as a tool for the "beautification" of the urban environment which should look more familiar and thus aesthetically pleasant [11]. The participants from Perth wrote such phrases pertaining to lawns as "aesthetic appeal", "aesthetic/beautification", "lawn is Australian Dream" and "turf is imbedded in Australian culture".

The beauty and tranquillity of the green colour provided by lawns are mentioned by urban citizens in other countries (e.g., Sweden and Germany), even in places where the green colour is quite dominant in all other types of urban green spaces and not only in lawns [5].

The use of the category "social status" that was identified by Perth's participants corresponded with the ecosystem service of "enhancing private property value, the symbol of prestige and power" that was identified for global lawns [1,5]. The aesthetic and social status are very connected in the case of Perth where green and well-kept private lawns indicated a local community status and an individual property status. The association of lawns with a "good citizen" and wealthy owners was reinforced during the modernist period in Australia when the minimalist well-kept low-cut lawns demonstrated the social norms and values of society [10]. Participants particularly noticed that lawns "provide eye-pleasing aesthetics to property" and that regarding having a lawn, "it represents wealth".

4.2. Use of Lawns for Various Activities (Human and Non-Human)

The analysis of activities in private and public lawns revealed that private lawns are used mostly for passive recreation, playing games and light exercise, while public lawns are mostly used for light exercise, walking with pets and as a transit area. Picnicking and playing sports also represented Perth's residents' favourite activities. Lawns in Perth cover a significant amount of space in public parks and school grounds. Interestingly, in a different part of the world, in the Swedish city of Malmö where public lawns are a prevalent type in public green spaces (parks and residential green spaces), typical activities have been shown to be very similar (walking, playing, jogging/exercising and transit) [5].

Lawn surfaces were created in place of native vegetation and bushlands, and the question of whether lawns are used by animals holds an important environmental and social message, given the increasing concern about losing native biodiversity in Perth. The participants provided quite detailed answers and mentioned native birds that often forage on lawn surfaces, including more generalist urban species as well as ibis and several parrot species (corella and galah) that have adapted to rely on grasses, clover and some weeds. People even noticed visits from kangaroos in some private lawns. Other creatures such as insects (including some native and honeybees) forage on flowering clover and weeds. Ants and lizards were noticed as well. Thus, these findings confirm that the lawn is seen as a specific novel biotope that attracts particular species that adapt to anthropogenic habitats. Dogs are also considered an important "user" of lawns in Perth.

Compared to European lawns, which have more native herbaceous plants (e.g., clover) that can bloom because of a more 'relaxed' mowing regime, Perth lawns are more homogeneous and less attractive for pollinators. However, Perth lawns are irrigated and attract more wildlife during the summer months compared to lawns in other parts of Australia where lawns are not irrigated during summer.

4.3. Maintenance and Perceived Quality of Local Lawns

The majority of respondents were satisfied with the quality of private and public lawns in Perth. For example, comments included that lawns are "kept green and tidy" and are "very well maintained and cared for by the LGA (Local Government Authority)". This "greenness" and good appearance is related to the regular irrigation of lawns in Perth in the summer months, frequent mowing (so that the grass is kept quite short to a length of less than 3 cm) the input of fertilisers and soil conditioners, which enable the retention

of moisture in the soil, and the provision of necessary nutrients to shortly cut grasses. Another important maintenance operation for Perth lawns is applying herbicides against spontaneously growing plants—weeds. The use of herbicides is a particularly controversial maintenance operation that is criticised by environmentalists as being harmful to people and the environment (water pollution). In many European countries, the use of herbicides in public green spaces is prohibited [5].

In our analysis, the demographics of participants that own private lawns showed that the groups of ages 35–44, 45–54 and 55–64 mostly own lawns and thus maintained lawns compared to the younger people. The older age groups own private lawns, potentially due to their greater financial stability, enabling them to be able to afford to buy a house with lawns, while the age groups containing younger participants may face financial constraints that make it challenging for them to own a house, including one with a lawn.

Among the respondents, there were also comments that the "Lawn is hard to keep in dry, hot Western Australia"; "The lawn closest to where I live is basically abandoned in summer and dries out"; "Public lawns can be overdone, e.g., some parks near me are excessively lawn-ey". People acknowledged the high level of care of public open spaces in Perth: "Having lived overseas I understand that well-maintained public spaces are a privilege. Upkeep of lawns is time-consuming and expensive, so we are very lucky to have the lawns are close to perfect". Recent hot summers in Western and Central Europe showed that places with no watering become dusty and fire-prone, thus turning ecosystem services into disservices [1,3]. However, this greenness is made possible at the expense of using water and a high input of resources. According to the Government of Western Australia Department of Water, 17% of urban water use goes to the irrigation of public parks. However, public park design and planning strategies have not planned to change the extent of lawns in sports ovals and some other grassed recreational spaces in the near future [17] because of the importance of lawns for human health during hot summers. The recent regulation on watering green spaces (including lawns) in Perth pushes for searching for more sustainable solutions, including for the maintenance of lawns, and more effective lawn surfaces that, on the one hand, can withstand heat and draught and, on the other hand, can create appropriate spaces for human recreation and even habitat provision.

4.4. Perceptions and Preferences Associated with Lawn Alternatives

In European countries, one of the most common alternatives to lawns is a meadow consisting of grasses and flowering perennials. The lawns can be turned into biodiverse meadows by decreasing the frequency of mowing which is often called "easy management" [6]. Recent research in European [6,47] and South American cities [46] confirmed that reducing the mowing frequency had a positive impact on plant and wildlife diversity. Because of the existence of sod, cut meadows could still be used for recreation similar to conventional lawns. There is also a series of alternative solutions in Europe and North America such as naturalistic plantings with a mixture of native and flowering exotic vegetation that aims to increase biodiversity and attract pollinators, particularly to improve the diversity of streetscapes, and decrease management input [9]. In Australia, there are only a few alternative solutions that have been tested, and all of them are related to the streetscape environment (verges). Such streetscapes can cover up to one third of public urban greenspaces in Australia [48]. Because of land ownership peculiarities and the limitation of resources, such places are not irrigated or mown, and this leads to the degradation of existing lawns. An alternative for streetscapes is planting low native plants instead of lawns. Recently, the Woody Meadow project inspired by English naturalistic plantings has become popular in Melbourne and Western Australia. These "meadows" use local native drought-tolerant species of shrubs and trees. A recent study on preferences for woody meadow plantings (using computer-generated images) compared to low-input non-irrigated conventional lawns in streetscapes showed preferences for woody meadows [48]. However, woody meadows cannot be walked on or used for recreation. Streetscapes and verges are the main targets in Australian cities for "rewilding" and native plant introduction (the substitution

of lawns) which have also been studied from a sociological point of view (social norms and ecological values) [49,50].

Our alternatives used in the survey suggested several options that can be used as possible solutions in the open public spaces of Perth. These scenarios used a low-growing native ground cover such as *Dichondra repens* that is already spontaneously growing in some lawns (imbedded into lawn grass *Cynodon dactylon* (couch)) and that can withstand some human traffic. Another option is a monoculture of low-growing (up to 20 cm) and flowering Scaevola cultivars that could be used in some areas of private gardens and dedicated public open spaces. Another suggestion is a more biodiverse version of lawns with commonly used grasses and clover (*Trifolium repens*) that are low-growing but can flower and thus provide a forage for pollinators. One of the options is also based on existing examples in Perth where lawn grasses are embedded with flowering annual weeds and, in spring, create low meadow-like lawns. Finally, an "uncut lawn" mimics the existing practice in some European municipalities to let lawn grass grow tall and be cut only once a season.

The findings indicate that respondents liked the Scaevola alternative and the lawn with Dichondra. The position of Scaevola with bright lilac flowers that resembles a beautiful carpet corresponded with the finding of public appreciation of naturalistic, grass-free and pictorial meadows in Europe because of an increase of attractive colourful flower displays in urban environments [51]. Scaevola flowering patches were most appreciated by the middle age groups which might be explained by the growing of environmental movements in Perth and the popularisation of rewilding private gardens by growing native plants. Surprisingly, the option of alternatives with flowering clover and the option of lawns with flowering annual weeds were considered as a possibility by all age groups. However, the older group of people had the least appreciation of non-traditional options for lawns. An indication of the necessity for more careful placement of lawns in open spaces as well as searching for more effective and smart maintenance was indicated in additional comments and definitions such as "Lawn creates a space that is multifunctional and reduces heating in an urban environment. However, lawns should not be used unnecessarily in spaces where the above-listed activities do not take place".

However, the comparative ranking of the five lawn alternatives revealed that participants clearly preferred those alternatives that resembled a standard lawn such as the lawn grass with Dichondra or clover. Furthermore, these types of lawn alternatives were far more preferred by respondents who defined the purpose of the lawn as being for social status. This indicated the continuing importance of lawns as an attribute of Perth suburban communities and as a very practical element in creating "culturally familiar environments" [11]. Taking into consideration that recreation is the most valuable use of lawns in Perth, the crucial criterion for alternative lawns would be a durable surface for walking.

Most respondents (of all age groups, education and gender) rated and ranked old uncut high grass negatively. This result reflected the history of Western Australian lawns. High grass vegetation resembles European pasturelands but is not presented in Western Australian native biomes. Instead, native shrubs and woodland vegetation with a complex "messy" structure and olive green and grey foliage contrast with the lawn. For lawns, people who use prefabricated "ready" turf that is regularly cut, and where all other plants (different kinds of weeds) are eliminated, uncut lawns are associated with a lack of care rather than an alternative biodiverse option. In addition, high grass in the Australian urban environment might be associated with the possible presence of dangerous creatures such as snakes and spiders. In Europe and the USA, the "cues to care" option where a strip of cut and manicured lawn borders "messy" meadow plantings are one of the preferable options in urban landscapes that can solve the dichotomy of introducing native nature into urban environments [5,52].

When given the opportunity to include additional comments in the survey, participants also expressed concern about using synthetic lawns, which is reflected in the latest urban phenomenon—using plastic and fake lawn nature [53,54]. Comments like "Plastic lawn is

an abomination" demonstrate the environmental and social awareness of Perth's citizens about the negative impact of synthetic turf on human health and the environment.

4.5. Limitations of This Research

This research had several limitations to consider. Firstly, while online survey methods enabled distribution to a dispersed sample population across the Perth metropolitan area, they are prone to self-selection bias, where respondents tend to be people who have ready access to the internet, are interested in the topic and are motivated to express their views. This is evident in the relatively higher education level of respondents compared to the census data for the general Perth population, even though the remaining respondent demographics were similar. While there was a bias in the sample towards university education, the analysis indicated that the education level was not significantly associated with lawn preferences, suggesting this bias did not influence the general findings of this research. Secondly, asking respondents to rate images on a screen to ascertain preferences is a common and accepted technique, but this has limitations in terms of preferences solely being determined by visual appearance. Designing a field experiment in which respondents directly experience different lawn alternatives in person may provide additional research insights. Online images are limited to purely visual cues, while a field experiment may add other components such as touch, sound and smell that could influence preferences. Designing a field trial or experiment would require significant resources to ensure a representative sample but would provide additional insights that could complement the online survey findings.

5. Conclusions

Despite the wide distribution of lawns in open public and private spaces in Perth, they have not been comprehensively investigated from a sociological point of view. Our study identified and analysed public views on the visual appearance, maintenance and uses of urban lawns and the visions on lawn alternatives in private gardens and public parks in Perth based on online surveys. The sample generally aligned with the greater Perth population profile, except in terms of the level of educational achievement. However, the education level did not have a significant effect on preferences for lawn alternatives.

Lawn is an important urban legacy in Western Australia with almost 200 years of colonial history. Participants value their lawns and recognise their importance in the urban landscape for a variety of recreation activities, cooling the environment and aesthetic benefits. At the same time, participants demonstrated an environmental awareness of lawns and the necessity of revisiting the existing planning and maintenance routine based on irrigation and intensive mowing by considering several alternative solutions. While valuing new solutions such as Scaevola patches in dedicated areas and "weedy lawns", participants still preferred alternatives closest in appearance to a conventional lawn (e.g., lawn grass with Dichondra and lawn grass with clover). There will be always a need in private and public green spaces for lawns that can provide durable surfaces for recreational activities such as sports, playing and picnicking.

There is an opportunity for further research into a "blended model" of urban lawns that would retain their essence as durable surfaces but could contain grasses and herbaceous and/or ground cover species that can withstand heat and recreational trampling and provide other ecosystem services such as a habitat provision for biodiversity. There also should be a search for more drought-tolerant species that might be considered more species-diverse versions of turfs. Another important direction can be the experimental planting of native Western Australian grasses and trying to create versions of native grass-dominated meadows. Several countries (e.g., Sweden, China, France) have initiated demonstration trials in botanic gardens and university campuses that test different options of alternative solutions and residents' perceptions of and preferences for alternative lawns [27,36].

The search for effective alternative solutions should ideally be based on a holistic view of how and where different lawn types should be located in urban green/open spaces and

what their design and management strategies and characteristics are. This direction would support already existing initiatives in Perth such as hydrozoning, ecozoning and verge rewilding. The results of our research on the preferences and expectations for lawns in Perth can be also used in developing planning and designing guidelines for urban public open spaces and also for the Western Australian turf industry, cities and municipalities.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land13020191/s1, Table S1: List of questions used for the survey; Table S2: Use of private lawn for various activities; Table S3: Use of public park for various activities; Table S4: Lawn alternatives that could be used in public parks; Table S5: Ranking of lawn alternatives; Table S6: Ranking of lawn alternatives.

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