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Exploring the role of configurational accessibility of alleyways on facilitating wayfinding transportation within the organic street network systems

Abstract

Despite the significant role of alleyways in urban spatial configuration and accessibility as critical structures of urban infrastructure, there remains a noticeable gap in understanding their specific role in urban transportation policies. The main aim of the present study is to investigate the role of configurational accessibility of alleyways in facilitating wayfinding within organic street network systems. A mixed method was applied using Space Syntax and empirical observations. Moreover, Pearson correlations and t-tests were used to discern the association between variables and compare independent groups using SPSS software. The findings from the syntactical analysis strongly indicate that alleyways significantly impact configurational accessibility within urban network systems. Furthermore, the complex and labyrinthine structure of organic alleyways was found to significantly hinder the intelligibility of urban areas, making navigation more challenging. The results revealed a significant correlation between vehicle mobility and connectivity values, with higher levels of mobility consistently linked to increased connectivity values. The outcomes also indicated that alleys connected to main streets play a crucial role in facilitating wayfinding within urban network systems. This study contributes to a more profound understanding of the role of alleyways in urban network systems for urban planners and transportation engineers, paving the way for more targeted sustainable urban planning strategies.

Keywords: Accessibility; Alleyways; Space Syntax; Spatial configuration; Transportation; Urban mobility; Wayfinding

1. Introduction

The recent increase in population, rapid urbanisation, and substantial changes in the spatial configuration of cities in recent years have generated significant challenges in achieving urban sustainability (Wu, 2014; Günaydin & Yücekaya, 2020; Garau & Annunziata, 2023). There is growing pressure in cities to realise the full potential of every element of public infrastructure as density and the demand for more urban resources increase (Machado et al., 2020). Various research has been undertaken across numerous disciplines to understand and examine these systems (Angel et al., 2005; Askariad & He, 2023; Batty, 2009; Bettencourt et al., 2007; Boeing, 2019; Fujita et al., 1999; Tong et al., 2019). The spatial forms of cities are shaped by streets, pathways, and transit lines that organise human mobility patterns within intricate urban network systems (Jacobs, 1995; Levinson & El-Geneidy, 2009). These elements have notably impacted travel behaviours, location decisions, and urban fabric systems (Boeing, 2021; Parthasarathi et al., 2015).

In the meantime, alleys are narrow pathways among or behind buildings that serve as streets or paths with walls on both sides, providing access for motorized modes, non-motorized modes, or both, and are typically defined by the municipal code of the study area (Aleman, 2020; Machado-León et al., 2020). For the purposes of this study, an alleyway is defined as a narrow passageway typically less than 12 meters (40 feet) wide, bounded by buildings or walls on both sides, primarily intended for access within the urban network system. They exhibit distinct spatial infrastructure characteristics compared to streets, which feature a narrow external circulation space bounded by the built environment, intended for pedestrians and vehicles (Davies & Jokiniemi, 2008). The narrow width of alleys and their layout give them a volumetric quality, often absent in multilane streets (Bain et al., 2012). Alleys facilitate accessibility to specific land uses, parking infrastructure, freight, and vehicle services for cyclists and pedestrians, particularly noticeable in cities with extensive alley networks (Newell et al., 2013). The primary role of alleys is to establish connectivity rather than facilitate mobility, particularly to the street network (Bain et al., 2012). Constrained and congested alleys can exacerbate queues of vehicles attempting to access them (Yang et al., 2019). Alternatively, they may provide opportunities for drivers to cruise in search of suitable parking spaces (Laurier & Dant, 2012). Moreover, alleys sometimes act as the sole access route to specific land uses (Machado-León et al., 2020), highlighting their significant role in enhancing the accessibility and mobility of urban transportation systems.

In recent times, with the noticeable growth in population and increasing dependence on public and private transportation, congested traffic in the central cores of urban areas has emerged as a major challenge for transportation systems. This issue is particularly pronounced in cities with old and organic spatial configurations found in developing countries. Inadequate planning to develop necessary infrastructure tailored to societal requirements, coupled with a significant rise in vehicle users and the unchecked production and distribution practices of car manufacturers, exacerbates traffic congestion issues in urban areas. These challenges have notably impacted the central cores of cities in northern Iran, characterised by organic spatial configurations, leading to severe traffic congestion due to insufficient infrastructure aligned with societal needs.

In particular, this study investigates four cities in Gilan province: *Rasht*, *Anzali*, *Rudsar*, and *RezvanShahr*. These cities are characterised by congested vehicular traffic in their central cores.

Such heavy traffic conditions have compromised the historical value of these old towns, creating an unappealing image for their recognised areas. While some have undergone pedestrianisation projects to revitalise these historic areas, the lack of practical solutions has simply relocated congested traffic to other urban zones. This underscores the need for comprehensive scientific studies to address these challenges through innovative approaches aimed at enhancing current infrastructure.

Studies have indicated that subsidiary alleys can play a connecting role in facilitating access to the transportation system (Bain et al., 2012; Machado-Leon et al., 2020). The principles of urban planning are challenged by the demolition and direct intervention of monuments and landmarks, given their recognised historical value (Bandarin & van Oers, 2012; Feilden, 2007). Therefore, the creation and reinforcement of subsidiary alleys in the spatial configuration can be considered as an alternative to address these issues. The primary objective of this research is to investigate the influence of configurational accessibility of alleyways on facilitating wayfinding transportation within organic street network systems. Consequently, the following questions are posed to obtain the necessary answers.

1. What is the influence of alleyway configurational accessibility on wayfinding transportation within urban spatial structures?

2. Is there a significant difference in the numerical value of connectivity between spatial configurations of cities with and without subsidiary alleys?

3. Is there a significant correlation between the value of connectivity and urban mobility?

4. What is the impact of subsidiary alleys on intelligibility of organic-configured cities?

The present research, it is hypothesised that subsidiary alleys play an efficient role in facilitating transportation accessibility within spatial configuration structures. Another hypothesis is that the quantitative value of connectivity will be mitigated in the hypothetical models by the elimination of subsidiary alleys from spatial configuration structures. Furthermore, a correlation between the value of connectivity and the mobility of vehicles within urban network systems is hypothesized. It is also proposed that subsidiary alleys will have a significant impact on facilitating legibility. The implications of the present research could be fruitful for urban planners and designers, as well as traffic and transportation engineers.

Typically, when urban design scholars have sought to investigate topics related to alleys, they have concentrated more on subjects such as green infrastructure (Brazeau-Béliveau & Cloutier, 2021; Newell et al., 2013; Wolch et al., 2010), natural disasters (Hagiwara, 2001), functional social spaces (Ismail and Ching, 2016; Seymour et al., 2010; Sovacool & Axsen, 2018), commercial spaces (Machado-León et al., 2020), age-friendly spaces (Furneaux and Manaugh, 2019), walking infrastructure (Alawadi et al., 2021; Yoshii, 2016), sense of safety (Askarizad et al., 2023; Jiang et al., 2017; Uyen et al., 2023; Wang & Taylor, 2006), accessibility of pedestrians to public transport (Alawadi et al., 2021), and pedestrian transportation (Alawadi et al., 2020). Through reviewing previous studies (Askariad et al., 2024), it is evident that few investigations have focused on alleyways and their roles in facilitating configurational accessibility in cities.

Furthermore, studies on adopting procedures to evaluate alleys based on the notion of spatial configuration as critical transportation infrastructure have been insufficiently addressed. However, subsidiary alleys play a significant role in shaping road network configurations worldwide and have the potential to enhance connectivity and circulation efficiency. Therefore, the present study aims to bridge this identified scientific gap and contribute to the body of knowledge. Based on these assumptions, the main goal of this paper is to understand the role of configurational accessibility of alleyways in facilitating wayfinding transportation within organic street network systems. To achieve this, the paper is organised as follows: Section 2 introduces the literature review on the impact of alleyways on the accessibility of street network systems; Sections 3 and 4 explain the theoretical framework, data, and methodology used for analysis; Section 5 elucidates the findings derived from the spatial analysis applied to the four cities; Sections 6 and 7 discuss the study and conclude by deliberating on prospective advancements of the adopted model.

2. Literature review

After reviewing previous works on the subject, it is evident that extensive studies have addressed the role of accessibility in urban transportation network systems. However, research on the specific impact of alleyways on street network system accessibility is notably limited. This review aims to address this gap accordingly. Seymour et al. (2010) highlighted that urban alleys can play a critical role in creating greener, healthier cities within urban development contexts, addressing issues such as unequal park distribution through innovative solutions. Wolch et al. (2010) asserted that the majority of back alleys in Los Angeles are underutilised yet possess potential as walkable, quiet, and clean spaces that could be transformed into green infrastructure, offering ecological, economic, and social benefits, including enhancing urban walkability. Seymour et al. (2010) noted that alleys are integral to daily urban life, eliciting a range of responses from residents and serving distinct purposes for both insiders and outsiders, aspects crucial to consider during the planning phase.

According to Imai (2013), an alleyway can be seen as a space that creates an imaginative border between the past and present, evoking memories of childhood and a sense of nostalgia (Imai, 2013). Newell et al. (2013) found that revitalising urban alleys through greening projects can contribute to environmental protection, economic development, and social equity. Seymour & Trindle (2015) suggested that alley revitalisation projects can significantly enhance pedestrian activity and promote social life in these areas. Wan (2017) explained that reinforcing a maze-like network of alleys offers significant opportunities for local communities to reconnect with their sense of place, and for travellers and tourists to explore urban spaces.

In their study, Furneaux & Manaugh (2018) investigated the role of back alleys in creating play spaces for children. The findings acknowledged that parents perceived alleys as safer spaces, allowing greater independent mobility for their children. Scoppa et al. (2018) suggested that narrow alleyways have a substantial influence on the performance of pedestrian networks within superblocks. Sidebottom et al. (2018) conducted a meta-analysis and proposed that gating alleys can significantly reduce burglary and crime occurrence in urban areas. Suchocka et al. (2019)

developed a framework to examine the environmental and natural values of alleyways, identifying that alleys are not only components of urban infrastructure but also unique natural habitats. Alawadi et al. (2020) developed a model to evaluate the efficiency of network connectivity with a primary focus on the contribution of alleyways, which indicated that alleys can enhance the efficiency of urban network connectivity.

Machado-León et al. (2020) elaborated that while alleys are considered valuable resources for transportation, their narrow width and location between buildings, often with multiple access points to parking facilities and pedestrian entrances, can limit vehicle operations and manoeuvrability. Hidayati et al. (2021) noted that narrow alleys in Indonesia, typically less than two meters wide, hinder pedestrian accessibility due to frequent motorcycle use, creating an unsafe walking environment. Recent research also suggests that alleys are predominantly used for parking, property access, and as playgrounds for children (Brazeau-Béliveau & Cloutier, 2021). Jamei et al. (2021) indicated that connected and permeable alleyways enhance urban life and integrate with the major urban elements of traditional Iranian cities to meet daily inhabitants' requirements.

In their study, Alawadi et al. (2021) examined the role of alleyways in enhancing the connectivity efficiency of urban networks to metro stations, demonstrating that alleys can transform disconnected street networks into more efficient ones. Similarly, ongoing research on pedestrian route directness suggests that reclaiming alleyways in suburban areas could significantly improve urban network connectivity (Alawadi et al., 2021). Studies in the UAE have also indicated that in some cases, alleyways are comparable to streets in terms of land occupancy, pattern, density, and length, and occasionally even exceed urban streets in physical characteristics (Alawadi et al., 2022). Askarizad et al. (2022) proposed that restructuring and enhancing the permeability of back alleys could promote interaction between spatial configurations and major city landmarks. Moreau (2022) found that conventional developments within residential alleys often create complex situations that significantly restrict social activities in these areas. Uyen et al. (2023) identified that strategies such as widening alleys can have a significant impact on enhancing the sense of safety. Examining previous studies reveals that most research on the role of alleyways in urban network systems has focused on predicting societal aspects and promoting a walkable built environment. Only a few studies have examined how alleyways affect the spatial configuration of urban network systems and, concurrently, how methods measuring the directness of pedestrian routes apply in urban contexts. As a result, there are no studies found that investigate the impact of subsidiary alleyways on configurational accessibility within organic street network systems using syntactical analysis. Therefore, the purpose of this research is to address this recognised scientific gap and make a valuable addition to the current body of literature in urban studies.

3. Theoretical framework

3.1. Accessibility of alleyways and its role in wayfinding transportation

Accessibility is defined as the relative proximity or adjacency from one space to another (Tsou et al., 2005). It refers to the ease with which a specific destination can be reached from a given origin point within the urban network system (Tannous et al., 2021). In transportation studies, accessibility is understood as the ease of interactions between people and spaces (Pinna et al., 2021; Garau & Annunziata, 2019; Farber et al., 2014). Consequently, it is considered a key concept in global transport policy (Wee, 2016). Accessibility is fundamental to urban life today, underpinning the need to evaluate access dynamics to public and private transport systems in areas plagued by severe traffic congestion (Lessa et al., 2019). According to Alawadi et al. (2021), neighbourhoods with higher accessibility feature shorter distances between origins and destinations, reducing the reliance on vehicles and promoting walking or cycling. On the other hand, wayfinding involves the process of navigating from one location to another, requiring mental orientation between points of origin and destination (Rezaei Lipaee et al., 2020). Previous studies have shown that spatial accessibility and legibility play crucial roles in facilitating everyday wayfinding (Khotbehsara et al., 2023). In this regard, legibility is the ability to arrange the environment with clear layouts that enhance their spatial perception and navigation (Filomena et al., 2019; Askarizad & He, 2022; Taylor, 2009). The primary aim of evaluating public transport accessibility is to enhance connectivity between people and places, thereby alleviating street congestion, facilitating wayfinding, and mitigating adverse impacts of car use on the environment and health (Saif et al., 2019; Rassu et al., 2020).

Previous studies have extensively focused on measuring the significant role of street design in network accessibility and sustainable planning (Kang, 2017; Tong et al., 2015; Zlatkovic et al., 2019). Research has affirmed the importance of considering alleyways alongside streets as crucial infrastructure for facilitating urban mobility, prevalent within city network systems worldwide (Alawadi et al., 2020; Machado-León et al., 2020). An alleyway serves as a space where public and private functions intersect, offering opportunities to experience the socio-spatial, personal, and cultural aspects of urban areas (Carmona et al., 2010). Despite their significant impact on road network connectivity, fewer studies have focused on this issue, primarily addressing the importance of alleyways in enhancing pedestrian walkability (Scoppa et al., 2018). Alleyways are narrow passages between building blocks, with functions that are adaptable and dependent on their distinct physical attributes (Wolch et al., 2010). Nevertheless, their primary functions typically revolve around pedestrian circulation, commercial activities, and functional services (Alawadi et al., 2020). Previous literature supports the crucial role of alleyways in enhancing the efficiency of denser urban fabrics (Hage, 2008).

Initially, urban planners and designers began to utilise alleyways for commercial purposes to alleviate pedestrian traffic issues in streets (Michel, 2010). The most significant outcomes of these policies include environmental sustainability goals, such as mitigating heat islands (Duany et al., 2001), fostering social activities (Wolch et al., 2010), and improving economic prosperity through the development of commercial land uses (Michel, 2010). Evidence indicates that urban developers often overlook the crucial role that alleys play in creating a sustainable built environment, favouring wider streets instead (Imai, 2013). However, in contexts such as Iranian cities, where urban networks have evolved spontaneously and organically based on vernacular patterns, the traditional function of alleys has remained steadfast (Sharifi & Murayama, 2013). Therefore, the current underutilisation of alleys in the urban network system of Iranian cities presents significant potential to enhance transportation accessibility and consequently alleviate congested traffic for vehicles.

3.2. Space Syntax as a processor of spatial configuration analysis

The theory of Space Syntax was initially developed at University College London in the 1980s. Its purpose was to enhance understanding of the complexity of spatial configuration in urban morphology and its impacts on urban life (Hillier, 1998; Hillier & Hanson, 1984; Peponis et al., 1997). In this context, spatial configuration can be described as a set of schemes that cover all movement territories within a space, and it can be considered a vigorous tool for configurational accessibility within the framework of Space Syntax theory (Peponis et al., 1998; Yamu et al., 2021). The founders of this method believed that this procedure is correlated with the discovery that spatial configuration is directly associated with the distribution of movement patterns of pedestrians and vehicles within urban areas (Hillier & Hanson, 1984; Hillier et al., 1993; Peponis et al., 1989). Previous studies have also shown that configurational accessibility provides a better understanding of street network systems (Lamíquiz & López-Domínguez, 2015).

Space Syntax has been used in various empirical studies to model and understand urban layout patterns and structures (Hillier & Hanson, 1997; Jiang & Claramunt, 2002; Penn, 2003). These studies include pedestrian modelling (Hillier et al., 1993; Lerman, 2014; Sharmin & Kamruzzaman, 2018) and analysis of transportation networks (Law, 2012; Shatu et al., 2019; Turner, 2007; Turner & Penn, 2007). Since the mid-2000s, the Space Syntax approach has been widely applied to the configurational analysis of urban networks, and consequently, configurational evaluations of urban street networks have been considered useful instruments in the study of city forms (Penn, 2003). In these studies, the analysis of street network systems (although alleyways are rarely included) takes priority over the analysis of buildings or land parcels (Alawadi, 2020).

Despite Space Syntax having achieved significant success and worldwide recognition, there are some constraints in typical Space Syntax applications (Pafka et al., 2020). For instance, it relies mostly on spatial structures emerging from the urban network, without considering important factors such as site circumstances, influencing functions, and land uses (Al-Sayed et al., 2014). Surveys, analyses of interviews, and field observation techniques can verify the accuracy of applying Space Syntax in the study area (Ratti, 2004). In order to provide a quantitative description of movement behaviour in the public domain, a set of coherent and structured on-site observations is usually designated to assess actual mobility conditions and test spatial predictions (Hillier et al., 1993). One of the most fundamental observational techniques for Space Syntax analysis typically includes counting individuals or vehicles at a certain number of points (Hillier et al., 1993; Jiang, 2009; Turner & Penn, 2007). Moreover, movement tracing is another observational technique that allows observers to follow the directions that drivers tend to choose (Al-Sayed et al., 2014). The research design framework of the present study has been depicted accordingly (Fig. 1).

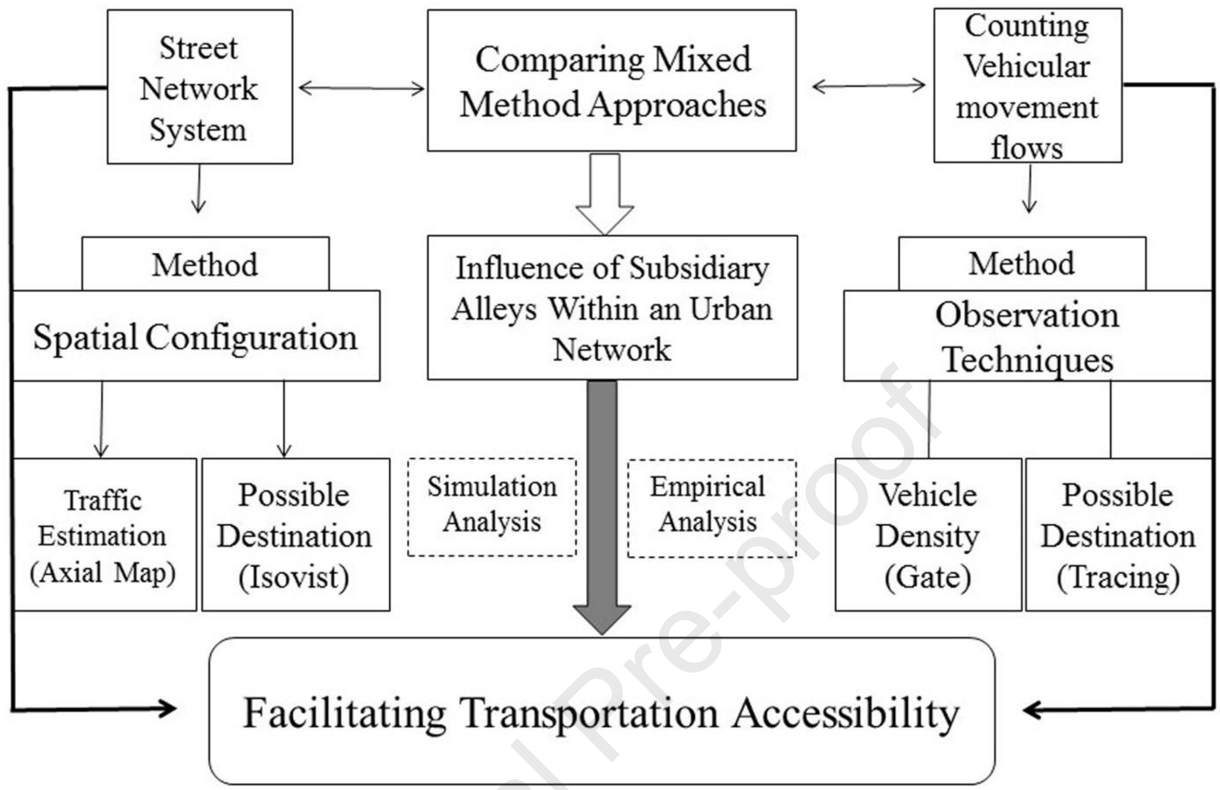


Fig. 1. Research design framework of the present study

4. Material and Methods

The research method used in this study encompasses both quantitative and qualitative approaches to analysis. Fundamentally, the analysis procedure of this study is based on the Space Syntax technique to quantify urban network systems. However, to further reinforce the research methodology, a couple of observational techniques have been adopted to validate the findings as accurately as possible. These observational techniques, particularly developed for syntactic analysis, include gate counts and movement tracing. The method used in this study involves implementing syntactic analysis by simulating and testing the existing urban network plans to measure and quantify the spatial configuration of urban networks as a first step.

In the second phase, hypothetical urban network systems were simulated by removing subsidiary alleys to measure potential quantitative transformations within the urban spatial configuration. Subsequently, findings from both simulated models were compared and discussed. Statistical Package for the Social Sciences (SPSS) software was employed to ascertain correlations between findings from existing and hypothetical models. Therefore, quantitative values obtained from syntactic analysis were compared using a t-test. Additionally, Pearson correlation tests were used to identify relationships between the data. Consequently, independent groups of parametric data were examined to determine significant correlations in the study's findings. To facilitate reproducibility, all relevant data, including syntactic properties and empirical analysis, are available upon request. The following subsections thoroughly explain each adopted procedure to clarify the implementation of instruments.

4.1. Spatial configuration analysis using space syntax

According to Space Syntax, the roadway structure of a settlement itself may identify its roadway units, conventionally identified as axial lines, closely integrated, and accessible from all other units (Hillier & Hanson, 1984; Hillier, 1999a). An axial line is defined as a unit of space, assuming that pedestrians or travellers prefer routes with fewer changes in direction to reach their destinations (Paul, 2013; Penn, 2003). The concept of axial lines was developed on the premise that travellers aim to minimise the number of turns required (Hillier, 1999a, b). In syntactical analysis, two essential variables impacting this are integration and connectivity (Al-Sayed et al., 2014). Higher integration indicates more cohesive use of space, while greater connectivity suggests enhanced accessibility within that space (Hillier, 2008). Therefore, these variables significantly influence the measurement of configurational accessibility within street network systems. Numerous studies have shown that the correlation between connectivity and integration enhances spatial intelligibility. Hence, higher correlation values also indicate greater legibility (Hillier, 1993; Hillier et al., 1986; Long & Baran, 2012; Peponis et al., 1989). Consequently, this study aims to explore how subsidiary alleys impact the configurational legibility of urban spaces.

In this research, the intention is to utilise the axial line map as one of the most vigorous and influential factors stimulating movement patterns of vehicles and pedestrians in urban network systems. During the initial stage of adopting this method, updated versions of urban plans for the study areas were collected, and the necessary modifications were made in the AutoCAD files. Consequently, two sets of models—existing and hypothetical—for each case were prepared, with and without the presence of alleyways in urban spatial configurations. Subsequently, each of these models was saved in DXF format to facilitate importation into UCL Depthmap software. After importing the required maps, by running an axial map, the initial graphs were created, and the subsequent analysis were performed. This process resulted in the reporting of required variables including integration, connectivity, and intelligibility, alongside obtaining quantitative values of spatial configuration for both the existing and hypothetical simulations. Ultimately, the quantitative values of each model were examined in SPSS using a t-test to determine whether significant differences existed between the quantitative values.

4.2. Empirical observations

4.2.1. Gate count observations method

The Gate Count method implies a technique that usually measures the density and flow of vehicles and pedestrians in an urban space. It allows researchers to gather a wide range of data about movement using quantitative values. The positions of gates in this study were specified across a diverse range of low-integrated, integrated, and high-integrated locations in the case studies. Accordingly, 20 gates were selected for each case study based on various syntactic characteristics of streets and alleys, aimed at validating the simulation data analysis covering both streets and alleys in the cities. It should be noted that the observations took place in February 2023. The collected data are based on maximum viewing angles to accurately count the vehicles passing through the designated gates. The application of the gate count method is driven by two main objectives: firstly, to understand the compatibility and validity of simulation analysis, and secondly, to capture the mobility patterns of vehicles in the study areas. This research primarily focuses on vehicles for empirical observations to measure their flow across the street and alley network systems.

4.2.2. Movement traces observation method (directional splits)

The Movement Traces method involves tracking and recording the dynamics of movement flow in a predetermined urban area. It helps to discover movement patterns of vehicles as drivers navigate through the study area, fundamentally considered a qualitative observation method. To effectively capture the movement patterns of cars and the destinations chosen by drivers within a 5-minute time period, the observer should position themselves to maximise their range of view across the layout. Observations are typically conducted in the study areas to empirically track and record drivers' choices of alleyways. This method is primarily used to validate the spatial characteristics previously obtained from the spatial configuration analysis of street network systems. When there is alignment between observations and simulations, it confirms and supports the initial assumptions regarding how spatial configurations influence the role of alleyways in accessibility. If discrepancies arise, further investigation is necessary to identify any external factors influencing the built environment (Al-Sayed et al., 2014). Therefore, Isovist analysis using Depthmap software is intended to determine whether there is correspondence between findings obtained from simulations and observations in this context.

4.3. Study areas

Prior to the modern era, Iranian cities lacked systematic planning or design. These cities developed and configured haphazardly according to the demands and needs of the community within various periods. This attribute set in place traditional Iranian cities among the so-called *organic* cities (Karimi, 1997; 2002). This study examined four cities as the case studies namely *Rasht*, *Anzali*, *Rudsar*, and *Rezvanshahr* with such particularities, located in *Gilan* province, northern Iran in order to generalise the research output as much as possible (Fig. 2). These cases were selected due to their consistency with the scope of the present study and their associated problems. Likewise, less attention has been paid so far on configurational attributes of these cities which had been mainly formed in the reign of Reza Shah Pahlavi and featured organic spatial configurations. In relation to characteristics of alleyways within the study areas it can be declared that there are no steady dimensions for the width of the alleyway due to their organic and unplanned nature. Notwithstanding, the average width for alleyways are varied between 6 and 10 meters in the study areas. Considering that they are completely distinguished from main streets, they are named as so-called subsidiary alleyways.

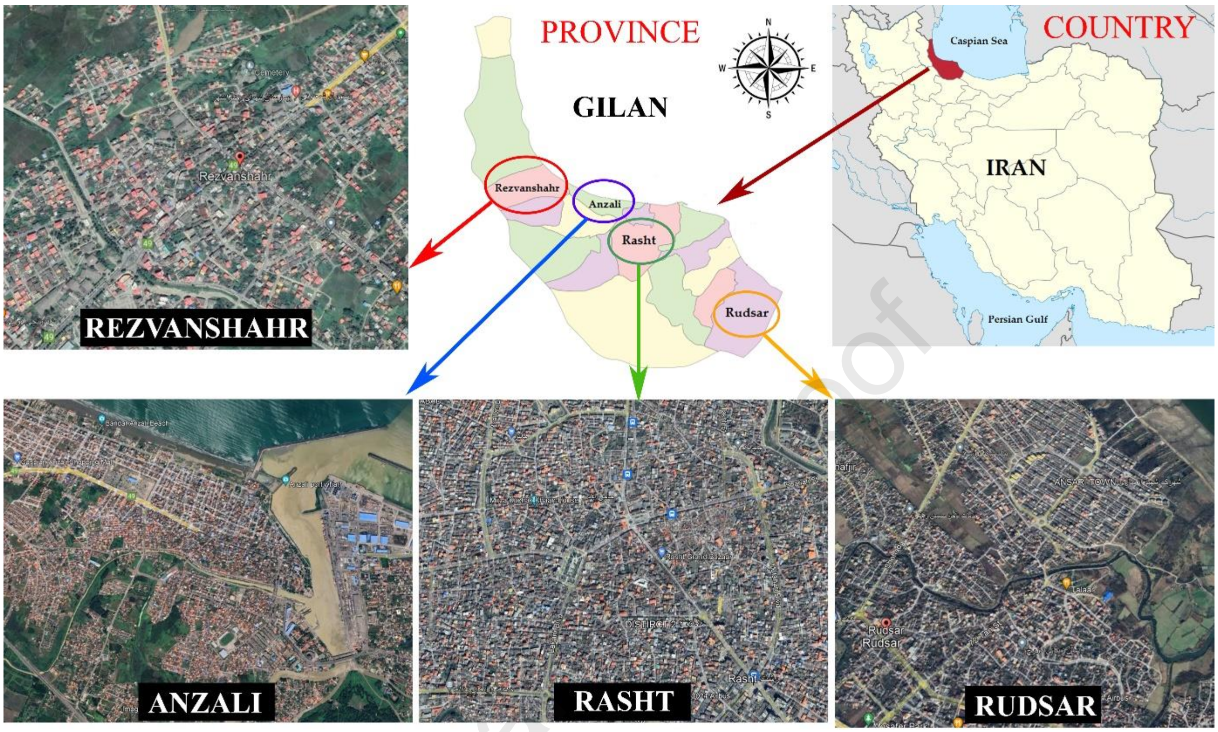


Fig. 2. The geographical location of the study areas on the map

In the selected cases for this study, the alleys are designed to accommodate both cars and pedestrians, which is a notable distinction from many other regions where alleys are exclusively pedestrian zones. This shared usage impacts the dynamics and interactions within these spaces, influencing factors such as safety, accessibility, and functionality. Figure 3 highlights the coexistence of vehicular and pedestrian traffic and provides a visual context for the physical attributes discussed in our study. Understanding the dual-purpose nature of these alleys is crucial for comprehending the unique challenges and advantages they present, and this distinction is a key consideration in the analysis of the network systems. Additionally, the physical attributes of these urban network systems are presented in Table 1. This table highlights the variations in network length, intersection count, and density between the existing and hypothetical models for each city. The total network length represents the cumulative length of all streets and alleys within the network. The number of intersections indicates points where different streets or alleys cross each other. Network density is calculated as the ratio of the total network length to the area of the city.

Fig. 3. Physical attributes of the alleys within the study areas

Table 1. Physical attributes of the identified streets and alleys within the case studies

City	Total Network Length		Number of Intersections		Network Density	
	Existing Model	Hypothetical Model	Existing Model	Hypothetical Model	Existing Model	Hypothetical Model
Rasht	123659 m	36402 m	1251	62	0.08	0.04
Anzali	100442 m	20244 m	338	22	0.07	0.03
RezvanShahr	72235 m	34430 m	489	66	0.07	0.03
Rudsar	64245 m	21758 m	447	31	0.08	0.04

5. Results

5.1. Spatial configuration analysis using space syntax

The results acquired from simulation of syntactical analysis were performed in four urban areas and in two different models. In the first step of analysis, the focused study areas were drawn with their current conditions and their quantitative values were obtained accordingly. In the second step, the subsidiary alleyways were omitted from the drawn urban plans and analyses were performed with the remaining main streets and their numerical syntactical values were acquired. Subsequent attempts were made to identify the effect of subsidiary alleyways on configurational accessibility within these organic street network systems using *t*-test.

The obtained findings from the case of *Rasht* in its current standing condition indicated that the highest value of connectivity is 96, and the highest value of integration is 2.17. However, the obtained results based on the hypothetical model by eliminating alleyways elucidated that the highest value of connectivity is 16, and the highest value of integration is 1.91. The result of the correlation test between connectivity and integration displayed that the value of R^2 in the first model, with existence of subsidiary alleyways, is 0.26; while the value of R^2 for the hypothetical model is 0.46.

The obtained results from the case of *Rezvanshahr* in its current configuration illustrated that the highest value of connectivity is 58, and the highest value of integration is 2.37. While the obtained findings from the hypothetical model by omitting alleyways indicated that the highest value of connectivity is 17, and the highest value of integration is 2.44. The obtained correlation between connectivity and integration showed that the value of R^2 in the first model, with existence of alleyways, is 0.38. This is despite the fact that the value of intelligibility in the hypothetical model is 0.61.

The outcomes obtained from the case of *Anzali* in the existing condition displayed that the highest value of connectivity is 70, and the highest value of integration is 2.34. Whereas the analysis obtained from the hypothetical model elucidated that the value of connectivity dropped to 17, and the value of integration mitigated to 2.06. The obtained correlation results between connectivity and integration indicated that the value of intelligibility in the first model, with existence of alleyways, is 0.25. While this value augmented to 0.59 in the hypothetical model by removing subsidiary alleyways from the spatial configuration.

Finally, the acquired results obtained from the case of *Rudsar* in its current condition, with existence of alleyways, demonstrated that the highest value of connectivity is 31, and the highest value of integration is 2.02. The highest value of connectivity is 8, and the highest degree of integration is 1.00 in the hypothetical model, without existence of alleyways. On the other hand, the R^2 value of correlation between connectivity and integration in the existing model is equivalent to 0.23, and in the hypothetical model, without existence of alleyways, the R^2 value of intelligibility is equivalent to 0.43 (Fig. 4 and 5). Mathematically, intelligibility denotes the correlation between the connectivity and global integration values of lines in an axial map. Thus, the use of linear regression is due to the fact that a higher R^2 value signifies a stronger correlation. The level of intelligibility of an urban network system can be assessed by examining the R^2 value describing the relationship between connectivity and integration; the higher the R^2 value, the greater the intelligibility of a layout (Hillier, 1996; Long & Baran, 2012).

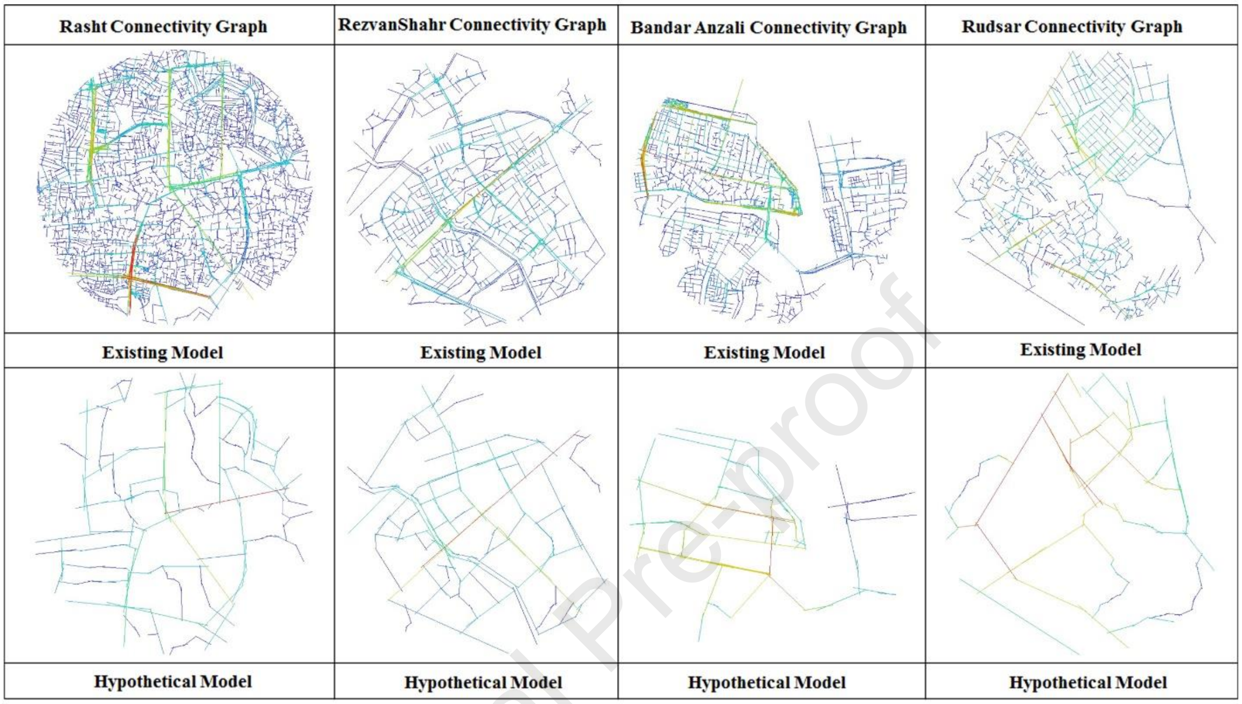


Fig. 4. The connectivity graphs of the study areas in their existing and hypothetical models

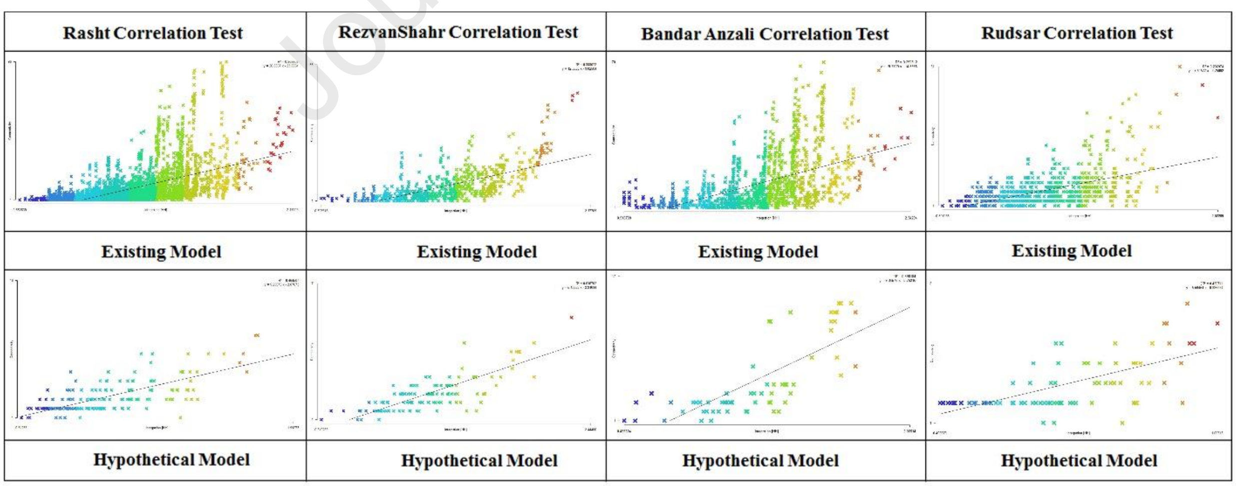


Fig. 5. The correlation tests between integration and connectivity of the study areas as an indicator of intelligibility in their existing and hypothetical models.

The obtained quantitative data were presented in the form of line charts to compare the existing models that include subsidiary alleys with the hypothetical models that exclude them. The results indicated a notable reduction in the values of connectivity, integration, and choice across almost all study areas when subsidiary alleys were not present. This suggests that the absence of subsidiary alleys has a substantial impact on the connectivity and integrity between different parts of the urban network. Conversely, the value of intelligibility with the existence of subsidiary alleyways diminished in all of the study areas (Fig. 5 and 6).

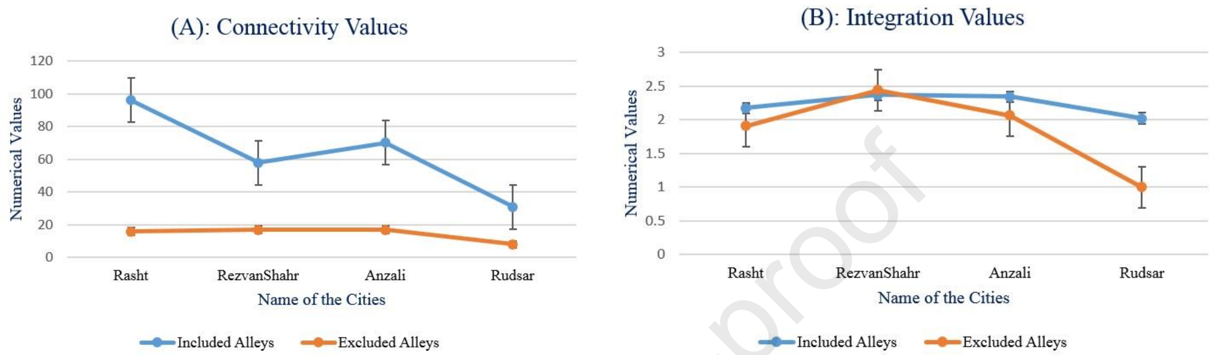


Fig. 6. (A) Data obtained from connectivity values of the study areas in their existing and hypothetical models; (B) data obtained from integration values of the study areas in their existing and hypothetical models.

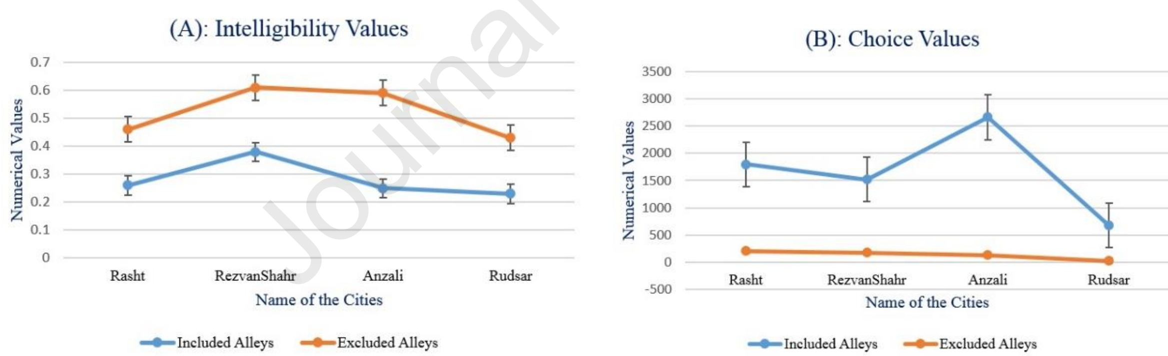
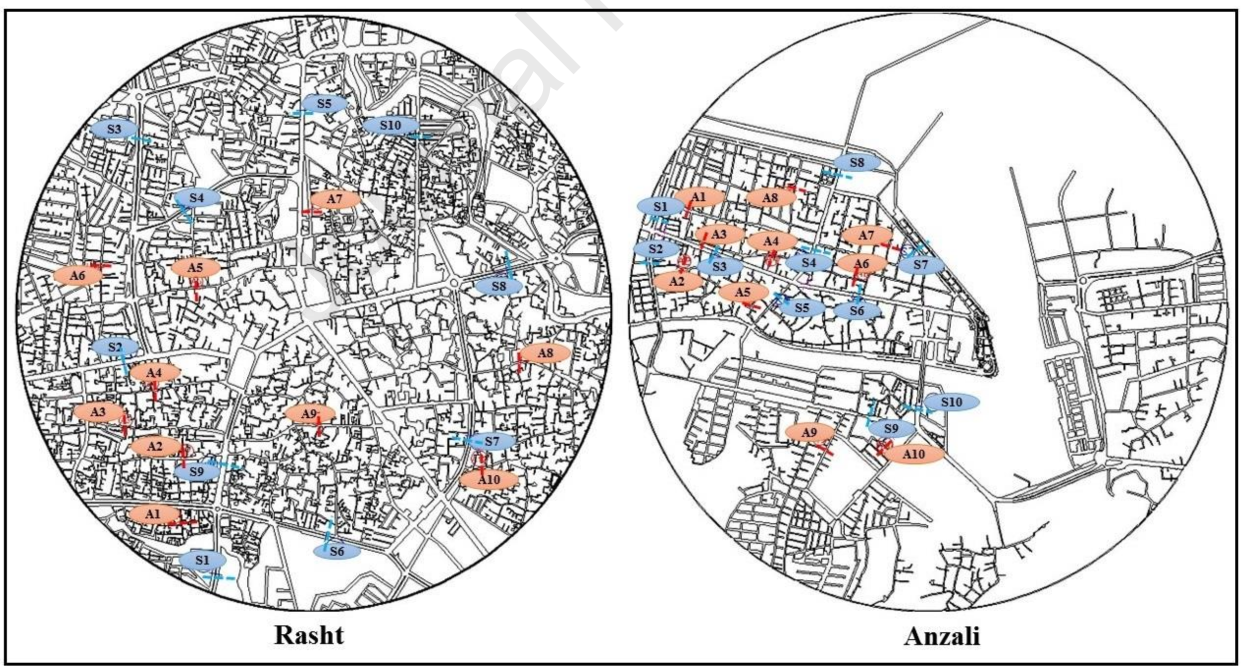


Fig. 7. (A) Data obtained from Intelligibility values of the study areas in their existing and hypothetical models; (B) data obtained from choice values of the study areas in their existing and hypothetical models.

In the next section of analysis, the obtained data is imported to SPSS software in order to understand if there is a significant difference between the quantitative obtained data using *t*-test. Due to the inferential nature of analysis, it is intended to initially consider the equality of variances using *Levene's* test. The level of significance for the equality of variances displayed the value of 0.084. Since the significance value is more than 0.05, it can be noticed that the variances of the connectivity, as a determinant variable in this study, are equal. The results acquired from *t*-test for equality of means revealed that the value of 2-tailed significance is equivalent to 0.011. Considering the fact that *P*-value is lower than 0.05, it can be declared that there is a significant difference between the data obtained from connectivity in the existing models and hypothetical models. In addition, the results obtained from the level of 2-tailed significance obtained from quantitative simulation of intelligibility was equivalent to 0.005. Since the obtained *P*-value was found to be lower than 0.05, it can be inferred that there is a significant difference between legibility level of existing and hypothetical models in study areas.

5.2. Empirical observations using gate counts

The results obtained from empirical observations of gate counts to understand the correlation between vehicle mobility and the value of connectivity in the spatial configuration of the study areas yielded outstanding outcomes. The findings were recorded in both streets and alleys to discern the differences between these two urban infrastructures. Moreover, 10 gates were considered within the streets for each case, and 10 gates were selected within the alleys for each case. Likewise, each gate was observed for 5 minutes in the afternoon, between 5:00 and 7:00 pm, which are considered peak hours for traffic congestion in the study areas. It should be noted that the location of each gate was selected based on its importance in terms of functionality, accessibility, popularity, and its connectivity values. The locations of gate count observations are delineated accordingly (Fig. 8).



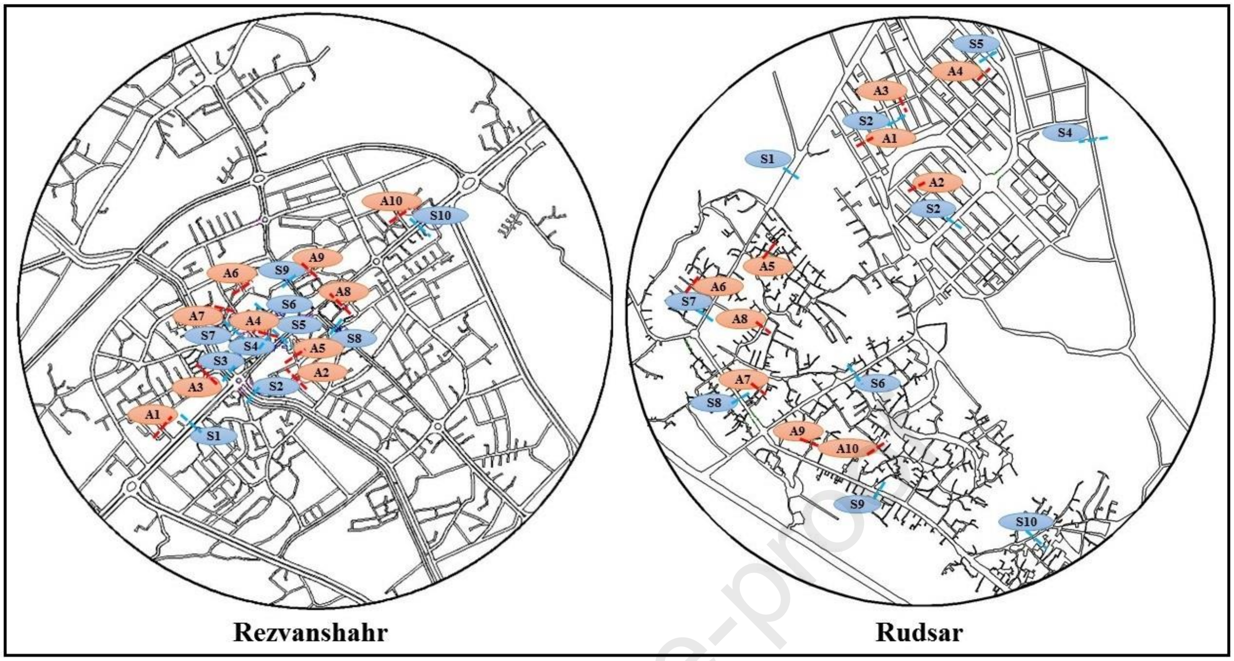


Fig. 8. Identification of gates in four case studies for counting vehicular mobility in both streets (S) and alleys (A), to explore their relationship with connectivity values.

In the next step, after obtaining the quantitative values of vehicle mobility at each gate within streets and alleys, their mobility values were compared to the connectivity value of each gate in the form of a set of comparative line charts. Afterward, by entering the obtained data into SPSS software, the Pearson correlations were performed in order to understand if there is a significant correlation between the acquired data. In general, the findings declared that there is a significant correlation between the value of vehicle mobility and its associated connectivity value in most of the cases. The observed results within the streets of *Rasht* indicated that the correlation coefficient was found to be 0.74 (p-value = 0.014), indicating a statistically significant positive correlation between the two variables. The Pearson correlation analysis was also conducted to examine the relationship between mobility and connectivity of alleys in *Rasht*. The correlation coefficient revealed a moderate positive association of 0.66 (p = 0.037) between the variables. This indicates that there is a statistically significant correlation between mobility and connectivity of alleys in *Rasht* case. Specifically, higher levels of mobility were found to be associated with increased connectivity values. These findings suggest that as the mobility within the alleys increases, there is a corresponding rise in their connectivity. The analysis was based on data collected from 10 observed gates and their associated syntactical values in the alleys of *Rasht* (Fig. 9).

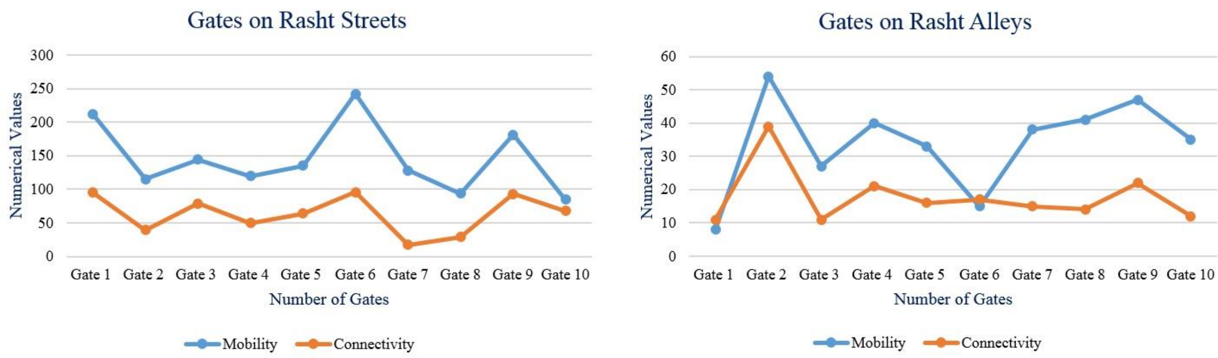


Fig. 9. The data obtained from examined gates for counting vehicular mobility and their associated connectivity values within the streets and alleys of Rasht.

A Pearson correlation analysis was performed to examine the relationship between mobility and connectivity of streets in *Anzali*. The analysis revealed a moderate positive correlation coefficient of 0.62 ($p = 0.054$) between the variables. Although the p-value did not reach conventional levels of statistical significance ($p < 0.05$), there is a notable trend suggesting a positive association between mobility and connectivity of streets in *Anzali*. The findings suggest that higher levels of mobility tend to be associated with increased connectivity values based on 10 experimented gates in both streets and alleys. The Pearson correlation analysis was performed to explore the relationship between mobility and connectivity of alleyways in *Anzali*. The correlation coefficient revealed a moderate positive association of 0.63 ($p = 0.047$) between the variables. The statistically significant correlation suggests that there is a meaningful connection between mobility and connectivity of alleyways in *Anzali*. The findings indicate that higher levels of mobility are linked to increased connectivity values, indicating that alleyways with greater mobility tend to exhibit higher levels of interconnectivity. This result provides valuable insights into the relationship between mobility and connectivity in the specific context of alleyways in *Anzali* (Fig. 10).

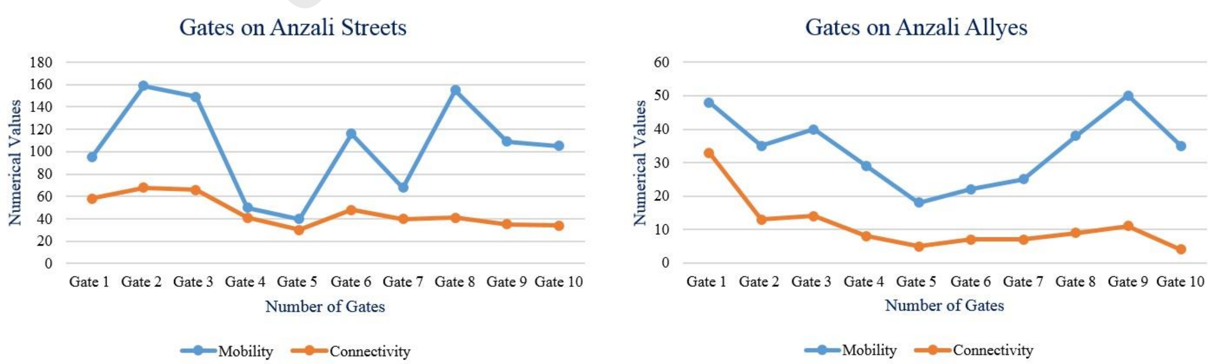


Fig. 10. The data obtained from examined gates for counting vehicular mobility and their associated connectivity values within the streets and alleys of Anzali.

The analysis demonstrated an intense positive correlation between urban mobility and street connectivity in *RezvanShahr*. The computed Pearson correlation coefficient was 0.905, demonstrating a strong degree of correlation between the variables. In addition, the two-tailed significance test (p-value) yielded a value of 0.00, which is lower than the conventional threshold of 0.05. This denotes that the correlation is statistically significant, suggesting that the correlation between urban mobility and street connectivity is unlikely to be due to chance. The analysis has also suggested a significant positive correlation between vehicular mobility and alley connectivity in *RezvanShahr* city. The Pearson correlation coefficient was calculated to be 0.836, indicating a striking association between the variables. Moreover, the two-tailed significance experiment displayed a p-value of 0.003, which is lower than the conventional threshold of 0.05. This demonstrates that the correlation is statistically significant, suggesting that the relationship between vehicular mobility and alley connectivity is unlikely to be accidental (Fig. 11).

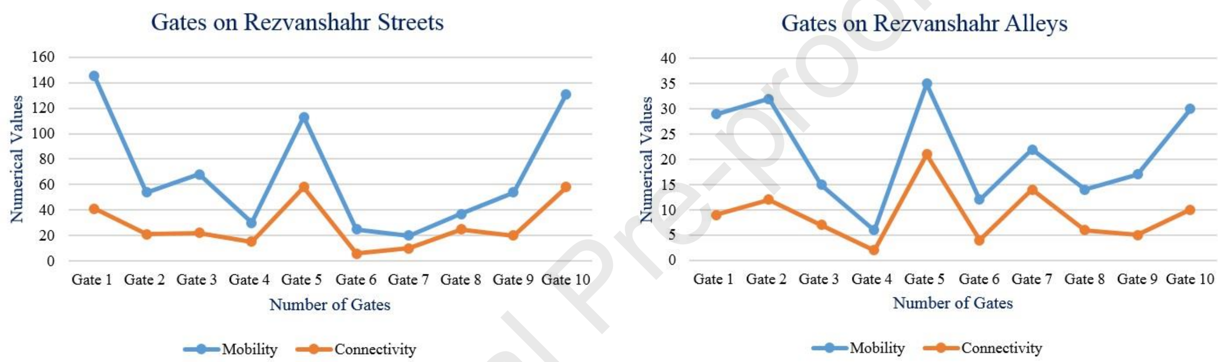


Fig. 11. The data obtained from examined gates for counting vehicular mobility and their associated connectivity values within the streets and alleys of RezvanShahr.

The analysis of the collected data illustrated a notable positive correlation between vehicular mobility and street connectivity in *Rudsar* City. The calculated Pearson correlation coefficient was 0.784, indicating a significant association between the variables. Furthermore, the two-tailed significance test indicating a p-value of 0.007, which is lower than the commonly accepted threshold of 0.05. This demonstrates that the correlation is statistically significant, suggesting that the connection between vehicular mobility and street connectivity is unlikely to occur incidentally. The analysis of the data showed a significant positive correlation between vehicular mobility and alleyway connectivity in *Rudsar* city. The Pearson correlation coefficient was calculated to be 0.942, resulted in a high degree of correlation between the variables. Moreover, the two-tailed significance test yielded a p-value of 0.000, declaring that the correlation is statistically significant. This outcome suggests that as alleyway connectivity increases, vehicular mobility also tends to increase in *Rudsar* city (Fig. 12).

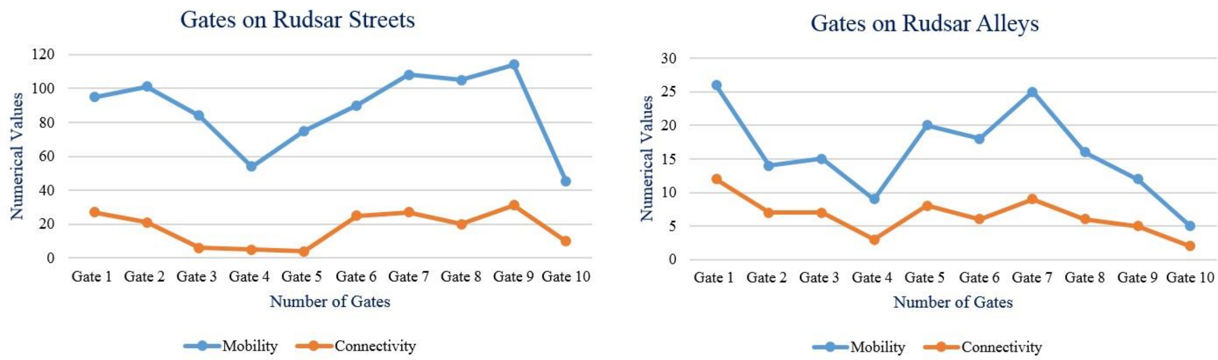
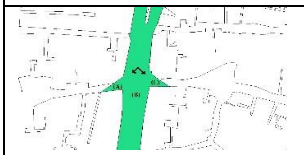
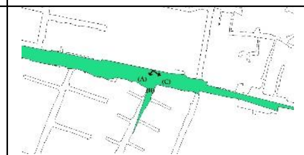
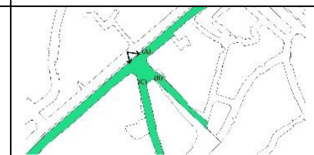
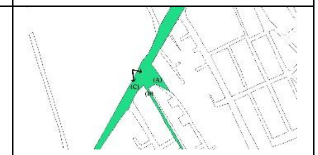
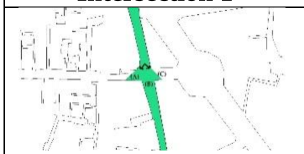
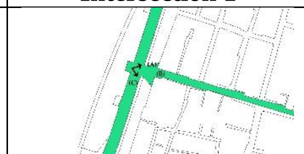
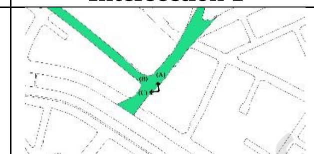
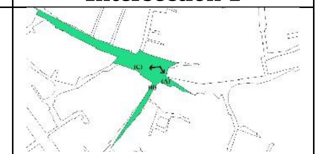
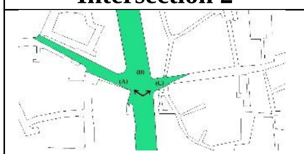
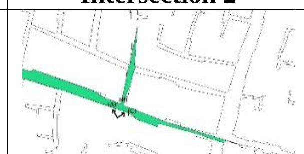
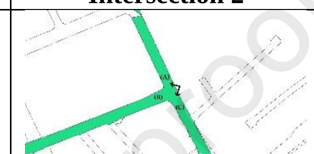


Fig. 12. The data obtained from examined gates for counting vehicular mobility and their associated connectivity values within the streets and alleys of Rudsar.

5.3. Empirical observations using movement tracing

In this part of empirical observations, it is intended to analyse the extent to which drivers tend to choose alleyways while driving for their navigation process. Likewise, it is aimed to discern the relationship between visual field of view and the tendency of drivers to choose their directions towards alleyways. To do so, according to the data acquired from vehicular mobility in the previous subsection, the top three alleyways recorded as the most densely occupied paths in terms of vehicular mobility were selected as spots for observing the movement tracing of vehicles. Accordingly, in the case of *Rasht*, the gate intersections of A2, A9, and A8 were chosen as target points for conducting movement tracing observations. In the case of *Anzali*, the gate intersections of A9, A1, and A8 were selected. In the case of *RezvanShahr*, the gate intersections of A5, A2, and A10 were chosen. Lastly, in the case of *Rudsar*, the gate intersections of A1, A7, and A5 were selected for conducting movement tracing observations (Fig. 8). The results indicated that, in most observed cases, streets possess a higher capacity to accommodate higher levels of vehicular mobility. Furthermore, the results revealed that the visual fields of drivers do not notably influence drivers' intentions to use a particular alleyway to navigate their directions. The results indicated that there is no direct correspondence between visibility field of view and vehicular mobility towards alleyways (Table 2). Based on the obtained results, drivers are choosing those alleyways not only because of their visibility capacity but also due to their familiarity with the urban network systems, which allows them to find shortcuts to reach their destinations. Figure 13 also displays the percentage distribution of categories A, B, and C across different intersections in the cities of *Rasht*, *Anzali*, *RezvanShahr*, and *Rudsar*. Each subplot represents a different city, with bars indicating the percentage distribution for each category at different intersections. The categories are stacked to visualize their relative proportions within each intersection.

Table 2. Isovist graph analysis of the intersections in the vicinity of most densely alleyways in order to understand to what extent visual field of drivers is effective in their route choice towards alleys

Rasht	Anzali	RezvanShahr	Rudsar
			
Intersection 1	**Intersection 1**	**Intersection 1**	**Intersection 1**
			
Intersection 2	**Intersection 2**	**Intersection 2**	**Intersection 2**
			
Intersection 3	**Intersection 3**	**Intersection 3**	**Intersection 3**

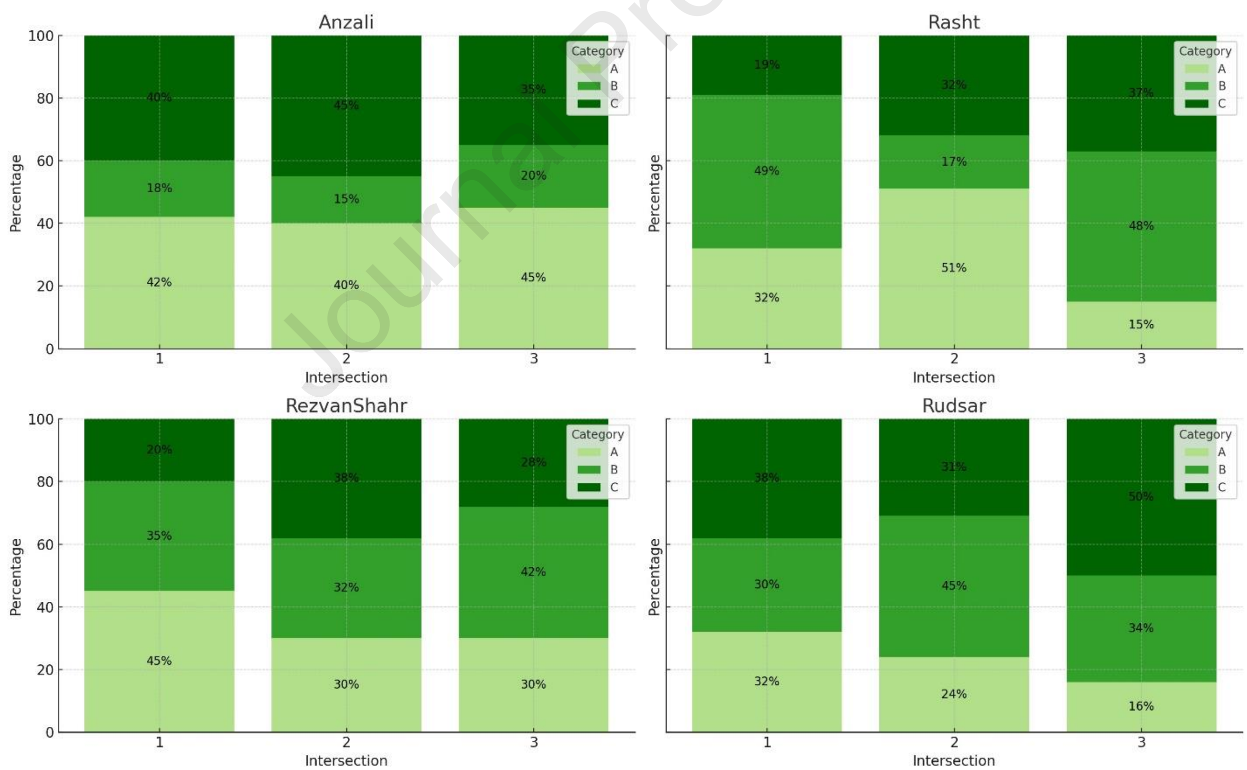


Fig. 13. The percentage distribution of different directions within the identified intersections in the studied cities

6. Discussion

6.1. Interpretation of the results and their contribution

The results obtained from the syntactical analysis strongly indicate that alleyways have a significant impact on configurational accessibility within urban network systems. Furthermore, the intricate and labyrinthine nature of organic alleyways was found to significantly hinder the intelligibility of urban areas, making navigation more challenging and potentially causing disorientation for drivers unfamiliar with the city's layout. The study revealed a noteworthy correlation between vehicle mobility and connectivity values in the majority of instances. In simpler terms, higher levels of mobility were consistently linked to increased connectivity values, suggesting that as mobility within the alleys increases, their connectivity also rises correspondingly.

Two models of alleyways were discovered among the studied urban configurations. The first type relates to short alleys that connect two other alleys together, while the second type comprises alleys connecting two main streets within the urban network system. The results indicate that the second type of alleys, which are connected to major roads, play a crucial role as urban infrastructure facilitating wayfinding transportation within the context of organic cities. Despite their intricacy and complexity, drivers tend to use these paths to shorten their journey and alleviate highly congested traffic within the central cores of urban areas. Consequently, further consideration and improvement of these types of alleyways in terms of structural clarity and legibility are necessary to promote a vibrant and sustainable transportation system.

Primary studies on alleyways in urban design initially focused on their latent potentials in promoting walkability, sociability (Seymour et al., 2010; Wolch et al., 2010; Seymour & Trindle, 2015; Alawadi et al., 2021; Moreau, 2022; Pham et al., 2022; Hennessy & Ai, 2023), and addressing safety concerns associated with these spaces (Furneaux & Manaugh, 2018; Sidebottom et al., 2018; Aleman, 2020; Hidayati et al., 2021; Uyen et al., 2023). Furthermore, previous literature suggested that the organic configurations of alleys evoke a sense of nostalgia and a considerable sense of place among their inhabitants (Imai, 2013; Wan, 2017). However, the primary focus of this study sheds light on the role of alleyways in urban network systems and their influence on configurational accessibility and wayfinding transportation. While this study aligns with previous literature emphasizing the importance of alleys in enhancing urban network connectivity (Alawadi et al., 2021; Khanal et al., 2024), it also underscores their role as essential urban infrastructure capable of improving transportation and reducing traffic congestion in the central cores of organic cities.

Previous studies have indicated that while Asian alleyways provide a nuanced perspective on urban development and a standardizing view of the process of metropolisation (Imai, 2013; Yoshii, 2016; Gibert-Flutre & Imai, 2020), fewer studies have focused on their specific role in urban studies. Recent evidence from China explores the conservation and reuse of alleyway spaces in historic urban neighborhoods (Song et al., 2024). Another recent study in American cities highlights the significant role of alleyways in crime prevention (Wo et al., 2024). Despite limited studies on alleys in Australia (Moreau, 2024), the United States (Wo et al., 2024), the United Arab Emirates

(Alawadi et al., 2024), Canada (Furneaux & Manaugh, 2018), Indonesia (Hidayati et al., 2021), South Korea (Lim & Pae, 2021), Vietnam (Uyen et al., 2023), and African cities (Alem & Domogalla, 2023), the majority lack substantial attention to their role in transportation policies according to existing international literature. A review of recent literature in this field reveals a significant gap regarding the role of alleyways in transportation policies and research.

However, this research also displayed a significant aspect that was not extensively addressed in previous literature. Specifically, it found that the intricate and maze-like nature of organic alleyways can hinder the intelligibility of urban areas, contradicting the notion that alleyways universally contribute to improved wayfinding. This highlights the need to consider the structural clarity and intelligibility of organic alleyways to ensure a vibrant and sustainable transportation system. Yet another noteworthy discovery in this research is the correlation between vehicle mobility and connectivity values within the alleyways. This finding underscores the interplay between mobility and connectivity in constituting urban transportation dynamics. It also corroborated the existing literature that supports the positive influence of alleyways on urban network connectivity. However, this research goes beyond the previous literature and reveals the potential challenges associated with the intricate nature of these alleyways, highlighting the importance of improving their structural clarity and legibility for a more effective transportation system, thus facilitating the bridging of the gap between theory and practice within the domain not only of transport policy, but also of sustainable urban planning.

On the other hand, studying organic patterns in urban planning has drawn less attention thus far (Karimi, 2002; Abdi & Soltani, 2022; Torun et al., 2020). Therefore, this study contributes to a deeper understanding of natural processes in the organic urban design process, such as development, evolution, and adaptation. Moreover, since organic street network configurations often encompass historical values, providing a set of guidelines for preserving and maintaining such recognised urban areas and their aesthetic contributions in terms of sustainable transportation policies is deemed valuable. Furthermore, the implications of this research extend beyond the studied areas in Iran, offering valuable insights for cities with similar organic spatial configurations worldwide. Thus, the implications of this study could also be applicable to cities that often reflect historical growth patterns and have evolved naturally over time, influenced by factors such as geography, social structures, and historical events. Additionally, the current study adopts a unique approach in its methodological design that could offer a suitable framework for other cities in the world with planned grid systems in their spatial configuration to test similar potential assumptions. It should be noted that since, in many organic-configured cities such as the old towns of Rome (Medieval parts), Barcelona (Gothic Quarter), Granada (Albaicín district), and Cairo (Islamic Cairo), alleyways are restricted to pedestrian use, their role can also be studied in walkability research using analogous procedures.

This paper contributes to the existing international literature by providing new insights into the role of alleyways in urban network systems and their influence on configurational accessibility and wayfinding in transportation. Previous studies have not addressed the specific impact of alleyways on configurational accessibility within urban network systems and their role in reducing traffic congestion in central urban areas. The current research bridges this void by conducting a syntactical analysis that reveals the significant impact of alleyways on urban mobility and connectivity. The findings indicate that alleyways, particularly those connecting to main streets, play a crucial role in facilitating transportation and reducing traffic congestion. This holds significant implications for urban planning and transport policy, indicating that improving the clarity and legibility of alleyways' structures can enhance their usability and support the development of a more sustainable transportation system. This contribution is highly important for the international community because it provides a deeper understanding of the functional and infrastructural roles of alleyways, offering valuable insights for cities with similar organic spatial configurations worldwide.

6.2. Implications for transport policy and planning

The findings of this study on the role of alleyways in facilitating wayfinding transportation within organic street networks offer several implications for public transport policy and urban planning. In terms of policy implications, urban planners should incorporate alleyways into the broader urban mobility framework. Alleyways that connect main streets play a crucial role in enhancing connectivity and reducing traffic congestion in central urban areas. Policies should encourage the maintenance and improvement of these pathways to facilitate smoother traffic flow. In terms of planning perspective, this can be achieved by ensuring these pathways are well-maintained, adequately lit, and clearly signposted to improve their usability for both vehicles and pedestrians.

In addition, policies should aim at improving the structural clarity and legibility of organic alleyways. Given that the intricate nature of these pathways can hinder intelligibility, measures should be taken to simplify navigation within these networks. For instance, implement urban design interventions such as better signage, maps, and wayfinding tools to aid navigation, can potentially facilitate this process. Moreover, reconfiguring certain sections of alleyways to reduce complexity without compromising their historical and cultural value, assigning regular required setbacks, and distinguishing vehicles and pedestrian routes can significantly enhance wayfinding.

Previous evidence verified that providing appropriate infrastructure for walking and cycling are crucial for reducing reliance on cars, mitigating traffic congestion, and the overall safety and support for sustainable transportation (Abreo et al., 2024; Ji et al., 2024; Koh & Wong, 2013; Olsson & Elldér, 2023; Zhou et al., 2020). Thus, developing pedestrian and cyclist-friendly alleyways by improving pavement conditions, providing adequate lighting, and ensuring safety can be considered as a set of pragmatic implications to urban planning. Moreover, policies should support the creation of green corridors within alleyways to enhance their appeal and functionality as sustainable transport routes.

Urban management can leverage the intrinsic potential of alleyways as alternative routes to alleviate the congestion of vehicular traffic in central urban areas. This can be particularly effective in cities with organic spatial configurations where main streets are often overburdened during peak hours. Implementing traffic management strategies that direct vehicles to these alternative routes to distribute traffic more evenly across the urban network can be deemed another practical implication of the current study. Investing in the infrastructure of alleyways, such as improving road surfaces and drainage systems, should also be taken into consideration, as the studied areas particularly suffered from these problems, to enhance their capacity to handle vehicular traffic.

Policies should aim to preserve the historical and cultural significance of alleyways while enhancing their functional role in urban mobility. This balance can contribute to the sustainability and heritage value of urban environments. Accordingly, developing conservation guidelines that protect the historical integrity of alleyways, encouraging community involvement in preserving these spaces, and ensuring that any modifications respect their cultural significance hold particular importance. In sum, the configurational accessibility of alleyways plays an indispensable role in urban mobility and wayfinding within organic street networks. By integrating these pathways into broader urban planning and transport policies, cities can enhance connectivity, reduce congestion, and promote sustainable transportation. These implications provide a roadmap for policymakers and urban planners to harness the potential of alleyways, ensuring they contribute effectively to the sustainable public and private transportation systems.

7. Conclusion

The main aim of this study was to investigate how the role of configurational accessibility of alleyways within the organic network systems may enhance wayfinding transportation. The originality of this research underscores the significance of nuanced comprehending of the intricate maze-like characteristics of organic alleyways and their subsequent influence on connectivity and intelligibility. By addressing these intricacies, this study contributes to a more profound comprehension of alleyways' role in urban network systems by illustrating the significant correlation between connectivity and urban mobility, paving the way for more aimful sustainable urban planning strategies. The outcomes of this research highlighted the implications for urban planners, policymakers, and transportation engineers, assisting them to design more efficient and accessible urban environments that prioritize both connectivity and wayfinding clarity.

While this study provides valuable insights into the influence of subsidiary alleys within an urban network on vehicular mobility and connectivity, several limitations must be acknowledged. One of the constraints associated with this study is that this study is limited to configurational accessibility of alleyways and its impact on facilitating wayfinding transportation using empirical simulations and observations. On the other hand, the study does not address the impact of this work on the existing understanding of land use transport interaction. Specifically, the interaction between land uses adjacent to the alleyways and the associated trip ends was not explored. This limitation suggests that future research should consider the role of land use patterns and the associated travel behavior to provide a more comprehensive understanding of the dynamics at play.

Future studies can be relied on other facets of accessibility using a miscellaneous range of instruments for comparing with the outcome of this study. Alternatively, direct interviews or questionnaires can be conducted with drivers to understand their viewpoint directly regarding wayfinding procedures. More precisely, the opinions of private and public drivers of transportation means such as taxi drivers may be captured to analyse their viewpoints regarding the process of wayfinding within urban network systems. Regarding further research suggestion, the sociability potentials of alleyways can be taken into consideration for future research agenda in this field. In addition, future studies can delve into the role of alleyways on transportation accessibility in cities with planned grid urban network systems to compare with the findings obtained from the current study. In summary, by expanding the scope of research to include these additional dimensions, we can pave the way for more comprehensive and effective urban planning strategies that enhance the functional aspects of urban transportation systems.

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Highlights

- Alleyways, especially those connecting main streets, significantly enhance connectivity and vehicle mobility within organic urban networks.
- The intricate, maze-like structure of organic alleyways complicates urban intelligibility, making wayfinding more challenging.
- Syntactical analysis reveals a strong correlation between vehicle mobility and alleyway connectivity values, indicating that higher mobility aligns with increased connectivity.
- Two primary types of alleyways were identified: those connecting two alleys and those linking major streets, with the latter playing a crucial role in reducing traffic congestion.
- The study suggests that urban planners should enhance the structural clarity and legibility of alleyways to improve wayfinding and support sustainable urban transportation systems.

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