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Gated but Connected? Evaluating Accessibility, Permeability, and Connectivity in Italian City 1, Erbil

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Abstract

Urban planning plays a vital role in ensuring inclusive, sustainable, and livable cities. This study evaluates three critical indicators of sustainable urban form—accessibility, permeability, and connectivity—using Italian City 1 in Erbil, Iraq, as a case study. A cross-sectional mixed-methods design was applied, combining infrastructure assessments with resident and visitor surveys. Two indices were developed: the Infrastructure Accessibility Index (IAI), based on field audits of sidewalks, bikeways, crosswalks, and public transport stops; and the Opportunity Accessibility Index (OAI), based on user-reported access to essential services. Both indices were tested using descriptive and inferential analyses to examine accessibility levels across subgroups. Findings indicate that Italian City 1 demonstrates satisfactory accessibility to local services but uneven infrastructure quality, particularly for crosswalks and public transport. Sidewalks performed better, while permeability was hindered by gated typology and limited pedestrian-only routes. Connectivity was relatively strong internally but car-dominated externally. Statistical analysis revealed significant differences in accessibility perceptions between younger and older participants. Although Italian City 1 demonstrates moderate walkability and service proximity, deficiencies in inclusive infrastructure and multimodal transport reduce sustainability and equity. Enhancing sidewalks, crosswalks, and disability access, alongside developing multimodal connectivity, are critical for future planning.

Keywords

Accessibility; Permeability; Connectivity; Sustainable Urban Form; Gated Communities; Erbil; Infrastructure Assessment; User Perception

1. Introduction

Urban growth is a key force shaping environmental sustainability, socioeconomic dynamics, and quality of life. Erbil, a historic city undergoing rapid development, faces increasing challenges in maintaining inclusive and sustainable urban forms. Among the most critical dimensions of urban form are accessibility, permeability, and connectivity, which collectively determine how residents experience and benefit from the built environment. Accessibility refers to the ease with which residents reach essential services and public spaces; permeability concerns the ability to move freely through spatial layouts; and connectivity reflects how well urban elements are linked internally and externally. Recent urban theories, such as the 15-minute city model, emphasize these dimensions as prerequisites for equitable and sustainable living.

Despite their growing importance, these indicators remain under-examined in the Middle Eastern context. Prior studies have focused primarily on Western and Asian urban forms, leaving a significant research gap in cities such as Erbil, where gated communities are increasingly shaping the urban landscape. Previous research highlights persistent challenges, including reduced walkability (Marcus & Colding, 2014), limited access to green spaces (Colbert et al., 2024), and car-dominated infrastructures that hinder inclusivity (Kerzhner et al., 2025). However, empirical applications of accessibility and connectivity indices remain limited in Erbil and other comparable Middle Eastern cities.

1.1. Research gap and objectives

There is a lack of empirical evidence on how accessibility, permeability, and connectivity function in newly developed gated communities in Erbil, particularly in Italian City 1—one of the city's first and most influential residential developments. This study addresses that gap by:

1. Developing and applying two accessibility indices (IAI and OAI) tailored to the Erbil context;
2. Assessing how infrastructure quality and user perceptions align or diverge; and
3. Evaluating the implications of gated urbanism for sustainable urban form.

1.2. Literature Review

Urban planning literature increasingly recognizes accessibility, permeability, and connectivity as interrelated dimensions that define sustainable urban form. Together, they determine the spatial efficiency, inclusivity, and functionality of cities (Coppola et al., 2014; Levine et al., 2019). Accessibility reflects how easily people can reach opportunities and essential services; permeability measures how freely individuals can move within a spatial network; and connectivity captures the structural and functional linkages between different areas (Karndacharuk and Hillier, 2019; Marcus & Colding, 2014). These three indicators collectively shape mobility behavior, land-use efficiency, and urban livability, forming the foundation of equitable urban environments (Litman, 2024; Gaglione et al., 2022). According to recent research, "The lack of mobility significantly impacts various aspects of life, including work, healthcare access, social interactions, and education for children" (Kerzhner et al, 2025). These results highlight how crucial it is to include socio-spatial theories in urban design, especially in places like Erbil.

Accessibility in urban planning is a multifaceted concept that includes logical, social, economic, and physical dimensions, and is particularly vital for vulnerable groups such as people with disabilities. Guida and Caglioni (2020) note that "the traditional focus on mobility… has created an issue: the fact that increased mobility does not always correspond to increased accessibility for all, especially vulnerable populations like the elderly. This highlights the need to redefine and better measure accessibility, particularly in cities like Erbil with unique urban challenges. Permeability, closely tied to city design, refers to how easily people can move through urban spaces. Higher pedestrian activity is often found in areas with better permeability. As noted by Benassai-Dalmau et al (2025) "areas with shorter edge links and more complex network structures show higher pedestrian permeability, which aligns with urban theories on walkability and accessibility. These insights emphasize the importance of integrating updated concepts of accessibility and permeability into urban planning practices.

Improving urban connectedness in Italian City 1, Erbil, depends on understanding current levels of permeability, which, along with accessibility and connectivity, plays a key role in how neighborhoods interact. Connectivity reflects how well different urban areas are linked, influencing sustainability and reliance on motorized transport. The 15-minute city concept offers a useful model by promoting access to essential services within a short walk or bike ride. As noted by Gaglione et al. (2022), "the 15-minute city model emphasises accessibility to essential services within a 15-minute walk or cycle, which addresses challenges such as older people and energy conservation" (p. 1). This approach is particularly relevant for Erbil, where improving interconnection remains a pressing issue. Erbil can benefit from recent urban planning research, especially studies from Italy and similar cities, to address challenges in equitable access to services. Applying general urban accessibility indicators to Erbil is difficult due to its unique socio-economic and cultural context, making it hard for policymakers to implement sustainable and inclusive strategies. Adapting proven planning frameworks to local needs could enhance green spaces, public areas, and infrastructure, particularly in underserved neighborhoods. Focusing on accessibility, permeability, and connectivity is essential as the city continues to grow. This research aims to close knowledge gaps and guide urban development in Italian City 1, helping ensure fair access to opportunities and essential services for all residents through the use of socio-spatial theories and current planning practices.

2. Sustainable urban form

A city structure that integrates land use and transportation planning to support environmental, social, and economic sustainability is known as a sustainable urban form. It seeks to lessen the need for travel, encourage public transit, reduce reliance on private vehicles, and use less energy and land. Because it concentrates housing and activity in high-density regions, compact urbanisation is sometimes seen as the most sustainable of the several urban types, lowering emissions and travel lengths. Polycentric development (dispersing activities across multiple centers) can also promote sustainable development if public transport is well connected.. On the other hand, expansive urban patterns usually result in more environmental consequences, increased land consumption, and increased automobile use. Creating effective, easily accessible, and ecologically conscious urban structures that improve the quality of life while lowering negative externalities is the main goal of sustainable urban planning.

2.1 Theoretical Foundations of Accessibility

The main tool for assessing the complexity of sustainable urban form is accessibility. The concept of accessibility is more comprehensive than just physical proximity to resources and services; it takes into account factors such as time, distance, cost, infrastructure quality, and user experience. In order to create urban areas are not only efficient but also equitable and environmentally sustainable, it is crucial to assess accessibility indicators. Time is a key component of accessibility and an indicator that has a big influence on how users experience urban environments. People's travel plans, modes of transportation, and, eventually, their level of happiness with urban living conditions are all influenced by time. Time perception can change how people behave; for example, a well-functioning transit system that reduces time spent driving might make the location a more desirable place to live. Planners may create transit systems that not only make mobility easier but also fit in with urban residents' lifestyles by considering this factor. Another important indicator for assessing urban accessibility is distance. The distances people must travel as well as the available means of transportation affect how effective transportation networks are.

Shorter distances to key services like shops, schools, and businesses promote higher public transit use and walkability, enhancing overall accessibility and urban desirability. However, transportation costs can create financial barriers, particularly for low-income groups, potentially leading to social exclusion despite public transit being relatively affordable. The quality of transportation infrastructure—such as clean roads, clear signage, and reliable public services—greatly affects travel convenience, safety, and trust. Supporting alternative mobility options like walking and cycling is essential for sustainable urban planning. Additionally, diverse and inclusive transport options are crucial to meet the varied needs of urban populations, including seniors and people with disabilities. According to Litman (2024), accessibility evaluations should consider both mobility performance and the quality of land-use distribution, not only distance-based measures. Infrastructure quality plays a vital role in shaping urban residents' perceptions of safety and security. Well-maintained environments encourage greater community engagement and public transport use, while poor infrastructure can increase fear and limit mobility. User satisfaction with transport systems is also influenced by factors like wait times and comfort, with negative experiences—such as overcrowded or unavailable buses—impacting perceived accessibility. Planners must consider these qualitative aspects to improve public transport usage. Additionally, noise pollution is emerging as a key accessibility indicator, as high noise levels deter walking and cycling, hindering sustainable transport efforts. Enhancing urban accessibility also requires better connectivity between transport modes. Seamless transitions between buses, trains, bike lanes, and walkways create an integrated, efficient system that supports environmentally friendly travel and reduces overall travel time.

People with disabilities often face unique accessibility challenges, such as the need for ramps, tactile guidance, or audio signals—features typically overlooked in standard transport planning. Applying universal design principles can enhance inclusivity for all urban residents. In sustainable urban development, accessibility is increasingly tied to environmental concerns. Promoting low-emission transport options and integrating sustainability into urban design can benefit both current and future generations. Evaluating accessibility requires considering factors like time, cost, distance, infrastructure quality, and user experience. A comprehensive approach to these elements supports sustainability, user satisfaction, and social equity. Ongoing research is essential to develop effective, inclusive urban planning strategies.

2.2 Understanding Permeability and Connectivity in Urban Systems

When assessing urban sustainability, urban permeability and connectivity are crucial factors to take into account. Planning for more livable settings can be guided by an understanding of how these aspects affect city functionality. Urban permeability is now measured using a variety of metrics, including qualitative ones like space syntax, which analyzes the impact of network layout on accessibility. Walkability indices and pedestrian counts are additional quantitative measures that offer information on accessibility and movement patterns. By looking at user views and experiences inside urban systems, qualitative evaluations are just as important as quantitative measures. A comprehensive understanding of urban settings is made possible by this combination of quantitative and qualitative methods, which also emphasises the different degrees of permeability and linked places. The choice of technique for assessing urban permeability and connectivity has a significant impact on the results. Studies of Asian cities have shown that different frameworks, such as dedicated pedestrian networks (DPNs) versus traditional street networks, can produce different levels of measurement accuracy. These differences emphasize the importance of context-specific assessment approaches. Existing tools have both strengths and limitations, often relying on assumptions that may not reflect informal or less traditional urban roads.

However, innovative approaches like the "frontage permeability" metric are gaining traction for their ability to better capture the dynamics between public and private spaces, enhancing urban vitality. Incorporating indicators like connectivity and permeability into traditional urban assessments offers a deeper understanding of urban dynamics. Urban planners increasingly use these measures to guide sustainable development, identify infrastructure gaps, and implement targeted improvements such as pedestrian zones and enhanced transport networks. Mboup (2013) emphasizes that street networks shape social interaction and urban prosperity, supporting the importance of evaluating permeability and connectivity in residential neighborhoods. This data-driven approach allows planners to predict outcomes and assess the impact of proposed changes. High-permeability areas often foster stronger community engagement and local economic growth, emphasizing accessibility's role in urban success. Comparative studies across different cities help reveal how various urban environments address local challenges, providing valuable insights for both research and practice. These studies support more effective, sustainability-focused urban planning strategies. Assessing urban permeability and connectivity requires a complex interaction between quantitative and qualitative measurements. The effectiveness of initiatives aimed at supporting sustainable urban environments can be affected by the approach adopted. As urban planners continue to grapple with the complexities of urban design, adopting more thorough approaches to permeability and connectivity assessments can ultimately help create more resilient and accessible urban places. This study considers accessibility, permeability, and connectivity as equally significant dimensions of sustainable urban form, analyzed in an integrated framework rather than as isolated indicators.

3. Case study: Italian City 1

One of Erbil's most appealing and well-designed residential neighborhoods is Italian City 1 (Fig. 1), which is a fine example of accessibility, permeability, and connectivity in a sustainable urban design. With its tiered townhouses, villas, and apartment buildings spread among 640 residential and 80 commercial units, this mixed-use development presents a modern approach to community planning. Italian City 1, which is only 4.8 miles from Erbil's city centre, has easy access from two main roads, Gullan Road and 100 Meter Road, guaranteeing good communication with the rest of the city. The community's internal layout, which includes evenly spaced neighbourhoods, pedestrian-friendly streets, and easy access for cars, further supports this accessibility.

The neighborhood places great emphasis on social and functional accessibility by locating necessary daily services in close proximity. Residents can benefit from an on-site supermarket, grocery store, mosque, nursery and office space by eliminating the need for long-distance driving and supporting a more sustainable lifestyle. Additionally, by accommodating a range of family sizes and income levels, the diversity of housing options promotes social integration. Italian City 1 is an example of how mixed-use zoning, mobility infrastructure and accessibility to services can contribute to the creation of self-sufficient, liveable communities from a sustainable urban planning perspective. Thus, this case study demonstrates how careful planning and the integration of land use can enhance the quality of life for locals while also supporting more general sustainability objectives.

Fig.1: Masterplan of Italian City 1 Source: (Google maps 2025)

4. Materials and Methods

An infrastructure assessment and a survey of travel habits for both residents and visitors in a particular Erbil neighborhood are used to gather data. The study's concept leads to the development of two accessibility indices, which could possibly be combined into a single accessibility index. To simulate accessibility for all users in an urban region, we provide a distance-based and infrastructure-based method. Fig. 2 provides a summary of the methodological procedures I used. Since the approach is general, it can be used to any region or district. Italian City 1, which is situated in Erbil, Iraq, is used in this paper.

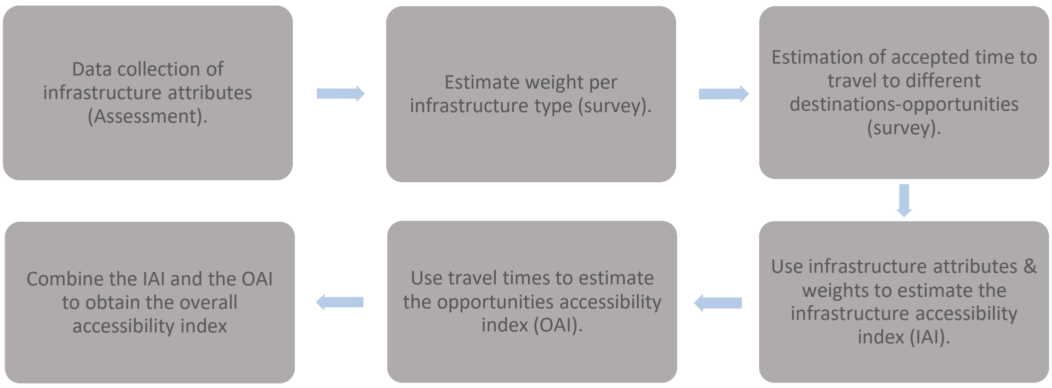

Fig.2 Methodological steps for the development of the accessibility index. (Source: Authors' own work, 2025)

4.1 Study Design

This research employed a **cross-sectional mixed-methods case study design**, combining quantitative infrastructure audits with qualitative and quantitative survey responses. The approach was chosen to capture both the physical characteristics of Italian City 1 and user experiences of accessibility, permeability, and connectivity.

4.2 Sampling and Participants

Participants were recruited through voluntary convenience sampling, facilitated by local community contacts and on-site distribution. A total of 30 respondents (18 males, 12 females) completed the structured questionnaire. While modest, this sample size is consistent with exploratory case study research in urban planning (Ewing & Cervero, 2010; Levine et al., 2019). The sample allowed for basic subgroup comparisons (e.g., age, gender) while capturing a diverse range of user experiences.

4.3 Data Collection

Data were collected between 20 and 30 April 2025 through:

1. **Infrastructure Assessment**: Conducted using a standardized checklist adapted from Karndacharuk and Hillier (2019), covering sidewalks, crosswalks, bikeways, and public transport stops. Each indicator was scored as "present" or "absent" and converted into a percentage-based score.
2. **Resident and Visitor Questionnaire**: A 20-item survey measured perceptions across 13 accessibility sub-indicators (time, distance, cost, ease of travel, safety, comfort, environmental considerations, disability access, etc.) and 7 connectivity/permeability indicators. All participants were over 18 and provided informed consent. The complete version of the questionnaire used in this study is provided in Appendix A.

4.4 Accessibility Indices

Two composite indices were developed to evaluate accessibility from both physical and perceptual perspectives:

- **Infrastructure Accessibility Index (IAI):** This index combines the physical audit scores of sidewalks, crosswalks, bikeways, and public transport stops. Each infrastructure type was assigned a weight based on user-reported priorities obtained from the survey. Participants identified which elements they considered most important, and these responses were normalized to derive proportional weights. This weighting approach follows methodologies applied by Coppola et al. (2014) and Gaglione et al. (2022), ensuring that the index reflects both objective infrastructure quality and subjective user preferences.

The IAI was calculated using the following formula:

$$IAI = \Sigma (Wi \times Si)$$

where Wi represents the weight assigned to each infrastructure component and Si represents its standardized score.

The final IAI was classified into five levels:

Not Accessible (0), Poor (1–25), Moderate (26–50), Satisfactory (51–75), and Excellent (76–100).

- **Opportunity Accessibility Index (OAI):** This index integrates survey responses on perceived access to essential services such as schools, healthcare centers, shops, and public transport stops. The percentage of respondents reporting acceptable access times for each service was computed and averaged according to the formula:

$$OAI = (1 / n) \times \Sigma Pj$$

where Pj is the percentage of respondents with satisfactory access to each service, and n is the total number of services considered.

Overall Accessibility Index (OAI_total):

To obtain a single composite measure that synthesizes both physical and perception-based accessibility, the two indices were combined as follows:

$$OAI\_total = (IAI + OAI) / 2$$

This overall index improves methodological transparency and supports the replication of this approach in other urban case studies. To operationalize the weight assignment, respondents ranked infrastructure components (sidewalks, crosswalks, bikeways, public transport stops) based on their perceived importance using the Likert categories shown in the questionnaire. For each component, the frequency of most-positive selections (category A) and moderately-positive selections was summed to represent importance, consistent with methods in Coppola et al. (2014). These raw counts were then normalized by dividing each by the total number of positive selections across all components, yielding proportional weights. This participatory weighting procedure ensures that the Infrastructure Accessibility Index reflects actual user mobility priorities rather than arbitrarily assigned values, aligning with the user-centered methodology recommended by Gaglione et al. (2022). The final normalized weights assigned to the infrastructure components are presented in Table 1, reflecting user-reported mobility priorities derived from the survey results.

Table 1 User-derived normalized weights for Infrastructure Accessibility Index (IAI) (Source: Authors' own work, 2025)

Infrastructure Type	**Weight (Wi)**
Sidewalks	0.38
Crosswalks	0.27
Public Transport Stops	0.17
Bikeways	0.18

4.5 Data Analysis

Data were analyzed using SPSS v.24. Descriptive statistics summarized infrastructure quality and user perceptions. Inferential tests were conducted to strengthen validity:

- Chi-square tests compared accessibility ratings across demographic groups (e.g., gender, age).
- Independent samples t-tests assessed differences in perceptions between younger (<35 years) and older participants.
- Correlation analysis (Pearson's r) examined relationships between IAI and OAI scores.

Results are presented with percentages and 95% confidence intervals where applicable.

5. Results

The findings from the infrastructure assessment and resident-based accessibility survey conducted in Italian City 1 are shown in this section. The results provide information on the neighborhood's transport infrastructure's physical state as well as how residents find accessibility in relation to several everyday destinations and services.

5.1. Sociodemographic Profile

Thirty participants completed the survey between 20 and 30 April 2025. The sample comprised 60% males and 40% females, with a mean age of 38.6 years (SD = 11.2). Respondents represented a range of occupations, with private employees forming the largest group (30%). While modest, the sample size is consistent with exploratory case study research and allows for meaningful subgroup comparisons. (See table 2)

5.2. Infrastructure Accessibility Results (IAI)

The audit revealed varied performance across infrastructure types. Sidewalks performed best (IAI = 55/100, 95% CI [48–62]), though accessibility was limited by obstacles and the absence of tactile paving. Crosswalks were less effective (IAI = 30/100, 95% CI [24–36]), often lacking ramps or clear markings. Bikeways scored lowest (IAI = 20/100, 95% CI [15–25]), as they were frequently shared with vehicles. Public transport access also scored poorly (IAI = 25/100, 95% CI [18–32]), with minimal facilities provided. (see Table 3) All numerical values and scores reported in this section (IAI values, percentages, and confidence intervals) are derived from the authors' field-based infrastructure audit and survey analysis conducted in Italian City 1, following the methodology adapted from Coppola et al. (2014) and Gaglione et al. (2022)

5.3 Travel behavior and perceptions (OAI)

Private cars were the dominant travel mode (33.3%), followed by walking (26.7%). Public transport use was low, reflecting poor infrastructure provision. More than 60% of respondents reached daily necessities in less than 10 minutes, resulting in an OAI score of 63.4% (95% CI [58–69]), classified as satisfactory.

5.4 Accessibility Experience by Indicator

The following conclusions were drawn from an analysis of survey results across 13 key accessibility sub-indicators:

- Time and Distance: More than 60% of participants took less than ten minutes to go to everyday necessities. This points to a thoughtfully designed land-use plan that supports short-distance, sustainable travel habits.
- Ease of Travel: Although some respondents noted challenges because of barriers from sidewalks and uneven pathways, over 80% of respondents said that moving within the neighborhood was "easy" or "very easy."
- Cost: Only 16.7% of locals said that transport prices were "very affordable," while others mentioned moderate to high expenditures for everyday mobility, especially for those without access to their own automobiles.
- Safety and Security: People felt comfortable walking during the day (66.7%), but they were concerned about their safety at night, particularly for women and the elderly. The problem is caused by the fact that common areas are deserted after dark and have poor lighting.

Table 2 Sociodemographic and transport behavior results (n=30) (Source: Authors' own work (2025)

Variable	Measure	Frequency	Percentage
Gender	Male	18	60%
	Female	12	40%
Age	18-24	1	3.33%
	25-34	3	10.00%
	35-44	12	40.00%
	45-54	8	26.67%
	55-64	4	13.33%
	> 65	2	6.67%
Occupation	Unemployed	2	6.67%
	Prefer not to answer	0	0.00%
	Municipal employee	4	13.33%
	Freelancer	7	23.33%
	Private employee	9	30.00%
	Household	3	10.00%
	Retired	4	13.33%
	Undergraduate student	1	3.33%

Table 3. Infrastructure Accessibility Index Findings (summarizes the IAI results) (Source: Authors' own work, 2025)

Infrastructure Type	Observed Conditions	Estimated Score	Accessibility Level
Sidewalks	Generally wide and well-kept, however, some lack curb ramps, tactile pavement, and are blocked by cars.	55	Satisfactory
Crosswalks	Inequitable distribution, absence of tactile and visual indicators, and side ramps provide particular challenges for individuals with disabilities.	30	Moderate
Bikeways	It is dangerous for young or inexperienced riders since it is frequently shared with automobiles and lacks markers or separation.	20	Poor
Public Transport Access	Limited internal access, few stations with few amenities, and a significant reliance on taxis and Careem.	25	Poor

- Infrastructure Quality: Sidewalks were rated favorably for their width and continuity, but crosswalks sometimes lacked curb ramps or tactile pavement, which presents an important barrier to accessibility for those with visual or mobility disabilities.
- Connectivity Between Modes: Most people said that internal connectivity, such as walking to major highways or between gates, was functional. However, because there were few bus stop facilities, there was little external access via public transportation.
- Disability Access: Forty percent of respondents indicated that infrastructure was "not accessible," and fifty percent said that it was only "somewhat accessible" to people with disabilities. Lack of tactile materials, inadequate wheelchair space, and a lack of aural signals were among the specific obstacles.
- Environmental Factors and Comfort: Only one-third of respondents said that the walking environment was "comfortable." Inadequate public seating, heat, and a lack of shade were identified as discomfort concerns. Furthermore, a considerable concern was found for noise pollution from surrounding roads, such as the Gullan Road, due to the currently under-construction areas. Fig. 3 illustrates the distribution of responses across key accessibility indicators.

Responses for each accessibility indicator were collected on four-point Likert scales. In the charts, categories A, B, C, and D represent the most positive, moderately positive, moderately negative, and most negative responses, respectively, following the structure of the questionnaire

5.5. Comparative Analysis and Implications

The combined evidence suggests that infrastructure presence alone does not ensure inclusive accessibility. Italian city 1 benefits from compact land use and numerous proximate services—factors that support walkability—but lacks several inclusive infrastructure elements (tactile paving, ramps, safe crosswalks, sheltered transit stops) necessary for equitable access. This pattern aligns with prior findings on gated developments that often deliver internal connectivity but restrict permeability and external multimodal access (Marcus & Colding, 2014; Coppola et al., 2014). Statistical tests support the interpretation that infrastructure affects perceptions: younger respondents (<35 years) rated ease of travel higher ($M = 4.2/5$) than older respondents ($M = 3.6/5$), $t(28) = 2.15$, $p < 0.05$, suggesting generational differences in mobility expectations or tolerance for infrastructure shortcomings. Females reported significantly lower perceptions of nighttime safety ($\chi^2 = 5.23$, $p < 0.05$). Pearson correlation between IAI and OAI was moderate and positive ($r = 0.42$, $p = 0.03$), indicating that better physical infrastructure tends to correspond with higher perceived accessibility, although the relationship is not determinative. Policy implication: improvements that target both the physical environment (ramps, crosswalks, transit shelters) and experiential factors (lighting, seating, enforcement against pavement obstruction) are needed to translate proximity into practical, equitable accessibility. When compared with international benchmarks, Italian City 1's overall accessibility score (OAI_total = 48/100) falls below the range observed in comparable studies of walkable urban communities in Europe and Asia, which typically achieve values between 60 and 75 out of 100 (Gaglione et al., 2022; Coppola et al., 2014). According to the World Health Organization & UN-Habitat (2016) guidelines for healthy and equitable cities, inclusive neighborhoods should provide safe pedestrian access to key services within 400–800 meters, with continuous sidewalks and accessible crossings. While Italian City 1 meets several spatial proximity targets, its infrastructure quality and multimodal access remain weaker than these international standards.

This suggests that although local design provides a compact form, it does not yet achieve the same level of accessibility performance found in best-practice global contexts. The statistical results underline meaningful subgroup disparities that align with global accessibility research. The significant difference in mobility perception between younger and older respondents mirrors findings in European and East Asian studies, where age strongly predicts comfort and travel mode diversity (Levine et al., 2019; Guida & Caglioni, 2020). Similarly, the lower sense of safety among women reflects global gendered mobility patterns documented by the WHO (2016), emphasizing the importance of designing inclusive nighttime lighting and surveillance. The moderate positive correlation between IAI and OAI ($r = 0.42$, $p = 0.03$) further indicates that objective infrastructure quality moderately explains perceived accessibility, confirming similar relationships reported by Gaglione et al. (2022) and Zecca et al. (2020). Together, these results suggest that improving both physical infrastructure and perceived safety is essential to meet international accessibility benchmarks.

5.6. Permeability results analysis

Permeability in Italian City 1 manifests as a mix of structural potential and operational limitation. Spatially, the neighborhood's semi-grid layout and relatively small block sizes support route choice and internal navigability; however, cul-de-sacs, walled plots, and the absence of inter-block pedestrian shortcuts reduce true permeability. Functionally, 70% of respondents indicated they can walk across the area easily, but 60% reported the absence of pedestrian-only routes, and 55% noted frequent sidewalk obstacles (parked cars, construction). This "partial permeability" dynamic—where visible sightlines and short routes exist but pedestrian freedom is curtailed—mirrors descriptions of gated urbanism in other contexts (Marcus & Colding, 2014). Addressing permeability, therefore, requires design treatments (pedestrian cut-throughs, dedicated pathways) and management measures (enforcement of pedestrian right-of-way) to enable practical, safe pedestrian circulation.

5.6.1. Spatial Permeability

Italian City 1's physical layout offers the potential for permeability through short blocks and multiple internal junctions. Nevertheless, the prevalence of walled boundaries and restricted inter-block links interrupts pedestrian desire lines, increasing walking distances and discouraging casual pedestrian movement.

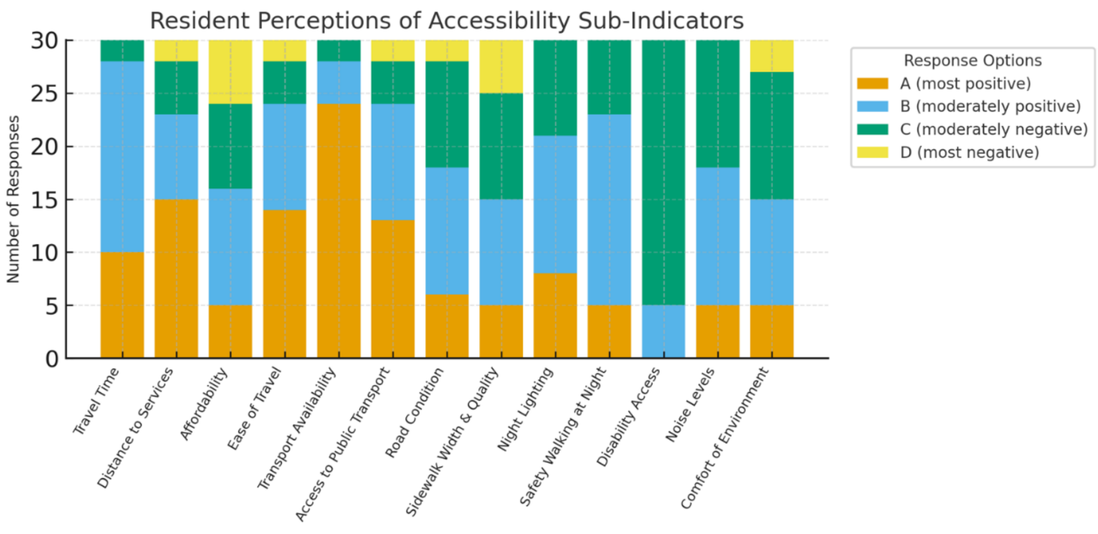

Fig. 3 Resident Perceptions of Accessibility Sub-Indicators in Italian City 1 Source: Authors' own work (2025)

5.6.2. Functional Permeability

Operational barriers—obstructions, a lack of pedestrian-only routes, and limited enforcement—reduce everyday permeability. Enhancing permeability should therefore combine targeted physical interventions (off-street pedestrian corridors, removal of parking on sidewalks) with governance actions (rules and monitoring) to maintain pedestrian space. (As shown in Fig. 4)

5.7. Connectivity results analysis

Connectivity shows a clear internal–external contrast. Internally, Italian City 1 benefits from multiple route options and a legible street pattern, with over 65% of respondents reporting several alternative paths to destinations. Externally, connectivity depends heavily on vehicle-based links (taxis, app-based ride services) rather than formal public transit; app-based taxis (e.g., Careem) provide quick links to major roads but do not substitute for accessible, sheltered transit stops. Inclusive and multimodal connectivity is limited: sidewalks often lack curb ramps and tactile guidance, bicycle infrastructure is absent, and transit-supporting infrastructure (shelters, signage) is minimal. Cognitive connectivity is relatively strong—over 80% of respondents said the layout was easy to understand, suggesting that wayfinding is not a primary barrier. Improving connectivity, therefore, requires adding multimodal infrastructure (bike lanes, bus shelters), making pedestrian–transit transfers seamless, and retrofitting accessibility features for people with disabilities.

5.7.1 Internal Connectivity

In terms of both spatial organization and user perception, Italian City 1 has a comparatively high degree of internal connection. The neighborhood's semi-grid street design, which mostly consists of three-way and four-way crossings, facilitates mobility and offers a variety of routes. This finding is supported by survey results, which show that more than 65% of respondents said they had many routes to go to their houses or other primary locations in the neighborhood. This structural diversity facilitates flexible navigation even in situations where certain streets are blocked or crowded, supporting what urban theorists refer to as network resilience. Logical circulation patterns are ensured by the well-proportioned roadways, small blocks, and obvious junctions, particularly for residents who drive or walk within the gated neighborhood.

5.7.2. External Connectivity

Despite being a gated community, Italian City 1 has rather good external connections, particularly when it comes to taxi services. According to the survey's findings, most participants said they could go to a taxi pickup location in five minutes or less, demonstrating the effective connections between the neighborhood's internal structure and important nearby roadways like Gulan Street and 100 Meter Road. The majority of locals have found that app-based taxi services like Careem have efficiently filled the void left by the restricted availability of traditional public transit, such as official bus stations with infrastructure. This is reflective of a trend towards digitally enabled, unofficial transit, which provides a useful link to the larger metropolitan network even if it is not a component of official infrastructure. The permeability of the outer border for cars and the low travel distances to important roads improve the overall functional external connectivity, even in spite of the physical obstacles that are usually associated with gated communities.

However, this connection is still mostly vehicle-based because road widths, the absence of crossings, and the lack of transit-supporting elements like shelters or signs continue to restrict bicycle and pedestrian access to the city outside the gates.

5.7.3. Inclusive and Multifunctional Connectivity

The inadequate provision for inclusive and multifunctional connections is another important result. Although most streets have sidewalks, they frequently lack necessary elements like curb ramps, tactile aids for those with disabilities, and enough width for wheelchair access. Crucially, roadways are not made for safe bicycle traffic, and there are no designated bike lanes. These shortcomings are highlighted by survey responses: 40% of respondents said that the infrastructure is inaccessible to those with disabilities, while 60% of respondents said that walking routes and transit are not well integrated. This is in line with criticisms in urban mobility theory that draw attention to how car-centric planning dominates in contemporary projects and how it excludes people with disabilities, bicycles, and pedestrians. The physical components required for broad accessibility and real multimodal transit are absent from Italian City 1.

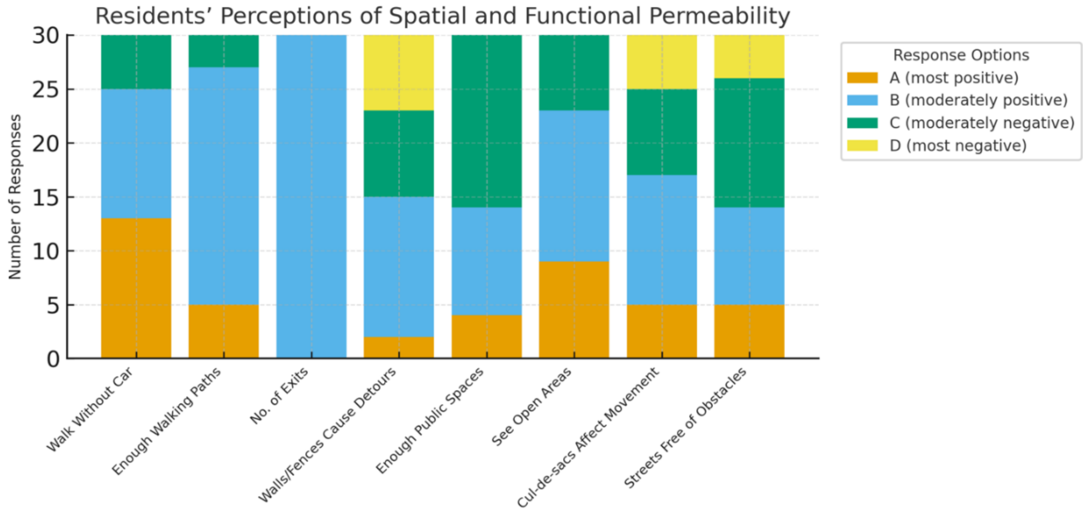

Fig. 4 Resident Perceptions of Spatial and Functional Permeability in Italian City 1 (Source: Authors' own work, 2025)

5.7.4. Cognitive Connectivity

Italian City 1 performs well in terms of cognitive or mental connectivity, in contrast to its physical connectivity problems. The street layout was straightforward to figure out and navigate for more than 80% of poll participants. Residents can create clear mental maps of the neighborhood because of its semi-regular grid structure and easily recognizable features, including the mosque, supermarket, and commercial zones. Italian City 1's internal navigability helps people feel more connected and clearer, even though there is still little physical connectivity with the rest of Erbil. Fig. 5 displays residents' perceptions of connectivity across internal, external, and cognitive domains.

Cognitive connectivity, which measures how easily residents understand and navigate the layout, was rated highest, showing that the street network is clear and legible even though external connections remain weak.) Using site interpretation and spatial analysis, Fig. 6 shows how well Italian City 1 performed on seven important urban connection and permeability metrics, ranging from 0 to 5. Due to well-integrated roadways and easy access to important thoroughfares like Gulan Street and Rotana Road, the neighborhood performs well in terms of both internal and external connectivity. A balanced urban pattern is facilitated by the fairly favorable block size and junction density. However, because of a curved layout that may make navigating challenging and a lack of dedicated pedestrian infrastructure, pedestrian pathways and wayfinding ease scored lower. The chart offers a thorough summary of the development's internal structure, advantages, and possible areas for improvement.

5.8. Overall Accessibility Index Results

To synthesize infrastructure and perception, the Overall Accessibility Index (OAI_total) was computed as the mean of the Infrastructure Accessibility Index (IAI) and the Opportunity Accessibility Index (OAI). Using the reported scores (IAI overall = 32.5/100 as the unweighted mean of component scores; OAI = 63.4/100) the combined index is:

Overall Accessibility Index (OAI_total) = (IAI + OAI) / 2 = (32.5 + 63.4) / 2 = 48.0 / 100

This 48.0 score indicates moderate overall accessibility: while service proximity and cognitive legibility are strengths, infrastructure deficits for inclusivity and multimodality reduce the overall performance. Presenting both component indices and this aggregate measure helps decision-makers prioritize interventions that will raise both perceived and functional accessibility.

6. Conclusions

This study evaluated accessibility, permeability, and connectivity as key indicators of sustainable urban form using Italian City 1 in Erbil as a case study. By combining field-based infrastructure assessment with user-perception surveys, two indices—the Infrastructure Accessibility Index (IAI) and the Opportunity Accessibility Index (OAI)—were developed and applied, leading to an overall measure of accessibility for the neighborhood. The findings reveal that Italian City 1 demonstrates moderate overall accessibility (OAI_total = 48/100). Sidewalks are generally continuous and of acceptable width, yet crosswalks, bikeways, and public transport facilities remain underdeveloped. Although proximity to daily services supports short walking trips, the quality and inclusiveness of pedestrian and transport infrastructure limit equitable access, particularly for people with disabilities and the elderly. Permeability was found to be partially constrained by gated boundaries and obstructed pedestrian routes, while connectivity was strong internally but weak externally, emphasizing the community's dependence on private vehicles. When positioned against international benchmarks, this outcome reflects a moderate accessibility level that is consistent with transitional urban contexts but below the standards observed in globally recognized 15-minute city frameworks.

These results underscore that physical compactness alone does not guarantee sustainable or inclusive accessibility. Improving infrastructure quality—especially safe crossings, shaded pedestrian routes, and barrier-free design—would

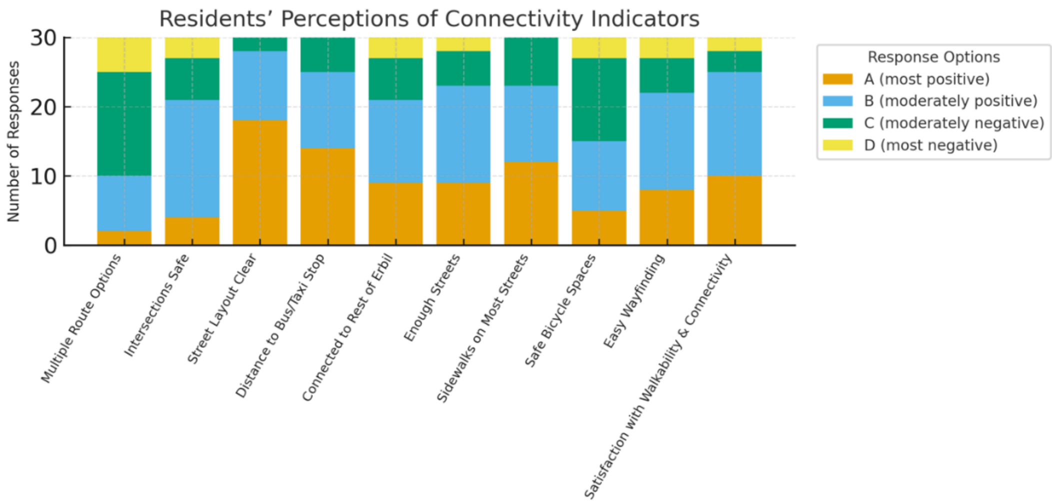

Fig. 5 Resident Perceptions of Connectivity Indicators in Italian City 1 (Source: Authors' own work, 2025)

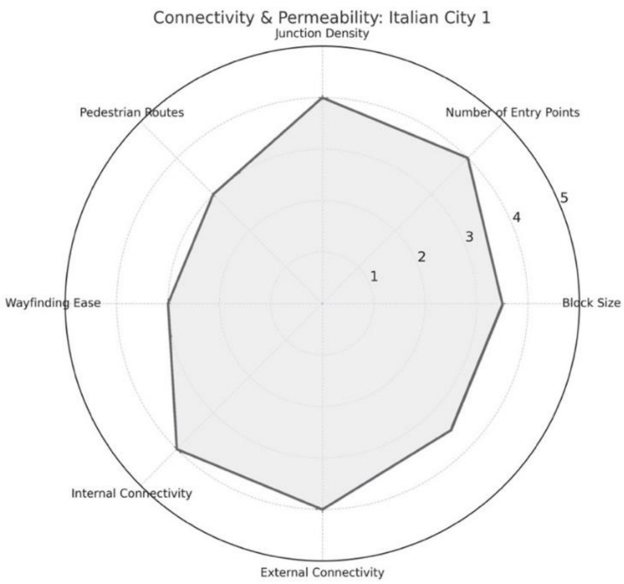

Fig. 6 adar chart showing performance (0–5 scale) across seven connectivity and permeability metrics: block size, junction density, pedestrian continuity, crosswalk quality, transit access, bicycle provision, and cognitive legibility. (Source: Authors' own work, 2025)

Significantly enhance functional and social sustainability. Strengthening multimodal connections with surrounding areas is also crucial to balance the internal coherence of gated developments with external urban integration. A limitation of this study is the relatively small survey sample and its focus on a single gated community, which restricts the generalizability of the findings. Future research should expand to multiple neighborhoods and integrate spatial network models, such as GIS-based accessibility analysis and Space Syntax, to complement perception-based indicators. Longitudinal studies could also assess how infrastructural improvements affect accessibility and livability over time. Overall, the study provides a replicable methodological framework for assessing sustainable urban form through quantitative and perceptual indicators. It highlights the need for policy interventions in Erbil and similar contexts to prioritize inclusive mobility, pedestrian comfort, and multimodal connectivity as core components of sustainable community design.

7. Recommendations

Based on the empirical findings related to accessibility, permeability, and connectivity, a set of targeted planning and design recommendations is proposed. These recommendations, summarized in Table 4, directly address the key infrastructural and spatial deficiencies identified in Italian City 1.

Table 4. Summary of Recommendations for Improving Accessibility, Permeability, and Connectivity in Italian City 1(Source: Authors' own work, 2025)

Recommendation Theme	Proposed Intervention	Expected Impact
Sidewalk Infrastructure	Continuous sidewalks (1.5–2 m width), tactile paving, curb ramps, and enforcement against sidewalk parking	Enhances walkability, universal access, and user safety
Crosswalk Safety	Zebra markings, raised crossings, tactile indicators	Improves pedestrian safety, especially for vulnerable users
Bicycle Mobility	Dedicated bike lanes, secure bike racks at key nodes	Supports multimodal transport and reduces car dependency
Public Transport Access	Shaded bus stops, seating, lighting, signage, and real-time information	Strengthens external connectivity and encourages transit use
Disability Access	Universal design elements, tactile surfaces, wheelchair-friendly infrastructure	Ensures inclusive and equitable mobility
Pedestrian Comfort & Safety	Shaded walkways, street lighting, seating, and neighborhood watch	Enhances comfort and nighttime safety
Visual & Social Integration	Landscape buffers, active street edges	Reduces enclosure barriers and improves social interaction
Multimodal Integration	Wayfinding signage, safe mode transfer points	Facilitates smoother movement between walking, cycling, and transit

The recommendations presented in Table 4 provide a practical framework for improving inclusive mobility and sustainable urban form in gated residential developments within Erbil and similar contexts.

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Ethics approval

This study was approved by the Department of Architectural Engineering. All participants were adults who provided informed consent before completing the survey. No personal, sensitive, or identifiable information was collected at any stage of the research.

Reference: Departmental Ethics Approval – April 2025.

Conflict of interest

The author(s) declare that there are no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data supporting the findings of this study are available from the corresponding author upon request. Access may be restricted due to ethical or privacy considerations.

Author Contributions

- **Conceptualization:** Arez Sarbast Namiq Alhawezi; Methodology: Arez Sarbast Namiq Alhawezi, Rebwar Ibrahim.
- **Formal Analysis:** Arez Sarbast Namiq Alhawezi; Writing—Original Draft: Arez Sarbast Namiq Alhawezi.
- **Writing—Review & Editing:** Rebwar Ibrahim; Supervision: Rebwar Ibrahim.

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8. Appendix

8.1. Appendix A

8.1.1. Accessibility Questionnaire

Section A: General Information (Optional)

1. **Age:** ____

2. **Gender:** ☐ Male ☐ Female ☐ Prefer not to say

3. **Type of resident:** ☐ Owner ☐ Renter ☐ Visitor

4. **Years living in Italian City 1:** ____

Section B: Accessibility Evaluation

1. How long does it usually take you to reach the nearest grocery store or supermarket within Italian City 1?

A. Less than 5 minutes

B. 5–10 minutes

C. 10–15 minutes

D. More than 15 minutes

(Indicator: Time)

2. How far is your home from key services (such as a mosque, nursery, office, or commercial center)?

A. Very close (within 300m)

B. Close (300–600m)

C. Moderate (600m–1km)

D. Far (more than 1km)

(Indicator: Distance)

3. How affordable is your daily or weekly travel within and around Italian City 1?

A. Very affordable

B. Affordable

C. Somewhat expensive

D. Too expensive

(Indicator: Cost)

4. How easy is it for you to move around inside the neighborhood?

A. Very easy

B. Easy

C. Difficult

D. Very difficult

(Indicator: Ease of Travel)

5. What types of transport are available to you regularly? (Check all that apply)

A. Private car

B. Taxi

C. Ride apps (e.g., Careem)

D. Bicycle

E. Public transport

F. Walking

(Indicator: Mode of Transport Availability)

6. Are public transport or taxis easily reachable from the community's gates?

A. Always

B. Often

C. Rarely

D. Never

(Indicator: Connectivity Between Transport Modes)

7. How would you rate the condition of roads, sidewalks, and pathways in Italian City 1?

A. Excellent

B. Good

C. Fair

D. Poor

(Indicator: Infrastructure Availability and Quality)

8. Are the sidewalks and pedestrian paths wide, clean, and safe to walk on?

A. Strongly agree

B. Agree

C. Disagree

D. Strongly disagree

(Indicator: Infrastructure + Safety)

9. How well-lit are the streets at night in your area?

A. Very well-lit

B. Adequately lit

C. Poorly lit

D. Not lit at all

(Indicator: Safety and Security)

10. Do you feel safe walking alone in Italian City 1 during the day?

A. Always

B. Usually

C. Sometimes

D. Never

(Indicator: Safety and Security)

11. Do you feel safe walking alone at night in Italian City 1?

A. Always

B. Usually

C. Sometimes

D. Never

(Indicator: Safety and Security)

12. How comfortable is it to walk or travel within the neighborhood (shaded areas, resting spots, etc.)?

A. Very comfortable

B. Comfortable
C. Neutral
D. Uncomfortable

(Indicator: Comfort)

13. Are facilities like ramps, tactile paving, or elevators available for people with disabilities?

A. All are available
B. Some are available
C. Very few
D. None

(Indicator: Accessibility for People with Disabilities)

14. Do streets and paths have clear signage and wayfinding signs?

A. Very clear
B. Somewhat clear
C. Not clear
D. No signs

(Indicator: Ease of Travel / Comfort)

15. How often do you experience delays or long waiting times (e.g., for transport or at gates)?

A. Rarely
B. Occasionally
C. Often
D. Always

(Indicator: Waiting Time)

16. How would you describe the traffic conditions inside Italian City 1?

A. Free-flowing
B. Moderate
C. Congested at times
D. Always congested

(Indicator: Time / Comfort)

17. How accessible are community services (e.g., healthcare, mosque, nursery, offices) for families with children or elderly?

A. Very accessible
B. Accessible
C. Not very accessible
D. Not accessible at all

(Indicator: Accessibility for Vulnerable Groups)

18. How often do you notice noise pollution in the area (traffic, construction, crowds)?

A. Never
B. Occasionally
C. Frequently
D. Always

(Indicator: Noise Pollution)

19. How environmentally friendly do you find the transport options in the area (e.g., walking, biking, low-emission cars)?

A. Very eco-friendly

B. Somewhat eco-friendly

C. Not eco-friendly

D. Don't know

(Indicator: Environmental Considerations)

20. Would you recommend Italian City 1 as a well-connected and accessible neighborhood?

A. Definitely yes

B. Yes

C. Maybe

D. No

8.1.2. Permeability and connectivity Questionnaire
Section A – General Information

1. **How long have you lived in Italian City 1?**

A. Less than 1 year

B. 1–3 years

C. 4–6 years

D. More than 6 years

2. **What is your main mode of transportation within and outside the community?**

A. Walking

B. Bicycle

C. Private car

D. Taxi or public transport

Section B – Permeability

3. **Can you easily walk across the neighborhood without using a car?**

A. Yes, very easily

B. Somewhat easily

C. Only in certain areas

D. Not easily at all

4. **Are there enough walking paths or pedestrian-only routes?**

A. More than enough

B. Enough

C. Few

D. None

5. **How many entry/exit points are there to your block or area?**

A. One

B. Two

C. Three

D. Four or more

6. **Do walls or fences make you take longer walking routes?**

A. Very often

B. Sometimes

C. Rarely

D. Never

7. **Are there enough public spaces (parks, green areas, etc.)?**

A. More than enough

B. Sufficient

C. Not enough

D. None

8. **Can you easily see open areas and directions while walking?**

A. Always

B. Often

C. Rarely

D. Never

9. **Do cul-de-sacs or dead-ends affect your movement?**

A. A lot

B. Sometimes

C. Very little

D. Not at all

10. **Are the streets and walkways in your neighborhood free of obstacles (e.g., parked cars, trash bins, construction materials)?**

A. Always clear

B. Mostly clear

C. Sometimes blocked

D. Often blocked

Section C – Connectivity

11. **Are there multiple route options to reach your home or the gate?**

A. Many options

B. A few options

C. Only one or two

D. Just one way

12. **Are intersections safe and easy to use as a pedestrian?**
    - A. Very safe and easy
    - B. Somewhat safe
    - C. Unsafe
    - D. Very unsafe

13. **Is the street layout clear and easy to understand?**
    - A. Very clear
    - B. Somewhat clear
    - C. Confusing in some areas
    - D. Very confusing

14. **How far is the nearest bus/taxi stop?**
    - A. Less than 5 minutes
    - B. 5–10 minutes
    - C. 10–15 minutes
    - D. More than 15 minutes

15. **Are the streets well connected to other parts of Erbil?**
    - A. Very well connected
    - B. Somewhat connected
    - C. Poorly connected
    - D. Not connected

16. **Are there enough streets to support easy movement?**
    - A. More than enough
    - B. Enough
    - C. Not enough
    - D. Very limited

17. **Are sidewalks available on most streets?**
    - A. Yes, everywhere
    - B. In most places
    - C. In a few places
    - D. Not at all

18. **Are there safe spaces for bicycles?**
    - A. Yes, throughout the area
    - B. In some parts
    - C. Very few
    - D. None

19. **Do you think the street layout makes it easy to find your way (wayfinding) without getting confused or lost?**

A. Very easy to navigate

B. Mostly easy

C. Sometimes confusing

D. Very confusing

20. **How satisfied are you with walkability and connectivity in the area?**

A. Very satisfied

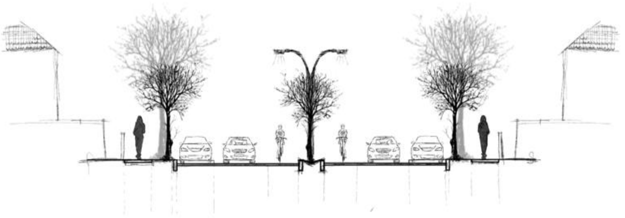
B. Satisfied

C. Dissatisfied

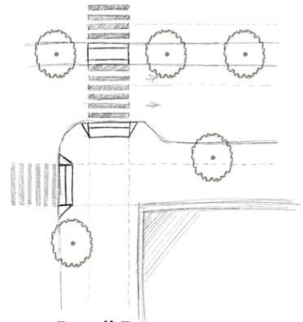
D. Very dissatisfied

8.2. Appendix B: Photos from field observations

8.3. Appendix C: Visual Recommendations for Enhancing Permeability and Accessibility



Detail A



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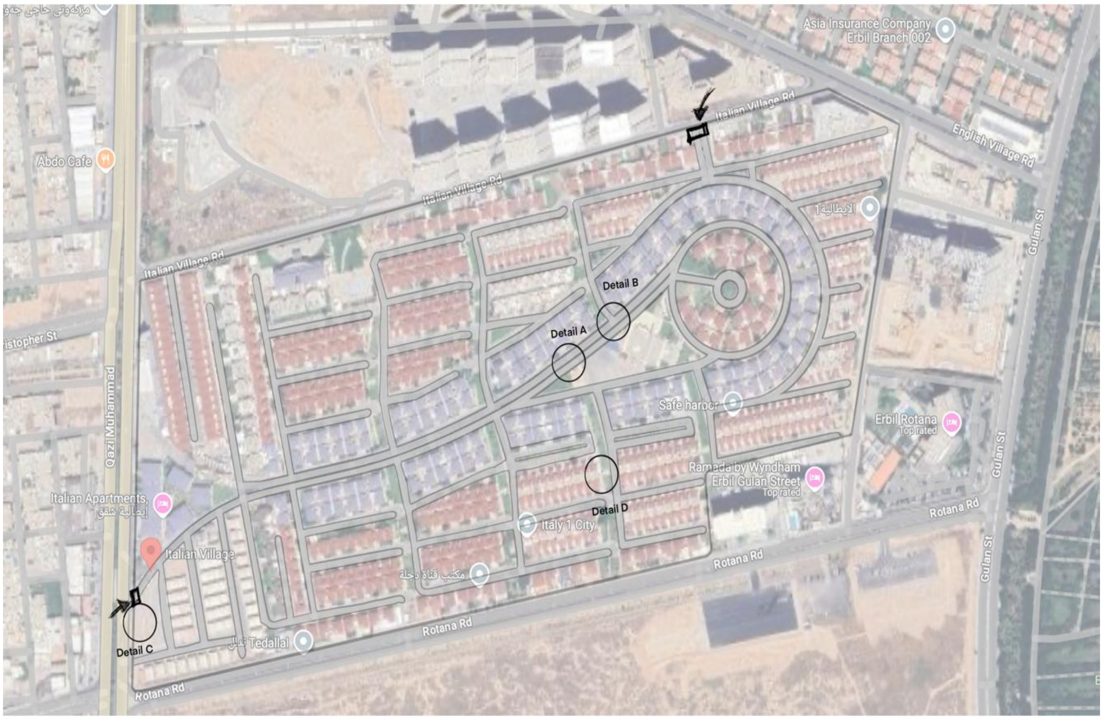

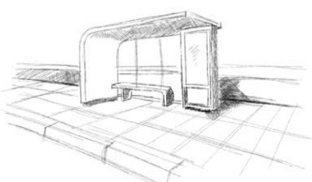

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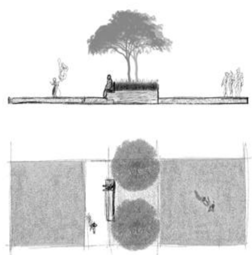

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