Effect of Housing Layout and Open Space Morphology on Residential Environments
–Applying New Density Indices for Evaluation of Residential Areas

Case Study: Tehran, Iran

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Abstract
Over time, urban developments with increased densities have led to a decrease in private open space with a lack of public open space. Residential open spaces are missing in housing legislations as they are estimated based on floor area ratio and building coverage ratio, whereas they cannot be used as an all-encompassing measurement tool. Moreover, it is important for designers to consider housing layout to ensure a pleasant environment for residents; eventually, a range of benefits and opportunities will be available in residential open spaces. Therefore, to achieve a better quality of space in residential areas, new indices in the evaluation of residential environments should be proposed.

This research assumes that there are links between the attributes of housing layout, space openness, and quality of space in residential areas. This study intends to examine some of the effects of housing layouts on residential open space through a comparative analysis of residential areas in Tehran. The relation between building arrangements, possibility of windows, and spatial openness will be analyzed; subsequently, two new indices—wall perimeter index (WPI) and spatial openness index (SOI)—will be proposed and target districts will be studied to compare different residential areas according to the new indices.

Keywords: density; indices; residential area; housing layout; open space

1. Introduction
Since the late twentieth century, owing to rapid urbanization, urban congestion, and decline in the quality of open space around the world, there is a necessity to expand the outdoor environment and open spaces as vital social and physical spaces.

When spatial behavior as a part of social existence is defined by spaces around us, owing to the lack of well-designed spaces marked by boundaries and walls, the activity between buildings becomes lacking, contacts become sharper and more on purpose, and people become more alone (Madanipour 1999).

Environmental and social problems owing to high density within cities could be an adequate motivation to adopt new standards in urban environments, especially residential areas (Woolley 2003, Wilson and Hughes 2011, Trancik 1986, Towers 2005, Gehl 2011, Rapoport 1975).

A variety of social activities happen in different places such as dwellings, private and semi-private outdoor areas, public areas, and gardens (Gehl 2011). Consequently, providing open spaces at different levels has been a vital concern in urban legislation and design development programs (Worpole 1992, Wilson and Hughes 2011, Towers 2005) and the internalization of open spaces in residential environments has been a crucial matter of discussion (Woolley 2003).

The urban structure contains three main elements—space, built environment, and movement system. Built environment includes the buildings, roads, sidewalks, utilities, homes, parks, and all other human-made entities that form the physical characteristics of a community. Buildings can affect the quality of spaces in two ways: the way their volumes and masses frame or enclose the space and the way their users interact with space. If buildings and spaces are considered together, it will provide a positive contribution to the quality of the urban area (Payami Azad et al. 2016). Among all the common types of buildings that shape the form of cities, housing is of major importance constituting the bulk of buildings (Polyzoides et al. 1992).

On the other hand, one of the ways to measure and analyze the structure of cities is density, and it is one of the most important indices and design parameters in the field of housing which has been the subject of
Density is a combination of built-up environment (housing) and population of the residents (Whitehead 2008). Good and bad environmental quality occurs at both high and low densities. Since a variety of factors affect density, it is impossible to relate residential density to environmental quality. Perception of density per person can significantly differ from a technical perspective on density. Perceived density estimates the number of users of space in a given area and relates the users and space. Spatial characteristics such as landscape, building type, building height, space openness, and aesthetics affect the perceived density whereas spatial density is one of the aspects of perceived density (Ng 2009, Bergdoll and Williams 1990, Alexander 1993, Rapoport 1975).

At a physical level, density affects housing layout, building form, and city structure; some of the qualities of built environments cannot be measured by density but they are a part of physical density owing to their contribution to perceived density. Urban planners exert precise control over density. Building density is determined by built form, urban morphology, and housing layout (Jensen 1966, Sugiyama 1984). Housing layout allocates land for buildings, roads, cars, pedestrians, public and private open spaces, and landscaping. (Biddulph 2007).

Terms related to density are plot area, height of buildings, setbacks, floor area ratio (FAR), and building coverage ratio (BCR), which shape the built form of urban areas (Payamiazad et al. 2016, Tonkin 2008, Alexander 1993). Of all the available studies on density, the majority concentrate on the discussion of BCR and FAR. Such studies concern themselves with population and building densities. Governments impose built-up density and height limitations through restrictions on FAR and BCR to express a density limit (Alexander 1993).

The average FAR of residential environments is a consequence of environmental, social, and cultural conditions. The BCR is used to express the relationship between built and non-built land. Built form and FAR are related, whereas coverage and heights of buildings depend on built form. In the last few years, however, the technical performance of many major municipal governments has significantly improved, but FAR and BCR restrictions have not been revised. In contrast, the aim of this study is to examine the standard of FAR and BCR by proving their incapability to analyze housing arrangements, and the way housing layout types could affect the residential open space.

In previous research (Payamiazad et al. 2016), following Professor Sugiyama (1984 and 2006) and Professor Tokuono’s (2006) studies, authors reveal that in old residential areas with the same FAR and BCR but different housing layouts, the morphology and enclosure of residential open space is different. Subsequently by applying two new indices, we evaluate the spatial openness and possibility of windows in residential areas.

2. Residential Open Space

Residential open space as a setting of dwelling is related to form, shape, plan, structure, and functions of the built environment and has a positive impact on residential environment quality (Trancik 1986, Gehl 2011, Pakzad 2007). Open space can be categorized into four groups: public, semipublic, semipublic-private, and private spaces. In this study, private, semi-public, and semipublic-semiprivate open spaces are considered. Private space is specific to an individual residential building, and semi-public areas such as streets within the neighborhood are the buffer zones between dwellings and public spaces. Some spaces are preserved by elements such as signs and boundaries and some others are enclosed by fences, walls, and gates (Madanipour 1999).

Open space is a vital component of residential layout including balconies, gardens, and communal areas. These areas provide a private space for residents to play, relax, communicate, and enjoy natural elements such as trees and vegetation, which make the atmosphere more attractive. They can also be used to define the borders between dwellings and the separation between neighboring houses. Allowing the penetration of sunlight and fresh air is another environmental function of open space.

The definition of open spaces within a residential environment in this research includes private open spaces (yards, gardens etc.), roads, and public open spaces in selected areas. Currently, it is estimated that 80% of open space within urban areas is in the form of streets. Accordingly, in order to calculate the total area during estimation, half of the road in front of each lot is considered.

3. Methodology

A comparative analysis of different residential areas is performed to identify the role of residential open space types and layout forms in spatial openness and possibility of windows. The five districts chosen for analysis were districts 1, 4, 8, 12, and 22 in Tehran. These areas were selected because they were built within 100 years of housing transition in Iran with low-rise and mid-rise buildings, which are adaptable to the analysis method. Although the samples in each district were selected randomly as a common type of residential layout, they demonstrate the characteristic of that area.

First, to estimate the open space area in residential areas, urban, numerical, and statistical reports have been analyzed to discuss the transition of residential areas in Tehran, with a focus on the physical attributes of residential open space. The second step involved...
4. Housing in Iran and Tehran
4.1 The Transition of Housing Layouts

It is necessary to understand the progress of development patterns, urban laws, and legislations to interpret the provision of open space in residential areas. In Iran, housing typologies have transformed over time (Fig.1.).

Historically, in the 19th century, through improvements in Iran’s relationships with Western and European countries, revolutions in social life, political, cultural, economic respects, and consequently architecture and urban laws in Iran occurred that resulted in fundamental changes in the country (Madanipour 1998, Haeri 2010). At the beginning of the 20th century, Iran experienced remarkable changes. Legislations, population growth, technological developments, and usage of electricity had a crucial role in the transformation of housing layout. Madanipour (1998) argues that planners and designers who were Western or educated in Western countries also had positive influences on Tehran’s development in the 20th century. All the aforementioned factors caused dramatic changes in Iranian housing. Space hierarchy, height modification, openness, enclosure of spaces, and many other factors have been neglected.

From the last years of the Qajar dynasty to 1961, a new style of housing started in Iran and this period was called a transitional period (Haeri 1997, Soltanzadeh 2005, Madanipour 1998, Costello 1998).

The primary residential unit was a courtyard house with several stories and its residents were members of the same family (Clark and Costello, 1973). The common orientation of the house was east–west in the direction of winds and right angles to the mountains, which resulted in the shape of lots and supported the checkered texture of the city through streets and land parcels (Costello 1998).

In 1953, for the first time in Iran, regulations were proposed for governing the massing and spatial arrangement of residential developments. Land subdivision created uniform parcels of land for some government schemes where the same rows of buildings were built. Residential lot size exhibited an increase with a geometrical shape (mostly rectangular) that influenced the spatial characteristics of dwellings.

Initially, cars were often nestled out of residential lots in the streets whereas later, in the first Tehran comprehensive plan, the position of cars inside the houses was confirmed owing to changes in transportation habits (Ghazizadeh and Rückert 2013). As a result of increasing car ownership, in order to provide access to the street from each plot, the buildings were in the northern part of a lot and 40% BCR for ground coverage was specified as 40% of the plot area on the north side.

In the first master plan of Tehran, which as suggested by Farmanfarmaian and Gruen in 1968 proposed a linear extension of the city toward the west, residential area density was a combination of low, medium, and high-density (Costello 1998, Shojai and Mori 2016). These new regulations influenced the building coverage and building density. The building is in the northern part of the lot, and the share of open space is 40% of land and building coverage is a maximum of 60%. These changes had a remarkable impact on the spatial organization of residential areas (Tehran Municipality 2012).

The definition of residential open space as a courtyard changed owing to the transition of residential units in modern architecture. The central courtyard is now located in the front, and multi-storied apartment buildings became the dominant type of preferred housing.

In recent decades, apartments have become more favorable and the physical characteristics of houses have changed significantly. Owing to changes in Iranian lifestyle and demands such as expectations in the standard of heating and lighting with a greater usage of electrical appliances, the role of cars, and higher rate of car ownership, the resulting changes in housing layouts can be addressed. In the new type of residence, each household has living areas and a shared yard (as opposed to the individual courtyard of traditional houses), which belongs to all the families living in an apartment building. The yard as a residential open space is on one side of the plot and the building is on the other side. Some Iranian architects...
such as Haeri (Haeri 2010) believed that current residential open spaces differ from the past, and yards are mostly for cars and connect the street and parking.

As a rule, the laws in residential areas are more focused on the location of buildings on a residential lot (northern part of the lot in general), building coverage, FAR, the number of floors, and main façade of the residential building. In contemporary residential buildings, daylighting is confined to façade windows from only one or two sides.

4.2 Housing in Tehran

In Tehran, in different parts of the city, there is a crucial difference in the average floor areas. According to the regulations, the average FAR is estimated based on the number of residents per dwelling and the pattern is the same for all districts. Southern districts have a higher density, whereas in the northern parts of the city, density is drastically lower. This difference is mainly due to the difference in the financial status of the families, which increase as we move from the south to the north (Tehran Municipality 2016).

In the new detailed plan (tarh-e tafzili) of Tehran, the residential zones have been classified, and each one has specifications regarding maximum height limit and maximum FAR. The maximum floor coverage in residential areas in all the districts is 60% and the maximum FAR changes based on the density. Thus, the maximum FAR in low-density residential zones is 120% in a two-story building, and the max FAR in high-density residential zones is 360% in a six-story building. The small size of lot subdivision and the extraordinary pressure to increase the floor area within has forced buildings upward (Tehran Municipality 2016). Moreover, the municipalities should supervise the open space area in residential buildings, and if there is any incoherence between housing density, building coverage, and open space area, the residential density should be decreased to satisfy the open space policies. The open area does not include parking and the path of cars.

5. Discussion

Currently, housing layout is of various forms; therefore, the physical form and arrangement of residential buildings and their relationship with open space should be deliberated in new housing developments (Wooley 2003). Recognition of housing typology requires a definition of the description of formal and spatial elements and their relationship. It is necessary to specify the housing layout types and classify dwellings based on common characteristics and forms to clarify the effect of building arrangement within residential areas on the quality, size, and form of open space.

The main differences in building arrangements are the passage of light while maintaining privacy, and the level of open and closed spaces adjacent to each other. Private and semipublic-semiprivate spaces that are formed because of the spatial form of a space create opportunities for social communications. Hence, the housing layout that provides more light and sufficient natural air ventilation with more open space is favorable.

Housing typology could be categorized into four main groups: parallel, courtyard, scattered, and massive linear. In the parallel topology, arrangements of urban blocks and design of the roads are easier since access to natural light and fresh air is possible from two sides of buildings owing to attached walls. In a courtyard layout as an inward type at a given lot area, the rate of the enclosure and access to light and air ventilation are higher. Further, scattered topology creates spatial diversity with a variety of public and open spaces with low spatial openness, and better natural ventilation and access to sunlight and daylight. In the massive linear form of topology, although geometrically the same as the parallel form, more land is released as open space. In this type, owing to deep plans, access to natural light and ventilation in the interior spaces of buildings is difficult. However, by increasing the usage of electronic devices, this problem can be solved.

The arrangement of a fixed number of floors of residential buildings in the same site area with the same depth of block and floor height leads to the formation of a large variety of residential open spaces (Fig. 2). Contrary to the common belief, changing the arrangement of buildings does not necessarily result in an increase in FAR and BCR; moreover, the mathematical relationships between BCR and FAR remain the same (Table 1). To compare the different layouts, we can employ many factors by regarding the impact of arrangement and architectural criteria such as enclosed spaces, height of buildings, and the lack and presence of open space and greenery.

Walls, when considered as a part of the physical form of buildings associated with the height of buildings, determine and shape the open space. The first perception of space quality is related to streets and building proportions, height of buildings, and perimeter of walls. In this research, residential open spaces are unbuilt areas around the residential buildings and include gardens, public spaces adjacent to the residential environment, roads within the site, and half the width of the surrounding roads.

Furthermore, one of the architectural elements of buildings is a window. Windows not only provide natural ventilation and allow daylight to penetrate the space but also offer a view to the exterior and establish a relationship with the adjacent areas. As the size and number of windows in buildings increase, the perception of density both inside and outside the buildings increase. As shown in Table 1., when the floor area and building coverage is the same for all four types of housing layouts with the same height of buildings and width of the block, two factors reveal certain aspects of the problems: the form and proportion of open area and openness; and the wall
length and perimeter, which are linked to the possibility of windows.

Following previous research (Payamiazad et al. 2016) by developing a theoretical model, authors measured and compared two practical factors on residential quality—spatial openness and the possibility of windows, both of which are affected by building layouts and morphology of residential areas.

In previous research (Payamiazad et al. 2016), to estimate the spatial openness index (SOI) and wall perimeter index (WPI), we calculated the indices depending on the perimeter of all the floors. In the current study, since the research deals with the arrangement of buildings in low-rise and mid-rise residential areas, wherein the building coverage and area of the first floor shape the layouts, the perimeter and floor area of the first floor (building coverage) are considered in the mathematical analysis.

Wall perimeter index $WPI_1$, which illustrates the possibility of windows, is equal to the total perimeter of the first floor of residential buildings divided by the total building coverage. As demonstrated in the model (Table 1.), the rate of $WPI_1$ (considering the perimeter and floor area of all the floors) and $WPI_1$ is almost the same.

In order to measure the spatial openness index $SOI_1$, the open space area (block area including the roads minus built area) could be divided by the total perimeter of the first floors of buildings. Referring to the estimations (Table 1.), there is a noticeable difference between $SOI_1$ and $SOI_A$ (considering the perimeter of all the floors); therefore, it could be assumed that calculating the SOI depends on the perimeter of the first floor ($SOI_1$), which mainly affects the housing layout.

Overall, the spatial openness in massive linear topology is higher than in the other three categories. The scattered topology by far has the lowest $SOI_1$ among all the types; its $SOI_1$ at 7 is less than that of the massive linear type at (12.09), whereas in parallel and courtyard types it is approximately 8.62 and 10, respectively. The scattered form, with a higher length of walls, has the highest WPI of 0.35. However, the WPI in parallel and courtyard types are slightly higher at 0.29 and 0.25, respectively, compared to the WPI of the linear type (0.20) (Fig.3.).

Thus, we could analyze the spatial openness of residential open space and the possibility of windows in residential areas based on the housing layout types, $SOI_1$ and $WPI_1$. This method is adaptable for low-rise and medium-rise dwellings.

| Table 1. Same FAR and BCR in Different Layouts (Applying Wall Perimeter Index and Spatial Openness Index) |
|---|---|---|---|---|
| **Type** | **A** | **B** | **C** | **D** |
| $S$ (Block Area) | 8 $\times$ 50 $\times$ 3 $=$ 1200 | 8 $\times$ (40 $\times$ 2 + 35 $\times$ 2) $=$ 1200 | 8 $\times$ 18.75 $\times$ 8 $=$ 1200 | 12 $\times$ 50 $\times$ 2 $=$ 1200 |
| $C$ (Building Coverage) | (8 $\times$ 2 + 50 $\times$ 2) $\times$ 3 $\times$ 4 $=$ 1392 | (40 $\times$ 2) + (51 $\times$ 2) + (24 $\times$ 2) + (35 $\times$ 2) $\times$ 4 $=$ 1200 | (16 + 37.5) $\times$ 8 $\times$ 4 $=$ 1712 | (12 $\times$ 50 $\times$ 2) $\times$ 4 $=$ 992 |
| $L_A$ (Perimeter of Buildings) (4 floors) | $L_A$=$(8 \times 2 + 50 \times 2) \times 3 = 348$ | $L_A$=$(40 \times 2) + (51 \times 2) + (42 \times 2) + (35 \times 2) \times 4 = 330$ | $L_A$=$(16 + 37.5) \times 8 \times 4 = 428$ | $L_A$=$(12 \times 50 \times 2) \times 2 = 248$ |
| $V$ (Total Floor Area of all Buildings) (4 floors) | $V$=$(8 \times 50 \times 3 \times 4 = 4800$ | $V$=$(40 \times 2 + 35 \times 2 \times 4 = 4800$ | $V$=$(8 \times 18.75 \times 8 \times 4 = 4800$ | $V$=$(12 \times 50 \times 2 \times 4 = 4800$ |
| Floor Area Ratio (FAR) $V/S$ | 114% | 114% | 114% | 114% |
| Building Coverage Ratio (BCR) $(C/S)$ | 28% | 28% | 28% | 28% |
| $WPI_A$ (Wall perimeter index) | 0.29 | 0.25 | 0.35 | 0.20 |
| $WPI_1$ (Wall perimeter index) | 0.29 | 0.25 | 0.35 | 0.20 |
| $SOI_A$ (Spatial Openness Index) | 2.15 | 2.50 | 1.75 | 3.02 |
| $SOI_1$ (Spatial Openness Index) | 8.62 | 10 | 7 | 12.09 |

$WPI_A = L_A/V$ (Possibility of windows based on the perimeter of walls in all floors)

$WPI_1 = L_1/V$ (Possibility of windows based on the perimeter of walls in first floor)

$SOI_A = (S-C)/L_A$ (Spatial openness based on the perimeter of walls in all floors)

$SOI_1 = (S-C)/L_1$ (Spatial openness based on the perimeter of walls in first floor)
6. Results

In Iran, there are two types of medium-rise housing: courtyard and massive linear. Notably, the definition of courtyard housing in this research differs from the traditional houses in Iran.

The results of estimation and district analysis are presented in Tables 2. and 3. The SOI and WPI are variable in different districts. The estimated indices on all the residential layouts are positive and statistically significant, as expected. Larger lot sizes, newer houses, and massive linear type of dwellings all contribute positively to the spatial openness. On the contrary, the possibility of windows in residential environments with courtyard layout is higher. As predicted by the theoretical model, the higher the length of outer walls on each floor, the greater the possibility of windows.

Our key findings regarding spatial openness and the possibility of windows in the target areas in Tehran can be summarized as follows: There is a considerable difference between the numerical result of SOIs based on the perimeter of a wall of the first floor (SOI₁) and all floors (SOI₂), especially in districts 1, 4, and 8, for which the role of building height could be addressed (Figs.4. and 5.). Increment of building height led to a decline in SOI₁, therefore, because of the different height of the buildings in target districts, an estimation based on SOI₁ is more valid (Table 2.).

SOI₁ shows the expected signs in district 22 as a newly developed district with, massive linear type, wide streets and an average of 10.22, whereas the average of the same index in district 12 with courtyard housing layout and narrow streets is 3.15. Otherwise, as estimations show, the WPI₁ and WPI₂ in different districts except district 12 are approximately in the same range (Table 2.). The differences in WPI₁ and WPI₂ could be rooted in the various heights of adjacent buildings, which affect the wall perimeter. Therefore, considering the wall perimeter of the first floors as WPI₁ appears more accurate.

The possibility of windows (WPI₁) in district 12 with courtyard layouts is higher whereas the same index for district 4 is less (0.15) (Table 2.). In districts with a massive linear layout, residential buildings are attached, internal side walls are shared, and wall perimeter is less; consequently, the window possibility is small. Therefore, districts such as 12 with courtyard layout could achieve the highest rate of window possibility owing to a higher rate of wall perimeter (Fig.5.).

The result also confirms the inadequacy of BCR in defining the housing layouts. For instance, although the BCR in Farmaniye, Narmak square 66th, Emanzade Yahya, and Odjalan is the same at 65%, the
## Table 3. Case Studies Analysis

| No. | Location | Info                          | Description                                                                 | Diagram | Aerial | Photo |
|-----|----------|-------------------------------|-----------------------------------------------------------------------------|---------|--------|-------|
| 1   | Farmanieh | Location: Farmanieh           | Located in the northern part of the city close to the mountains resulting   |         |        |       |
|     |          | No. of parcels: 59           | in an organic urban texture                                                 |         |        |       |
|     |          | Land use: Residential        |                                                                             |         |        |       |
|     |          | Years (Ave.): 30             |                                                                             |         |        |       |
|     | Zaferanieh | Location: Zaferanieh     | Large plot size, wide streets and high price of property                     |         |        |       |
|     |          | No. of parcels: 27           |                                                                             |         |        |       |
|     |          | Land use: Residential        |                                                                             |         |        |       |
|     |          | Years (Ave.): 20             |                                                                             |         |        |       |
|     | Velenjak  | Location: Velenjak           | Large plot size, wide streets and high price of property                     |         |        |       |
|     |          | No. of parcels: 26           |                                                                             |         |        |       |
|     |          | Land use: Residential        |                                                                             |         |        |       |
|     |          | Years (Ave.): 20             |                                                                             |         |        |       |
| 4   | Heravi Sq.| Location: Heravi Sq.         | The linear residential blocks, wide streets and most apartments are         |         |        |       |
|     |          | No. of parcels: 64           | south-facing                                                                |         |        |       |
|     |          | Land use: Residential        |                                                                             |         |        |       |
|     |          | Years (Ave.): 20             |                                                                             |         |        |       |
| 8   | Narmak, Sq.| Location: Narmak, Sq.       | Repetitive rectangular blocks with centralized open space                   |         |        |       |
|     | no. 66   | No. of parcels: 104          |                                                                             |         |        |       |
|     |          | Land use: Residential        |                                                                             |         |        |       |
|     |          | Years (Ave.): 30             |                                                                             |         |        |       |
| 12  | Emamzadeh | Location: Emamzadeh Yahya    | One of the oldest residential areas in Tehran with narrow streets and high  |         |        |       |
|     | Yahya     | No. of parcels: 43           | built-up density                                                            |         |        |       |
|     |          | Land use: Residential        |                                                                             |         |        |       |
|     |          | Years (Ave.): 70             |                                                                             |         |        |       |
|     | Odjalan   | Location: Odjalan            | One of the oldest residential areas in Tehran with narrow streets, and high |         |        |       |
|     |          | No. of parcels: 46           | built-up density                                                            |         |        |       |
|     |          | Land use: Residential        |                                                                             |         |        |       |
|     |          | Years (Ave.): 70             |                                                                             |         |        |       |
|     | Darvazeh Ghar | Location: Darvazeh Ghar | One of the oldest residential areas in Tehran with narrow streets, and high |         |        |       |
|     | Ghar      | No. of parcels: 136          | built-up density                                                            |         |        |       |
|     |          | Land use: Residential        |                                                                             |         |        |       |
|     |          | Years (Ave.): 70             |                                                                             |         |        |       |
| 22  | 2nd Sarvestan Ave. | Location: 2nd Sarvestan Ave. | The newly built linear residential blocks, wide streets and dwellings are   |         |        |       |
|     |          | No. of parcels: 49           | south–north facing                                                          |         |        |       |
|     |          | Land use: Residential        |                                                                             |         |        |       |
|     |          | Years (Ave.): 10             |                                                                             |         |        |       |
|     | 4th Banafshe Ave. | Location: 4th Banafshe Ave. | The newly built linear residential blocks, wide streets and dwellings are   |         |        |       |
|     |          | No. of parcels: 61           | south–north facing                                                          |         |        |       |
|     |          | Land use: Residential        |                                                                             |         |        |       |
|     |          | Years (Ave.): 10             |                                                                             |         |        |       |
|     | 12th Yas Ave | Location: 12th Yas Ave.  | The newly built linear residential blocks, wide streets and dwellings are   |         |        |       |
|     |          | No. of parcels: 75           | south–north facing                                                          |         |        |       |
|     |          | Land use: Residential        |                                                                             |         |        |       |
|     |          | Years (Ave.): 10             |                                                                             |         |        |       |
housing layouts are different, and the range of WPI, and SOI, in these areas are significantly different. Therefore, when the differences among the various housing arrangements in residential environments are recognizable based on WPI and SOI, expanding these indices could be an appropriate approach for evaluating the quality of space in residential environments.

7. Conclusion

It appears that the results are consistent with previous research and theory. FAR and BCR have serious shortcomings in measuring the quality of open space and do not allow us to distinguish between different housing layouts. An alternative approach is the use of new variables in urban design. Applying new indices such as SOI and WPI can be an efficient way to design residential environments with high environmental quality. These provisions improve the amenities of residential open space to ensure that they satisfy the user demands.

On the other hand, it could be concluded that, during the last decades, owing to fundamental changes in Iranian lifestyle, economic concerns, land price, and construction expenses, housing layouts have been transformed profoundly from courtyard to massive linear topology. Consequently, the dwellings became smaller and the role of open space as an effective contribution to housing layout was neglected. Buildings became more closely packed, and the possibility of windows declined; however, through attention to urban design and policy, the rate of spatial openness increased.

The survey results have several vital implications. First, both private and public open spaces must be considered in legislations. Second, culture, religion, traditions, climate, and environmental issues have affected residential buildings in Iran.

7.1 Future Research

In this study, authors explored the relation between housing layouts, spatial openness, and window possibility by concentrating on density (FAR and BCR) and housing layouts. The role of roads within and surrounding the residential area is also important, considering which, road width proportion could be reviewed in future research. Moreover, the influence of the height of buildings on the morphology of residential open space and the rate of spatial openness in the different floors of buildings requires further research.

However, there are other urban factors including climate, culture, and legislation that may affect the spatial form of residential open space and the location and number of windows. Further research needs to be performed to understand the role of these factors.

7.2 Limitations

Unfortunately, there is no quantitative data regarding residential open space in Iran, which makes the analyses difficult. Moreover, since the quality and quantity of open space in high-rise buildings is different, these indices are only applicable to low-rise and middle-rise housing.

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