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THE ROLE OF OPEN-BUILT SPACE MORPHOLOGY IN RESIDENTIAL ENVIRONMENT QUALITY ASSESSMENT OF CLUSTER HOUSING (1)

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INTRODUCTION

Urbanization is causing the expansion of existing cities, leading to an increase in the built-up density concerning worldwide available land (**Figure 1**). Housing constitutes a large part of the built density. Planners advocate high-density development as a solution for the optimum use of available land and resources, leading to haphazard large-scale development, especially in the housing sector, to meet the population's ever-growing needs (Sofi et al., 2017). This haphazard development is causing a decrease in the quality of residential built environments. Residential environment quality (REQ) is a subjective terminology mainly related to inhabitants' quality of life. Aspects such as nature, open space, infrastructure, built environment, and natural environment all affect human needs and desires. It also affects users' health, safety, welfare, and satisfaction. Although determining the quality of any residential space is complex and widely includes sociocultural and economic environments, it associates with the built environment that depends primarily on spatial patterns (Gavrilidis et al., 2016; Zhang et al., 2020).

Further understanding of the built environment is necessary for its impact on residential quality. Any built environment encompasses buildings, space, and movement systems. How the buildings' volume and mass enclose a space and how users interact with them significantly impact the space's quality. As a built environment, housing is a physical entity in which people live, but it is beyond those walls. It is a complex system consisting of many different components, such as structures that comprise all the physical attributes of a dwelling, accessibility, and facilities that constitute services related to housing (Dezhi et al., 2016). Large-scale housing developments like cluster or group housing display the critical inter-relationship between these attributes creating many internal and external spaces. The vibrant environment created by the interior and

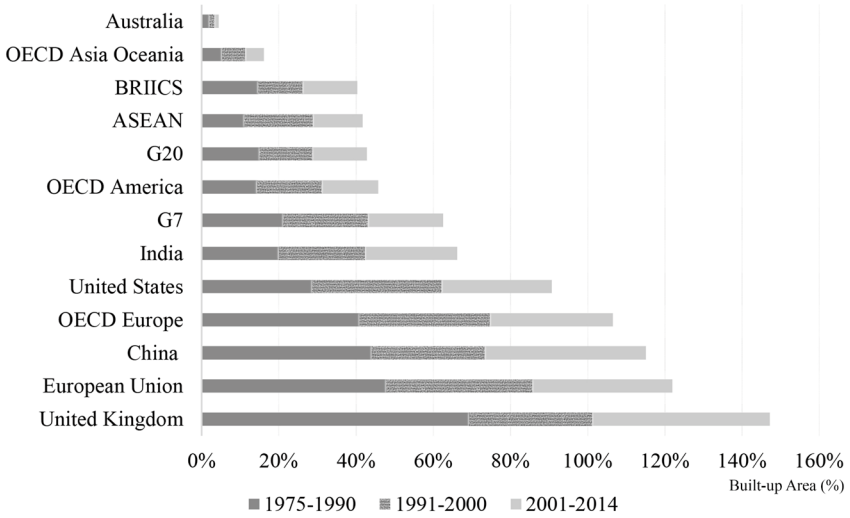


Figure 1. Percentage increase in built-up areas concerning total land areas (OECD, 2014)

exterior of the dwelling helps people grow and live a quality daily life (Chan and Ma, 2020; Ibem et al., 2015; Musa and Zahari Wan, 2015).

Background

Assessment of REQ focuses on the quality of interior spaces, services, and large public open spaces. Apart from these, the built-form arrangements give multiple intermediate open spaces in residential layouts like cluster housing. These spaces have multiple functions that act primarily as transitional but sometimes turn into community spaces fostering social interactions. As Marcus and Sarkissian (1986) have highlighted in their comprehensive study on cluster housing, housing success depends more on handling the spaces between buildings. Thus, for evaluating housing quality, a housing layout's internal and external environment and the relationship between open space and the built-form should be considered (Evans and Kantrowitz, 2002; Park et al., 2015; Wooley, 2003). Unfortunately, such intermediate open spaces are often ignored while designing and assessing the REQ. Thus, identifying various open-built space morphologies in cluster housing layouts is necessary. These can be classified based on common characteristics and forms to elucidate the relationship between the physical arrangement of the built-form and the quality of open spaces.

Researchers use various ways to analyze these built-forms, where density is one of the most crucial housing indices that define their characteristics (Dave, 2011; 2010; Raman, 2010). Although, there are two basic approaches to density viz-a-viz physical and perceived density (Berghauser Pont and Haupt, 2007). There is a vast difference between both, where researchers often prefer using physical density for such studies. The physical density considers the measurements and dimensions of the built-form. Physical density can be classified broadly into two categories: population density and built-up density (Kamble and Bahadure, 2021). Population density gives us an idea about the number of people living in a specific area. In contrast, the built-up density represents the built-up area of the plot.

Indicators like dwelling density, land-use intensity, building coverage, and spaciousness help understand technical aspects of built-up density (Gao et al., 2006; Bramley and Power, 2009; Steadman, 2014; Kennedy and Buys, 2015; Kostourou and Psarra, 2017). In addition, urban form

significantly affects built-up density in residential spaces. In town planning, development control rules regulate the urban form and built-up density for a particular area by using the Floor Space Index (FSI) and building ground coverage area to measure built-up density. The vital role of FSI is to maintain a balance between open and built space. However, FSI cannot anticipate the physical form of the building or its height. For this, building ground coverage in percentage is specified. Building ground coverage indicates the distribution of built mass over the total site area. Like FSI, government authorities specify the maximum permissible building ground coverage percentage, which helps balance open and built spaces and achieve the desired natural light/ventilation and the residential unit's quality. It also intends to provide enough space for ancillary areas like playgrounds, internal roads, and service areas. Thus, analysis of built-up density indices such as FSI, building ground coverage, built-up area, and the number of dwelling units helps to understand the quality of the residential environment.

Nonetheless, users' perception is as important as the built-up density to improve REQ (Dutta and Bardhan, 2017; Ali, 2018). The visual image of the built form and the openness in the residential areas, both internally and externally, influence the perceived density. There are many components of housing, like the quality of open spaces, visual connections to the outdoors, vegetation, and building aesthetics, including texture and materials, that affect the perceived density. However, most users give more weightage to the availability of quality open spaces while buying such properties (Hur et al., 2010; Lo and Jim, 2010; Musa and Zahari Wan, 2015). Empirical studies have found that different amounts of enclosures or openness benefit the users' overall social and cultural lifestyle (Hunter et al., 2019; Rapoport, 1969). The plot's openness determines the probability of enhancing the area's overall quality for the availability of light, ventilation, and opportunities for users' recreational activities (Faragallah, 2018; Fisher-Gewirtzman, 2018; Fisher-Gewirtzman and Wagner, 2003; Gulati, 2019).

Additionally, researchers have stressed the importance of physical and visual access to these outdoor spaces concerning maintenance and security of the built environment (Newman, 1976; Webb Jamme et al., 2018). Thus, the perceived density is directly related to the area and quantity of the openings (Fisher-Gewirtzman, 2017; Sugiyama, 1986). As an architectural element, windows allow viewing of the surroundings, forming an association with external spaces. Researchers have argued the importance of carefully planned windows for positively impacting the REQ (Ai and Mak, 2015; Ismail et al., 2015; Sarbu and Pacurar, 2015). Therefore, there is a need to consider the availability of windows while assessing REQ. Accordingly, the building's perimeter corresponds to the open space's shape and size and the probability of windows. Previous studies postulated two alternate density indices, Spatial Openness Index (SOI) and Wall Perimeter Index (WPI), to measure the quality of residential spaces concerning spatial openness and probabilities of windows (Sugiyama, 1986; Azad et al., 2016; 2018). SOI is the ratio of the total open space within the residential layout to the perimeter of the buildings. WPI is the ratio of the ground coverage area in the residential layout to the total perimeter of the buildings. Thus, these are quantitative indices to analogize different spatial configurations within the residential environment as the users perceive.

Cluster Housing in India

During the post-Independence era in India, there was a sudden demand for housing due to urbanization, the migration of people, and the establishment of new industries and institutions. Due to the growing economic discrepancies, India faced severe challenges associated with housing demand, supply, and utilization. As Independent India's political and economic vision shifted from capital goods to an agrarian economy to industrial to services, the housing policy also shifted its focus. Along with a housing shortage, land was scarce. High-density housing with good environmental quality was the need of the hour, which led to greater use of cluster housing. As seen in **Figure 2**, the government introduced different housing programs like Subsidized Housing Scheme for Industrial Workers, LIG Housing Scheme, and MIG Housing Scheme in urban areas in the late 20th century (Tiwari and Shukla, 2016). For the controlled and well-directed growth of the housing sector, the government at the national level formed the Housing and Urban Development Corporation (HUDCO) in 1970 (Mittal, 2014).

The government established many housing boards like HUDCO in all the states. These bodies were responsible for building affordable housing in different parts of the country to meet its growing demand for housing. However, with limited time, and inappropriate usage of resources, most projects followed a standardized design. Such designs seldom consider location, climate, and overall housing quality. Few architects identified this problem and tried to change the situation by proposing improved and comprehensive solutions for cluster development. B.V. Doshi, Charles Correa, and Raj Rewal were the first visionary architects to practice this in post-independent India. Under different government schemes, they proposed some exceptional designs to resolve the issue of increasing housing demand without compromising the quality of housing units. They proposed a well-planned hierarchy of interlocking and open-to-sky spaces that provided an intelligent housing solution with all amenities to maintain housing quality (**Figure 3**). All the houses had a small private open space at the front or rear with multiple intermediate common open spaces at the neighborhood level.

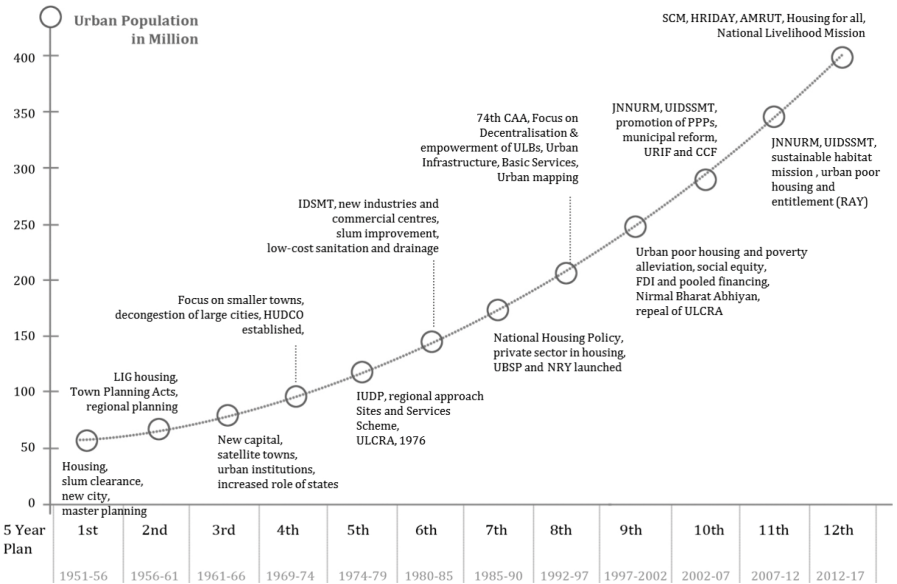


Figure 2. Urban development goals achieved in India (Bhattacharya et al., 2015)

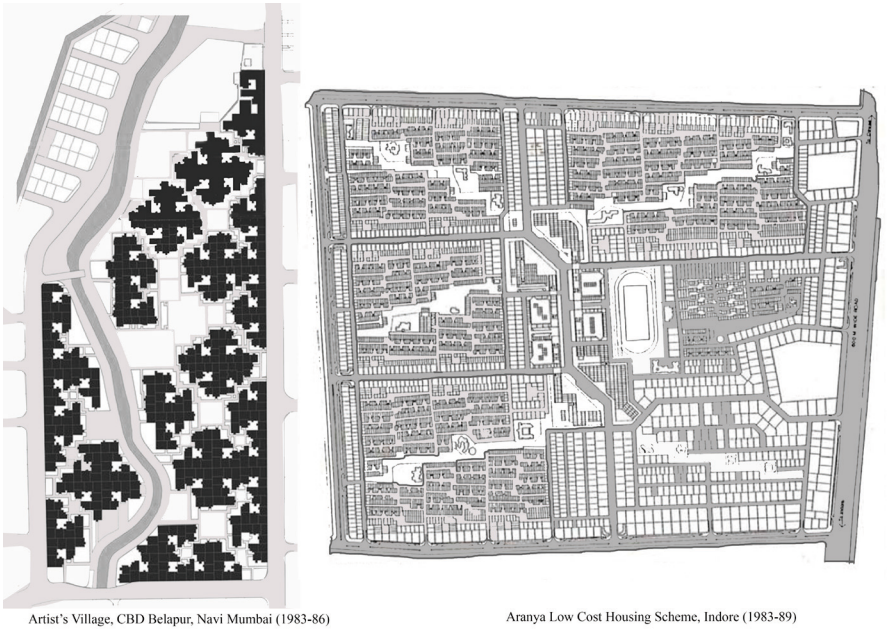


Figure 3. Cluster housing plans displaying the hierarchy of open spaces (Kashmira, 2017; Vastu Shilpa Foundation, 1995)

A brief study of housing norms in Indian cities shows a lack of clear rules for open spaces in cluster housing (Govindarajulu, 2014; Ramachandra et al., 2017; Udas Mankikar, 2020). Almost every housing layout focuses on accommodating the maximum number of dwelling units in the given area rather than providing users with a good quality of life. It has led to the development of monotonous built clusters without providing the desired quality of spaces to the resident. Besides, there are provisions in the Development Control Rules for the developer to buy additional FSI to increase the occupancy density within the plot, as permissible by the City Development Plan. Present unclear rules related to open spaces in cluster housing have led to the pooling of land by the developers (Ahluwalia and Mohanty, 2014; Ram and Needham, 2016). It is a commonly observed state of affairs in other parts of the globe (Yoshino and Paul, 2019). Therefore, providing optimum housing layouts with better-planned open-built spaces is the need of the hour.

With decreased available land, there has been a steady increase in mass housing developments in cities today. Cluster housing is looked upon as a solution to meet the housing demands of the growing urban population. With changing open-built form patterns in cluster housing layouts, it is imperative to understand the relationship between the open-built space morphologies and density indices such as FSI, building ground coverage, WPI, and SOI to assess their REQ. The current study aims to identify and understand the role of open-built forms in assessing REQ with the help of appropriate methods and indices.

METHODOLOGY

The study intends to understand the role of open-built space morphology in analyzing the REQ of cluster housing. The researcher uses the library method and field survey method for this study. This analysis method excludes any other land uses except residential. A specific residential typology – cluster housing, was identified for a comparative analysis of

their housing layouts. The study focuses on the physical attributes of the housing and not the people's perception.

Since cluster housing is widely used in India, selecting case study projects for the current study was challenging. The first criteria for selecting the case study are that the cluster housing needs to be built in the post-independence period, specifically after the implementation of the town planning acts, and is widely studied for its cluster housing characteristics. Secondly, these case studies need to be of a varied period. Thirdly, the study considered housing projects that displayed the principal nature of cluster housing, including replicating built-form patterns. Lastly, projects should have more than 100 Dwelling Units (D.U.), making them adaptable to the analysis method. Table 1 shows the nine identified case studies based on the selection criterion.

A preliminary study analyzes housing layouts of different cluster housing projects to classify open-built space morphological types. Further, among these identified projects, nine institutional cluster housing projects are selected for comparative analysis, as indicated in Table 2. Using density indices such as FSI, building ground coverage, WPI, and SOI, a comparative analysis of these identified cluster housing projects compares their open-built space morphologies. The study used the following formula to calculate FSI.

$$FSI = \frac{Total\ Built\ up\ Area}{Total\ Site\ Area}$$

Further, researchers performed a theoretical analysis to validate the applicability of alternate density indices, WPI and SOI, in describing open-built space morphology in a cluster housing layout. Earlier studies have undertaken such theoretical analyses to establish a relationship between built-form and density indices (Azad et al., 2018; 2016). Therefore, the current study adopts a similar framework.

A study calculates WPI and SOI using the perimeter of a single floor. The perimeter of all floors of the buildings was also undertaken to detail their applicability. WPI_1 represents the probability of windows by dividing the perimeter of a single building floor by the buildings' ground coverage. In contrast, WPI_A represents the probability of windows by dividing the perimeter of all floors of all the buildings by the total built-up area (Azad et al., 2018).

$$WPI_1 = \frac{\text{Total Perimeter of Single floor of the buildings}}{\text{Building Ground Coverage}}$$

$$WPI_A = \frac{\text{Total Perimeter of All floors of the buildings}}{\text{Built} - \text{up Area}}$$

Likewise, the SOI_1 represents spatial openness by dividing the total open space area by the perimeter of a single floor of the buildings. In contrast, SOI_A represents spatial openness by dividing the total open space area by the perimeter of all floors of the buildings (Azad et al., 2018).

$$SOI_1 = \frac{\text{Total Site Area} - \text{Building Ground Coverage}}{\text{Total Perimeter of Single floor of the buildings}}$$

$$SOI_A = \frac{\text{Total Site Area} - \text{Building Ground Coverage}}{\text{Total Perimeter of All floors of the buildings}}$$

RESULTS AND ANALYSIS

Classification of Open-Built Space Morphology in Cluster Housing Layouts

In cluster housing, built-form arrangements give multiple intermediate open spaces that can be public, semi-public, and private based on their access. Generally, built-forms only define the size and shape of semi-public and private open spaces. However, built-form has a more significant spatial impact on semi-public open spaces than private open spaces due to several alternatives. Thus, the spatial study of identified cluster housing projects studied the arrangement of built-form around semi-public open spaces for open-built space's morphological classification (**Table 1**). As a result, these open-built space morphologies have been classified based on the different access to the semi-public open spaces created due to the arrangement of the built-form around it, respectively. Accordingly, four variations of four side enclosed open-built space forms (Type 1, 2, 3 and 4) and two variations of three side enclosed open-built space forms (Type 5 and 6) were identified (**Figure 4**).

As seen in Table 1, the identified projects contain a variety of open space shapes or forms created due to the built-form. Almost all the projects portray a blend of the identified open-built morphological types. The dominating type for the project, however, is repeated frequently. For instance, Type 3 is prevalent in Sheikh Sarai Housing and Parsik Hill CIDCO housing, Type 2 in the GSFC Staff Housing, and Type 1 in Sector 19 CIDCO Housing plans, respectively. Similarly, Type 5 is the most prevalent typology in the remaining projects.

Comparative Analysis of Identified Cluster Housing Projects

For the detailed analysis, the present study considers open-built space morphology prevalent in the identified project's present-day housing layouts (**Table 1**). As seen in Table 2, the analysis of cluster housing projects reveals that all the estimated indices like FSI, Built-up Area (BUA), ground coverage ratio, WPI, and SOI are positive. The data and results are significant statistically. The FSI ranges from as low as 0.2 to as high as 1.2. The ground coverage ratio ranges from 13% to 30%. It also states that higher FSI and ground coverage ratios lead to decreased spatial openness and an increase in the possibilities of windows. However, there is no clear

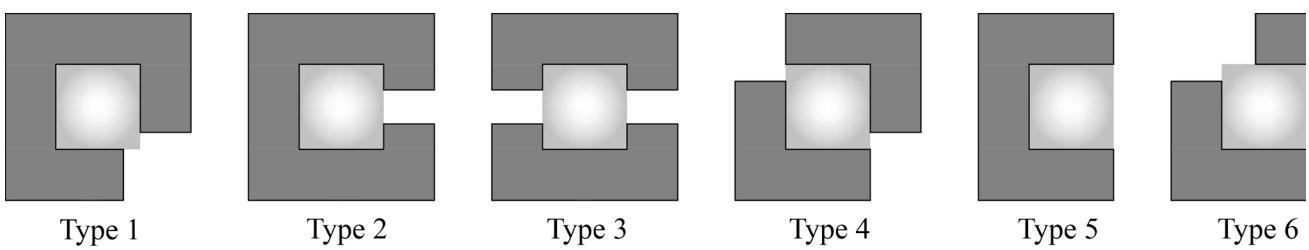


Figure 4. Typical open-built space morphology types found in cluster housing in India

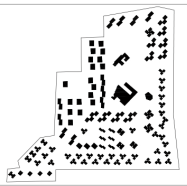
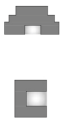
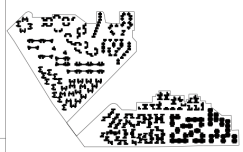
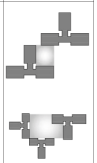
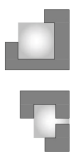
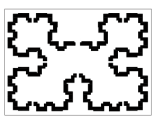
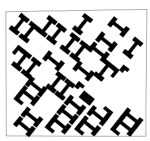
Sr. No.	Name of the Project	Plan (not to scale) N	Classifications of Open Spaces					
			Type 1	Type 2	Type 3	Type 4	Type 5	Type 6
1	GSFC Staff Housing, Vadodara 1968							
2	IIT Delhi Faculty Housing, New Delhi 1965 - 2020							
3	Asian Games Village New Delhi 1982							
4	Parsik Hill CIDCO Housing, Navi Mumbai 1993							
5	IIT Gandhinagar Faculty Housing, Gandhinagar 2011							
6	Sector 19, CIDCO Housing, Navi Mumbai 1991							
7	Jodhpur HUDCO Housing, Jodhpur 1986							
8	ACC Staff Housing Wadi 1984							
9	Sheikh Sarai Housing, Phase I, New Delhi 1982							

Table 1. Spatial analysis of identified group housing projects in India (GFSC Limited, n.d.; IIT Delhi, n.d.; PK Das & Associates, n.d.; Raj Rewal Associates, n.d.; Torus, 2012)

correlation between the FSI and ground coverage ratio with the open space morphologies.

Concerning SOI and WPI, the spatial openness is high in cluster housing with dominant Type 5 open-built space morphology. In contrast, those with Type 3 open-built space morphology displayed more probabilities of windows. Nevertheless, project 1, with Type 2 open-built space morphology, shows a significantly higher value of SOI, and project 6, having Type 1 open-built space morphology, shows a higher value of WPI. These variations may be due to smaller unit sizes, leading to more open-built forms. Thus, the size of the open-built space morphology may also affect the WPI and SOI of a housing layout.

The values of WPI_1 and WPI_A are the same for all case studies. Thus, it may be appropriate to consider the WPI_1. The WPI_1 of project numbers 4, 6, and 9 are considerably higher than other case studies. It also indicates that case studies with Type 3 open-built space morphology display higher probabilities for windows. It signifies that a higher rate of wall perimeter achieves a higher probability of windows.

Considering SOI, there is a significant dissimilarity between SOI_1 and SOI_A. The percentage difference between them is considerably high in project numbers 1, 4, and 7. This difference may be due to the lower number of floors than the other case studies. Therefore, an estimation based on SOI_1 seems more valid for consideration. The SOI_1 in project numbers 1, 2, 5, 7, and 8 are higher than the others. Also, case studies with Type 5 open-built space morphology had higher spatial openness than other types. The only exception is project number 1 with Type 2 open-built space morphology, possibly due to a lower ground coverage than the site area.

The study also highlights the inefficacy of FSI and a ground coverage ratio in describing housing layouts. For example, even though the FSI in project numbers 4 and 8 is similar, i.e., 0.6, their open-built space morphology type and WPI_1 and SOI_1 values are significantly different. Similarly, the ground coverage ratio in project numbers 4 and 5 is 23%, and in project numbers 3 and 6 is 24%; their open-built space morphology type, WPI_1, and SOI_1 values are significantly different. It further specifies the purpose of open-built space morphology and housing layouts in residential environments. Thus, indicating that WPI and SOI could be appropriate approaches to analyzing different housing layouts.

Analysis of Theoretical Method for Applicability of WPI and SOI

A theoretical method compares various open-built space morphologies in cluster housing layouts. Based on the identified open-built space morphologies (**Figure 4**), different housing layouts with the same site areas having similar ground coverage and FSI are designed (**Figure 5, Figure 6a**). It intends to understand the applicability of alternate density indices, viz. WPI and SOI in analyzing different housing layouts.

Like the comparative analysis of housing projects, the current analysis calculates WPI_1, WPI_A, SOI_1, and SOI_A. When applied to the identified open-built space morphology types (**Figure 6c**), the WPI_1 and WPI_A are the same; hence, it can be presumed that WPI_1 is appropriate for further studies. Similarly, the values of SOI_1 and SOI_A show a significant difference, indicating that evaluating SOI depends on the perimeter of the single floor considerably, which mainly impacts the residential openness (**Figure 6d**). Hence, SOI_1 is appropriate for further studies. Thus, the residential area's

Sr. No.	1	2	3	4	5	6	7	8	9
Name of Project	GSFC Staff Housing, Vadodara	IIT Delhi Faculty Housing, New Delhi	Asian Games Village, New Delhi	Parsik Hill CIDCO Housing, Navi Mumbai	IIT Gandhinagar Faculty housing, Gandhinagar	Sector 19 CIDCO Housing, Navi Mumbai	Jodhpur HUDCO Housing, Jodhpur	ACC Staff Housing, Wadi	Sheikh Sarai Housing, Phase I, New Delhi
Dominant Open Space Morphology Type	Type 2	Type 5	Type 5	Type 3	Type 5	Type 1	Type 5	Type 5	Type 3
Site Area (sq.m.)	629855	210625	178575	77000	64000	44000	33894	33800	30000
Avg. No. of Floors	2	3	4	2.5	3	4	2	3	4
Built-up area (sq.m.)	150724	62336	169450	44250	45000	43040	12180	19989	36000
Ground Coverage (sq.m.)	75362	27650	42370	17700	15000	10760	6090	6663	9000
Total Perimeter length single floor (m)	23414	9500	15875	11590	4575	5700	1282	1968	3700
Floor Space Index (FSI)	0.2	0.3	0.9	0.6	0.7	1.0	0.4	0.6	1.2
Ground Coverage (%)	20	13	24	23	23	24	18	20	30
WPI_1	0.31	0.34	0.37	0.65	0.31	0.53	0.21	0.30	0.41
WPI_A	0.31	0.34	0.37	0.65	0.31	0.53	0.21	0.30	0.41
SOI_1	23.68	19.26	8.58	5.12	10.71	5.83	21.69	13.79	5.68
SOI_A	11.8	6.4	2.1	2.0	3.6	1.5	10.8	4.6	1.4

Table 2. Comparative Analysis of Density Indices in Cluster Housing Projects

built-form and open-built space morphology influence both the spatial openness and the probability of windows. Thus, it reciprocatively suggests that WPI and SOI effectively describe the built-form and open-built space morphologies.

The study shows that housing layouts with open-built space morphological Types 2, 3, and 4 have higher WPI than others due to longer wall perimeter lengths. Thus, a more extended perimeter of the outer walls on each floor increases the probability of windows. In addition, the spatial openness in layouts with Type 1, 5, 6, and 2 open-built space morphology was higher than the others, as observed in the comparative analysis of housing projects. Thus, the housing layout with Type 2 open-built space morphology presents a higher value of WPI and SOI both. The findings are almost similar to that observed in the comparative analysis of the case study projects. Furthermore, it is also evident from this analysis that the sizes of the open-built forms impact WPI and SOI values. Thus, confirming the analysis of the comparative analysis of cluster housing projects.

DISCUSSIONS

With the increase in population density, policymakers and planners across the globe are giving more attention to improving the quality of life by

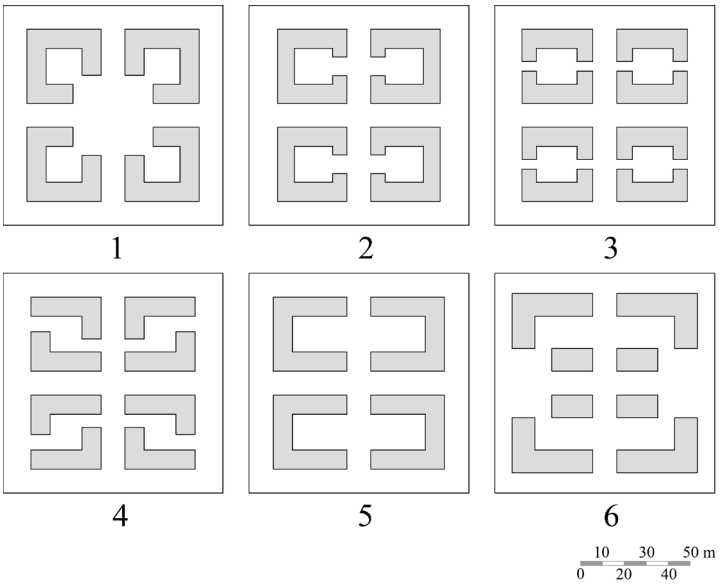


Figure 5. Arrangement of typical open-built space morphological typology in cluster housing layouts with the same number of floors (4 floors)

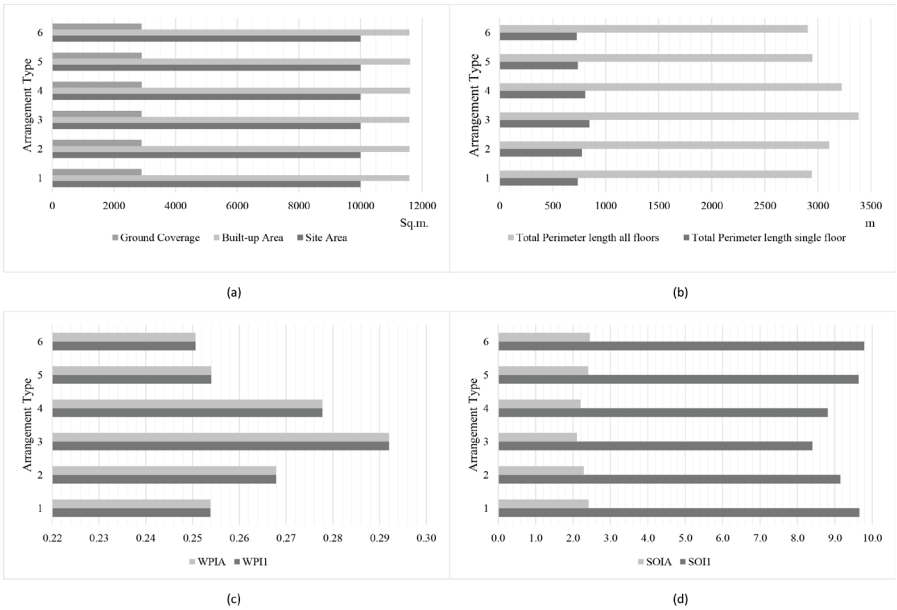


Figure 6. Comparative Analysis of housing layout arrangement types concerning FSI, ground coverage, WPI, and SOI

emphasizing good quality open spaces in the cities. Most of the policies by development authorities focus on higher densities, believing it to be a universal solution for accommodating the country's increasing population. Many studies have consistently reflected a strong positive impact of open spaces on neighborhood satisfaction and social cohesion (Karuppannan and Sivam, 2011). Earlier studies have highlighted the importance of better-planned housing layouts with provisions for open spaces in user satisfaction (Bergdoll and Williams, 2012; Chan and Ma, 2020; Fisher-Gewirtzman, 2017; Yang et al., 2019). Researchers have attempted to identify and classify various built-forms within a housing layout through a spatial study of residential neighborhoods (Deilmann et al., 1977; Kropf, 2014; Shayesteh and Steadman, 2015). However, these studies tend to overlook the role of intermediate open spaces formed due to the shape of the built-form. The present study highlights the need for an open-built relationship-based classification of built-form, specifically at the cluster

level. Thus, researchers classified typical open-built space morphology types through a detailed spatial study of various housing layouts at the cluster level.

Authorities have agreed that REQ assessments involve two complementary methods: the objective method based on observable and quantifiable indicators and the qualitative method based on the user's perception (Gavrilidis et al., 2016). However, the literature study found that most studies incorporate physical density parameters to study REQ, which are often objective. The current study indicates that spatial openness in an area reduces significantly due to high FSI and building ground coverage. Earlier studies indicate similar observations (Berghauser Pont and Haupt, 2007; Dave, 2010; Haarhoff et al., 2016; Steadman, 2014). The study also states that FSI and building ground coverage do not entirely govern the built-form shape and size, as pointed out by earlier studies (Kropf 2014; Azad et al. 2016; 2018). Authorities often suggest using FSI and building ground coverage for defining built-form, which contradicts the current findings (Berghauser Pont and Haupt, 2007; Kostourou and Psarra, 2017; Shayesteh and Steadman, 2015; Steadman, 2014).

Multiple assessment systems assess the housing layouts and built-up density to evaluate the REQ. FSI, ground coverage and the number of floors have often been used to analyze urban forms concerning built-up density. Researchers established various correlations between these density indices to classify urban forms. Earlier studies have analyzed REQ based on the urban form classifications (Haarhoff et al., 2016; Kostourou and Psarra, 2017; Shayesteh and Steadman, 2015; Steadman, 2014). However, the current study shows that these correlations between density indices fail to justify REQ in specific situations. A residential area design based on FSI and building ground coverage creates multiple open spaces within the residential area due to different physical and spatial configurations of open-built space forms. Other factors such as landscape, building typology, height, space openness, and aesthetics influence the individual's perception of density (Alexander, 1993; Bergdoll and Williams, 2012). The built-form, building layout, and open-built space morphology also determine the built-up density within the residential area (Jensen, 1966; Sugiyama, 1986). A change in the arrangement and form of the buildings within the site does not necessarily impact the FSI or ground coverage area. The mathematical correlation between both factors may remain constant (**Figure 6**). It indicates that these parameters are inadequate and dismiss any differentiation between various spatial layouts. Hence new factors or elements are needed for describing residential environments and differentiate between various housing layouts.

Due to urbanization, the built-form of housing has changed significantly, making other elements such as open spaces and windows influencing factors for the quality of residential spaces. The literature study shows how intermediate open spaces next to the dwellings play an essential role in achieving the desired housing quality (Hunter et al., 2019; Hur et al., 2010; Lo and Jim, 2010; Musa and Zahari Wan, 2015). Similarly, as indicated in the literature, windows play an essential role in achieving desired perceived density for the users (Azad et al., 2016; Ismail et al., 2015; Sarbu and Pacurar, 2015; Sugiyama, 1986). Thus, the current study validates that density indices such as WPI and SOI, based on the built form's wall perimeter, prove effective alternatives for analyzing different open-built forms in housing layouts, specifically in cluster housing. These findings

resonate with the earlier studies (Sugiyama 1986; Azad et al. 2016, 2018). The study also indicates that other density parameters affect the WPI and SOI. Hence, further studies need to establish correlations between alternate and traditional indices. However, as per the current study, the size and shape of the built form considerably affect the WPI and SOI in a housing layout. Where longer perimeters of built-form significantly increase the probability of having more windows, a more significant number of open-built space morphologies also increases the chances of spatial openness in a housing layout. Earlier studies observed the same (Azad et al., 2018, 2016). Though the users prefer multiple open spaces, the same may not be valid for the number of windows. Since windows affect internal and external environments, their quantity, shape, and sizes largely depend on location and corresponding climatic conditions.

CONCLUSIONS

The current study indicates that intermediate open spaces are essential in classifying built-forms in residential areas. Thus, a proposed classification of open-built space morphologies defines built-forms in cluster housing layouts. The study's findings show a significant impact of identified open-built form types on alternate density indices. The observations also confirm that the identified open-built forms can help understand the REQ in cluster housing layouts and facilitate the design decision-making process.

Researchers often use density parameters such as FSI and ground coverage area to assess residential environments. However, these parameters do not give a clear idea of the quality of the residential environment in specific situations. Therefore, considering only these parameters to evaluate density is not advantageous for the future development of the cities. The present study confirms previous studies stating that density indicators such as FSI and building ground coverage are inadequate to assess the quality of spaces in low-rise residential environments.

Furthermore, the study validates alternate density indices, viz. WPI and SOI effectively analyze open-built space morphologies in low-rise cluster housing layouts. Such indices will help architects choose appropriate open-built forms while designing low-rise cluster housing to provide optimum quality to residents.

The location, culture, climate, and legislation may also affect the open-built space morphology. Therefore, the application of WPI and SOI in analyzing such open-built space morphologies needs further study concerning these factors. However, the current study focused on the relationship between building arrangements, spatial openness, and probability of windows by addressing density, i.e., FSI and building ground coverage. The relationship with other built-form parameters, such as the number of floors, must be looked into in more detail. Only when the density is measured as a comprehensive aspect of all factors can it be used as an indicator of housing quality. For example, the role of building height and the space between two built structures on external and internal space quality needs to be analyzed concerning open-built space morphology and built-form. In addition, internal roads within the site could affect the overall quality of the open space created due to building form. Thus, the effect of the proportion of road width on open-built space morphology and space quality could also be reviewed in the future.

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Anahtar Sözcükler: Konut çevre kalitesi; yapılı açık alan morfolojisi; yapılı çevre; yoğunluk; konut indeksleri; konut tasarımı

KONUT KÜMELERİNİN ÇEVRESEL KALİTE DEĞERLENDİRMESİNDE AÇIK-YAPILI MEKAN MORFOLOJİSİNİN ROLÜ

İşlevi konut olan her yapılı çevre, kullanıcılarına konforlu bir konut ortamı sağlamayı amaçlar. Araştırmacılar genellikle, kat alanı katsayısı (KAKS) ve taban alanı katsayısı (TAKS) gibi fiziksel yoğunluk indekslerini kullanarak konut çevresi kalitesini (REQ) değerlendirir. Ancak, bu araçlar konut çevrelerini değerlendirmek için yeterince kapsamlı değildir. Mevcut çalışmalar, kaliteli açık alanlara sahip konut yerleşimlerinin sakinlerine nasıl fayda sağladığını açıklamaktadır. Ancak, yapılı çevre formlarının mevcut sınıflandırmaları, konut yerleşim planlarında bulunan ara açık alanları nadiren dikkate almaktadır. Bu nedenle, bu çalışma, küme konut planlarında açık-yapılı mekan morfolojisini sınıflandırmak için mekansal analize başvurmaktadır. Belirli küme konut planlarında bu tür morfolojik tiplerin karşılaştırmalı bir analizi, bunların REQ değerlendirmelerindeki rolünü anlamaya yardımcı olur. REQ değerlendirmesinde, "duvar çevre endeksi" ve "mekansal açıklık endeksi" gibi alternatif endekslerin uygulanabilirliği de bu araştırmada incelenmiştir. Analiz sonuçları, bu morfolojilerin genel REQ'yu etkilediğini göstermektedir. Çalışma aynı zamanda, farklı küme konut düzenlerini analiz etmek için alternatif endekslerin uygun olabileceğini de göstermektedir.Küme konut düzenlerinde açık-yapılı mekan morfolojilerinin bu şekilde sınıflandırılması, açık-yapılı form ilişkilerinin daha iyi anlaşılmasını sağlayacak ve gelecekteki araştırma çalışmalarına yardımcı olacaktır.Ek olarak, konut yerleşimlerinin analizinde alternatif yoğunluk indekslerinin doğrulanması, bu indekslerin REQ değerlendirmeleri için uygulanmasının yaygınlaşmasına yardımcı olacaktır.

THE ROLE OF OPEN-BUILT SPACE MORPHOLOGY IN RESIDENTIAL ENVIRONMENT QUALITY ASSESSMENT OF CLUSTER HOUSING

Any residential built environment aims to provide a comfortable residential environment to its users. Researchers often assess the residential environment quality (REQ) using physical density indices such as Floor

Space Index and building ground coverage. Nevertheless, these tools are not comprehensive enough to assess residential environments. Earlier studies enunciate how optimum housing layouts with good quality open spaces benefit its residents. However, current classifications of built forms seldom acknowledge intermediate open spaces present in the housing layouts. Thus, the current study used spatial analysis to classify open-built space morphology in cluster housing layouts. A comparative analysis of such morphological types in identified cluster housing projects tries to understand their role in REQ assessments. Also, the applicability of the alternate indices viz. Wall Perimeter Index and Spatial Openness Index in REQ assessment of low-rise cluster developments are studied. The analysis shows that these morphologies affect the overall REQ. The study also indicates that alternate indices could be appropriate for analyzing different cluster housing layouts. Such a classification of open-built space morphologies in cluster housing layouts will assist in a better understanding of open-built form relationships and help future research studies. In addition, validating alternate density indices in analyzing housing layouts will help generalize the application of these indices for REQ assessments.

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