

# Street Network Configuration: A Criterion to Assess Walkability Potential of a Traditional and Modern Settlement in Chennai, India

Ar. P. Dharmambigai<sup>1\*</sup> and Dr. S. Lakshmi<sup>2</sup>

<sup>1</sup>Research Scholar, School of Architecture and Planning, Anna University, Chennai – 600025, Tamil Nadu, India

<sup>2</sup>Professor, Division of Transportation Engineering, Department of Civil Engineering, Anna University, Chennai – 600025, Tamil Nadu, India

\*E-Mail: dharmambigaik@gmail.com

\*Corresponding Author

**Abstract**—Walking is a physical activity that comes with numerous health benefits. The walkability of a built environment is influenced by the spatial characteristics of the street network. Traditional organic settlements and planned contemporary neighborhoods have different spatial configurations, which affects their walkability potential. In this study, two urban settlements, in Chennai, Tamil Nadu, namely, Triplicane and Anna Nagar were analyzed to determine their walkability potential. The study involved space syntax analysis using DepthmapX to evaluate the syntactic values of connectivity, integration, intelligibility, and synergy of the street network in both areas. The findings of the study were validated through on-site evaluation. The research revealed that both settlements had varied levels of connectivity and integration. The study concluded that the walkability potential of a neighborhood is not only dependent on the spatial characteristics of the street network, but, also on the objective site conditions, microscale-built environment attributes, and walkability barriers.

**Keywords:** Walkability, Street Configuration, Space Syntax, Walking, Connectivity, Integration

## INTRODUCTION

Walking is the most sustainable mode of transportation and a healthy physical activity (Fonseca *et al.*, 2021). Walkability refers to the potential of the built environment's influence on people to walk to different destinations and purposes (Garau *et al.*, 2020). This is mainly influenced by the street network, its spatial characteristics and linkages (Molaei *et al.*, 2021). Indeed, a rapidly growing body of literature has recognised the importance of street characteristics like connectivity (Hajrasouliha & Yin, 2014), compactness (Cervero & Kockelman, 1997) and proximity (Lee & Moudon, 2004) on walking behaviour and the choice of walking as

a mode of commute. The street network configuration and the corresponding walkability levels can vary between a traditional organic settlement and a modern planned neighbourhood. Evidence suggests that spatial configuration is a vital correlate of walking in the Space Syntax theory. Space syntax explores the association between human societies and space (Bafna, 2003). This method has been widely used to explore the spatial characteristics of street networks in developed countries (Farzadi Moghadam, 2018; Hajrasouliha & Yin, 2014; Paraskevopoulos *et al.*, 2020). Despite such comprehensive studies in developed

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countries, insufficient work has been carried out to examine the spatial configuration of street networks in developing countries.

In summary, there are several gaps in the literature that this study aims to address: (a) there is a dearth of studies that analysed the spatial network configuration and its impact on walkability levels in developing countries like India; (b) comparative analysis of the spatial structure of the street network in a traditional and a modern settlement and its impact on the walkability potentials were rarely explored together in the same study; (c) Until recently, only a few studies have used the space syntax methodology to identify and evaluate street segments with poor connectivity and integration that require immediate attention to enhance walkability.

This paper comprises five sections. Section two presents the theoretical background of the research explaining that street spatial structure correlates with walkability. The third section discusses the study area selection criteria, the data used and the methodological framework adopted. The fourth section presents comprehensively the results obtained by comparing the spatial network configuration in the traditional and contemporary settlement and their corresponding walking potentials. The streets have been ranked based on their capacity to attract pedestrian movement. Furthermore, street segments with poor connectivity and integration have been identified, evaluated and recommended for immediate action. Finally, the conclusion section summarises the findings of the research, their implications, and the scope for further research.

Walking is the most elemental and primitive form of urban mobility, that enables people to move around to reach destinations and experience urban spaces (Millan, 2009). It is the most sustainable and safe mode of transport and does not require any equipment (Hart, 2009). The benefits of walking have been well documented in previous studies. WHO recommends at least 150 minutes of weekly physical activity in adults and older adults to achieve healthy and active ageing (WHO, 2011). Major benefits of walking include good health (physical, mental and social well-being), environmental protection (reduces carbon footprint and traffic congestion), enhanced social cohesion, economical as a mode of commute and results in habitable communities (Blaga, 2012; Litman, 2013). In the 2030 Agenda for Sustainable Development and the associated New Urban Agenda, the UN has stressed the importance of creating accessible environments and improving walkability. Walking is so vital that it contributes to the four Sustainable

Development Goals (SDG) in a big way – SDG 3 (Good health and well-being), SDG 7 (Affordable and Clean Energy), SDG 11 (Sustainable cities and communities) and SDG 13 (Climate Action) (UNDESA, 2023).

The built environment must be conducive to make the walking episode a pleasant experience. This makes the environment walkable. Walkability is an umbrella term that has been given several connotations. Forsyth & Southworth defined walkability as the characteristic of an urban area that promotes physical activity. It is a built environment that is located near essential destinations, has no barriers, is secure, and has proper pedestrian infrastructure and green spaces (Forsyth & Southworth, 2008). This concept is also mentioned in the seminal work of Wang & Yang (2019) as a type of accessibility that provides comfortable walking in a specific area and reaching destinations on foot. The association between walkability and city streetscapes provided a better ambiance for people to take up physical activities like exercise, leisure or recreation. (Wang & Yang, 2019).

The design of street networks, their connectivity and configuration have a vital role to play in attracting people to walk and improving the walkability rate (Sdoukopoulos *et al.*, 2017). Connectivity indicates the spatial relationship between streets in a network. It explains the availability of alternative routes, that can attract or repel pedestrian usage to reach a destination (Nyunt *et al.*, 2015). In comparison, integration explains the cognitive complexity of reaching a street. It shows how a street segment is integrated or segregated from the network (Baran *et al.*, 2008).

Space Syntax Theory and analytical methodology were developed by Bill Hillier and his colleagues in the year 1989 (B. Hillier & Hanson, 1989). Space Syntax is a mathematical model for street networks based on the Graph Theory to calculate “spatial topological relationships”. It provides a theoretical basis and methodology that explains and quantifies the spatial correlates of the built environment and their impact on socio-economic activities (Van Nes & Yamu, 2021) This theory derives its roots from the Graph Theory and the Theory of Natural Movement. Space Syntax considers how each space is connected to all other spaces by directional and angular changes in the spatial system. It measures the to-movement (closeness) and through-movement (betweenness) potentials of every street segment to all other segments in the network (B. Hillier, 1999; W. R. G. Hillier *et al.*, 2012).

In Space Syntax streets are represented in the form of axial maps and segment maps. An axial map has a minimum number of axial lines which represent the longest line of sight for movement (the way humans move linearly in urban street networks) in a set of convex spaces. Segment maps are obtained by splitting the axial lines at junctions and account for the change in direction from the origin to the destination (Turner *et al.*, 2005; Van Nes & Yamu, 2021). A well-connected street network contributes to better walkability by providing many potential route choices and easy access to more destinations (Jiang & Liu, 2009). It is a static local dimension that includes all the direct links a street has with other streets located in its proximity. Thus, a street with many connections to its neighbouring streets is said to have high connectivity value and vice versa.

Connectivity is calculated using one-step analysis or two-step analysis based on the scale of the area to be analysed (B. Hillier & Hanson, 1989; Van Nes & Yamu, 2021). Integration indicates the ease with which one can reach a particular line in an axial map. Mathematically, it is

expressed as an algebraic function of the number of axial lines that must be crossed to move from one axial line to the other in an axial map. The higher the integration values lower the number of axial lines to be traversed. The global integration [HH] of a street or axial line is the degree of accessibility of a street to all other streets in the entire urban system under study. Local integration [HH]<sub>R3</sub> is the degree of accessibility of a street to another street within a specific syntactic radius, 3 in this case. It shows how each street is connected to its vicinity in terms of three times direction changes. The axial line with the highest value of global integration is the street that can be accessed from all other streets with minimal change in direction (Baran *et al.*, 2008; B. Hillier & Hanson, 1989).

### MATERIALS AND METHODS

This section is divided into (a) a brief introduction of the two study areas; and (b) the methodology used for the analysis. A diagrammatic representation of the methodology is depicted in Figure 1.

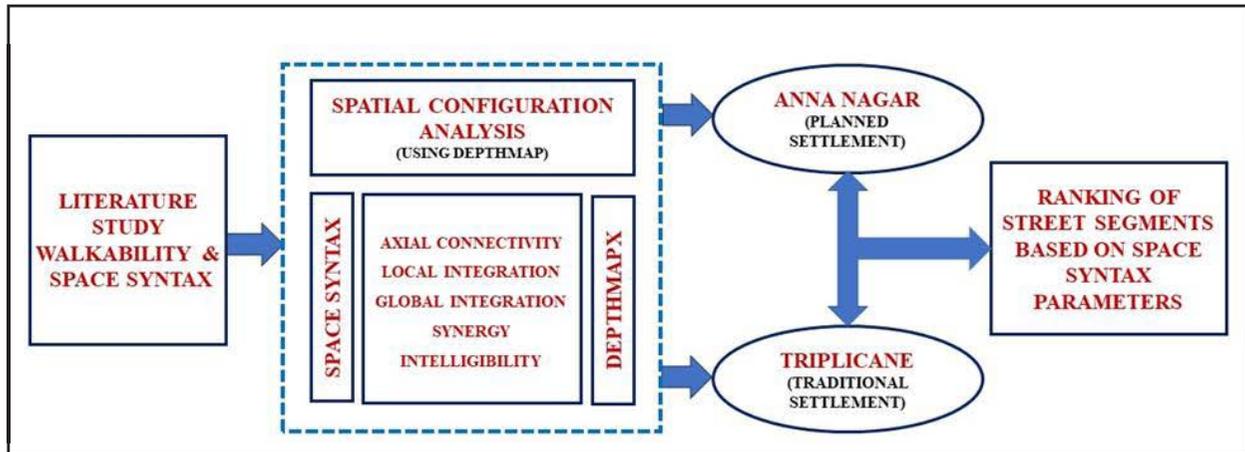
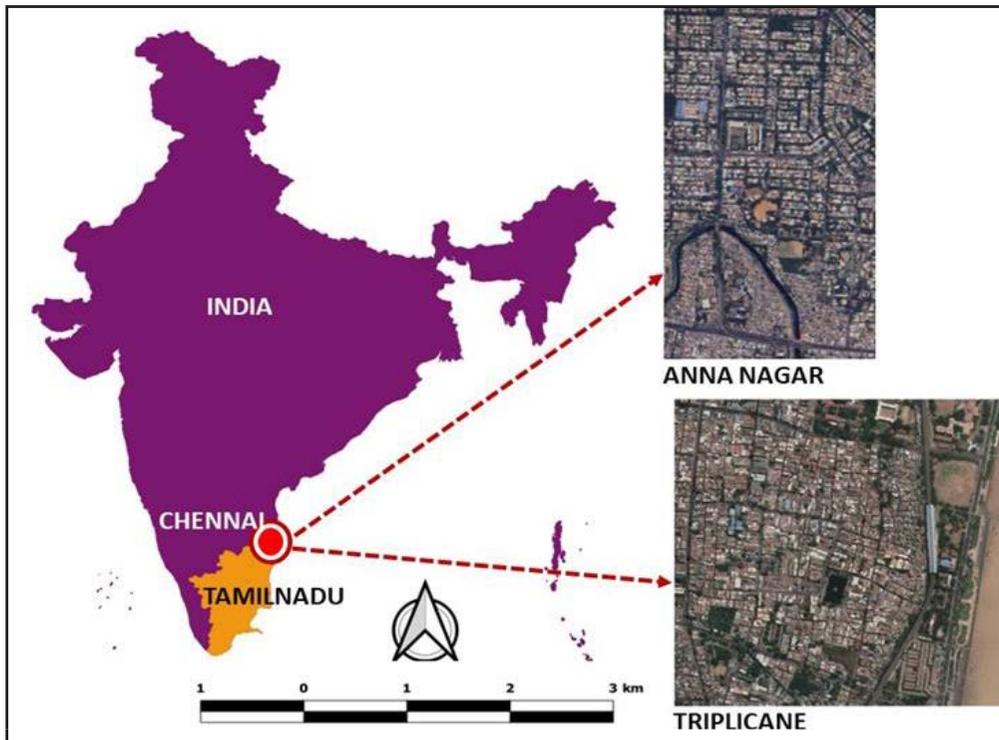


Fig. 1: Conceptual Framework (Source: Author)

### STUDY AREA

The study is based in the Chennai Metropolitan Area (CMA) that comprises 15 zones and is further subdivided into 200 wards. The study areas (Figure 2) are Triplicane (Ward No. 116) and Anna Nagar (Ward No. 101) in Chennai, Tamilnadu, India. Triplicane is a traditional organic settlement located in South Chennai while Anna Nagar is a planned settlement

located in the Central part of Chennai. These study areas were chosen to compare the layout of street networks and their walkability potentials in two neighborhoods with vastly different spatial characteristics. Moreover, these areas possess attraction poles like neighbourhood parks, beaches and places of worship which are of heritage importance.



**Fig. 2: Map showing the location of Triplicane and Anna Nagar in Chennai, Tamil Nadu, India.**  
(Source: Google Earth Software modified by Author)

### SPACE SYNTAX ANALYSIS

The study utilised Space Syntax to examine the spatial character of the street network in the two study areas. The analysis focussed on the topological characteristics of the streets, their connectivity, and their accessibility in a network. In a space syntax map, each street is represented by an axial line which is the longest line of vision in a street. In this study, the space syntax analysis was done using the DepthmapX software. This software is user-friendly and has fast data processing capabilities. It presents an immediate visualisation of the hierarchy of streets based on their spatial character. The connectivity and integration values of the streets are visually depicted with a graduated colour symbology. Higher values are represented by warm colours like orange or red and lower values are represented by cool colours like blue or green.

Two different space syntax methods were used in the analysis, namely connectivity and integration. The connectivity of any axial line is the number of lines that directly intersect the axial line under study. If more lines intersect a particular axial line, it is marked with a higher connectivity value, denoted on maps by warm colors such as

red. The implication of an axial line having a high connectivity value is that it has high access potential to a large number of axial lines or streets in the network. Integration aids in understanding how close the place of origin is to all other axial lines in the network. This is calculated at two levels, Global Integration (at radius =  $n$ ) and Local Integration (at radius = 3). High integration from the topological standpoint refers to a space that can be easily accessed and hence is well integrated. Intelligibility explains the correlation between axial topological integration ( $R=n$ ) and axial topological connectivity. A value of high intelligibility implies a strong correlation between these two indices and it marks the strong relationship between the entire urban space under consideration and the elements that make up the system. Synergy is the correlation between the axial topological integration values at the global level and the local level. This explains the degree to which the parts of the spatial system refer to the global or the entire system in which it is located.

### RESULTS AND DISCUSSION

The syntactic properties were evaluated using space syntax analysis in both areas. The analysis yielded syntactic

measures like connectivity, local integration, global integration, intelligibility and synergy. The main parameters of the space syntax analysis of the two areas from an all-line axial map are presented in Table 1. Triplicane (Figure 3), a traditional settlement, 3337 axial lines constitute the street network. In terms of connectivity, the number of possible street connections a street can have may range between 6 and 411. However, the streets with more connections are the main roads like the Dr. Besant Road, Pycrofts Road and the Venkatarangam Pillai Street. This explains high level of accessibility along these street segments. The streets with more connections are marked in red and the ones having the least connectivity are depicted in blue.

The calculation of network centrality was done at the global

and local scales. Axial integration was computed for two topological radii namely,  $R=n$  for analysis conducted at the global scale (Global integration) and  $R=3$  for analysis conducted at the local level (Local Integration) (Refer Table 1). The broad and extensive main roads, like Dr. Besant Road, Pycrofts Road and Venkatarangam Pillai Street showcasing enhanced connectivity, demonstrated substantial global integration. Similarly, on a local scale, wide and elongated streets exhibited superior integration metrics in contrast to their narrower, dead-end counterparts. The heightened local integration within the vicinity inclusive of Dr. Besant Road, Venkatarangam Pillai Street, and Canal Street establishes a primary pedestrian thoroughfare, thereby contributing to enhanced walkability within the community.

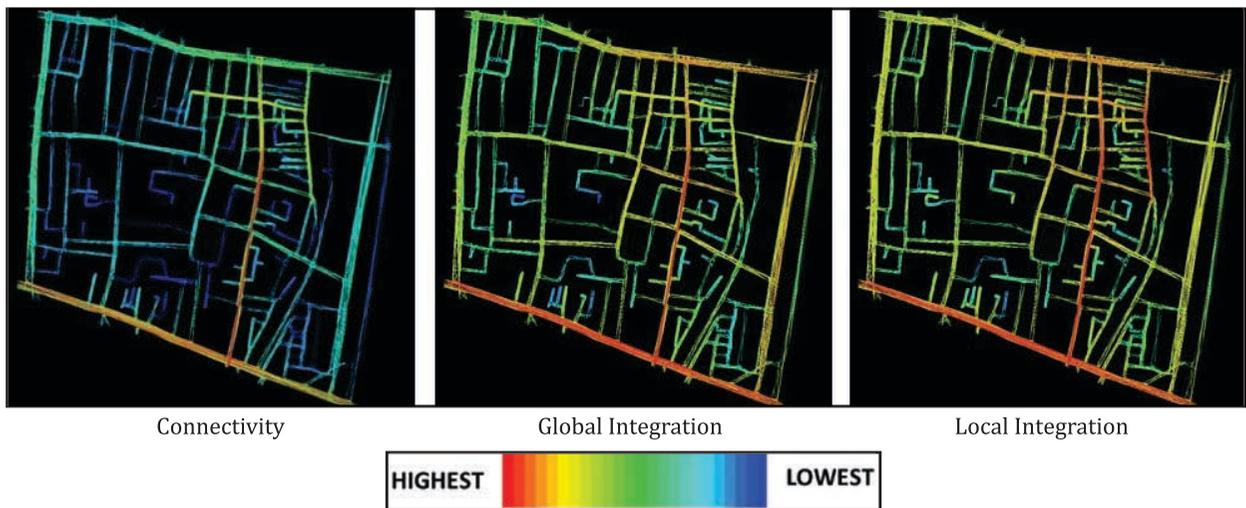


Fig. 3: Map showing Space Syntax Analysis of Triplicane, Chennai, Tamil Nadu. (Source: Author)

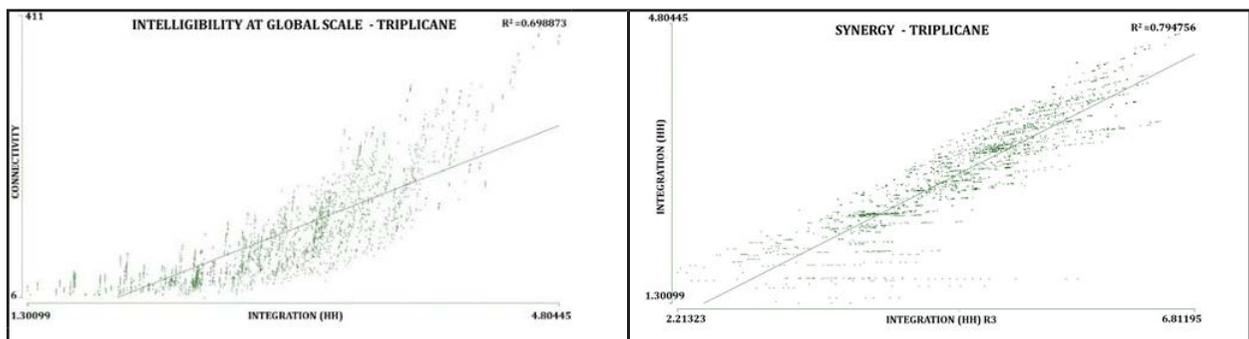


Fig. 4: Intelligibility and Synergy values of Triplicane, Chennai, Tamil Nadu. (Source: Author)

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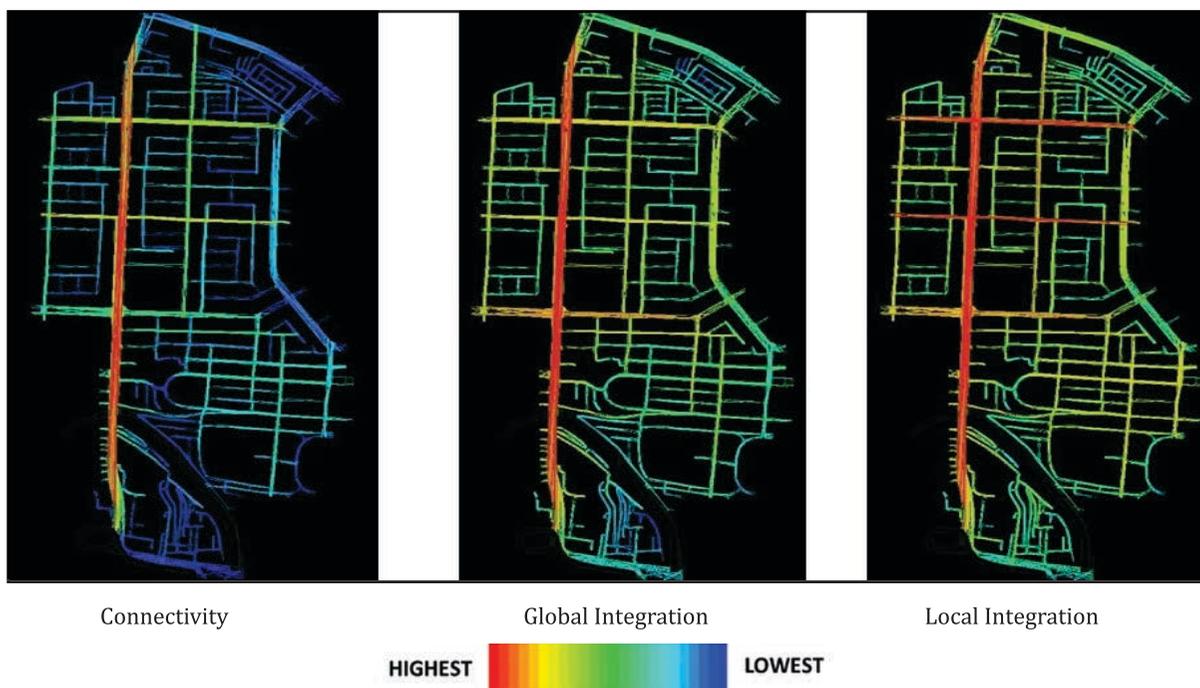
In Space syntax the intelligibility of a space explains the level of correlation between the local space and the entire spatial system. The R2 value of intelligibility that falls within a range of 0–0.5, indicates weak spatial identifiability. A value of R2 between 0.5–0.7 signifies good spatial identifiability, while a range of R2 between 0.7–1.0 signifies strong spatial recognizability (Xu *et al.*, 2020) The intelligibility value of Triplicane (Figure 4) shows a linear correlation between the axial connectivity and Global Level Integration with an R2 value of 0.698873. The value indicates that the visibility of the street axis of the block is good. The intelligence value in Triplicane suggests that pedestrians can more easily discern the overall spatial structure from local perception, leading to increased spatial intelligibility.

The synergy value is described by a linear regression index of the local integration degree (R3) and the global integration degree (Rn). A higher synergy value signifies easier spatial recognition and stronger axial synergy. Typically, values ranging from 0.5 to 0.7 are utilized. A value below 0.5 indicates poor synergy, while a value surpassing 0.7 denotes good synergy. Triplicane exhibits a synergy value of 0.794756. The calculated value surpasses the maximum value of 0.7, signifying a high level of synergy and a well-established spatial interaction between the local area and entire neighbourhood. This suggests that pedestrians

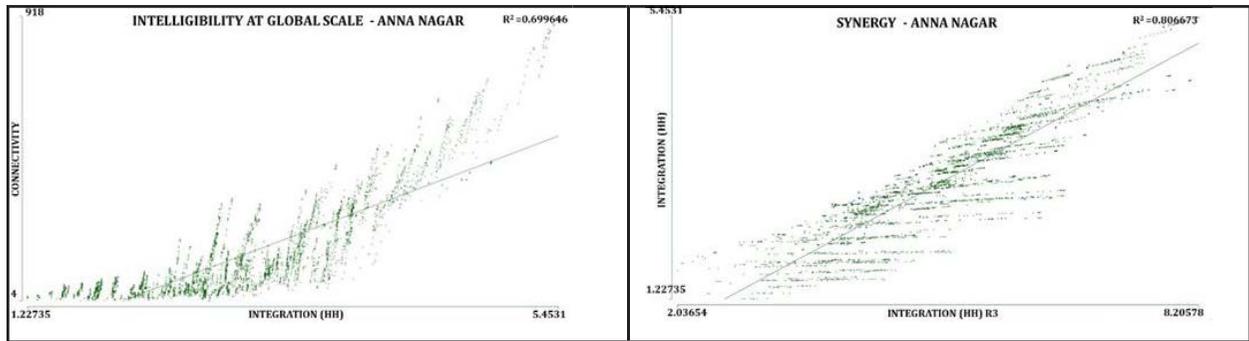
can easily comprehend the overall spatial layout through the local streets and alleys, thus contributing to better walkability.

In Anna Nagar (Figure 5), the planned settlement, 5121 axial lines constitute the street network in the fewest line axial map. In terms of connectivity, the number of possible street connections a street can have ranges between 4 and 918. The streets in this study area follow a spatial hierarchy of avenue roads, main roads, local streets and service lanes. The streets higher up in the hierarchy have higher connectivity than the local streets. The 3rd Avenue Road, which is a central spine runs across the entire neighbourhood has the highest connectivity. The streets with more connections are marked in red and the ones having the least connectivity are depicted in blue.

Axial integration performed at the global level showed greater integration surrounding the 3rd Avenue Road, one of the longest and widest in the settlement. Here the streets are of gridiron pattern meeting at right angles. Local integration is also higher near the 3rd Avenue Road, 6th main road, 5th main road and 2nd Avenue Road. In Anna Nagar, the scatter plots for Intelligibility and Synergy show a linear correlation with high R2 values of 0.699646 and 0.806673 respectively (Figure 6). The elevated levels of intelligibility and synergy



**Fig. 5: Map showing Space Syntax Analysis of Anna Nagar, Chennai, Tamil Nadu. (Source: Author)**



**Fig. 6: Intelligibility and Synergy values of Anna Nagar, Chennai, Tamil Nadu. (Source: Author)**

in Anna Nagar can be ascribed to the structured hierarchy of road networks, which encompasses avenue roads, main roads, and local streets. The adherence to a grid iron pattern by the streets enhances legibility and spatial cognition, thus augmenting the walkability potential of the neighborhood.

On comparing the two study areas, Anna Nagar is well connected when compared to Triplicane. In terms of Global

Integration, Triplicane has higher integration than Anna Nagar. This implies that most destinations in Triplicane are easily accessible by walk. However, in the context of local integration Anna Nagar is well integrated than Triplicane providing more scope for walking. Anna Nagar being a planned settlement, has many pedestrian thoroughfares encouraging more walkability and access to local destinations.

**Table 1: Syntactic Parameters of the Two Study Areas**

Sl.	Space Syntax measures	Triplicane	Anna Nagar
1	Connectivity		
	Minimum	6	4
	Average	87.2223	147.243
	Maximum	411	918
2	Global Integration [HH]		
	Minimum	1.30099	1.22735
	Average	2.85179	2.92352
	Maximum	4.80445	5.4531
3	Local Integration [HH] R3		
	Minimum	2.21323	2.03654
	Average	4.6184	5.08243
	Maximum	6.81195	8.20578
4	Intelligibility	0.698873	0.699646
5	Synergy	0.794756	0.806673

This study is further supplemented with the on-site assessment, which throws light on the other parameters like street width, sidewalks, presence of barriers to walking and road conditions.

Triplicane is an old settlement with high density. The on-site survey in Triplicane, revealed that most streets were narrow lanes and had no sidewalks. On the contrary, the main roads

with high connectivity and integration, had sidewalks on both sides. In the narrow lanes, the pedestrians were compelled to walk on the carriageway, which had projecting manholes, uneven speed bumps without markings and intrusion of stray cattle (Figure 7). In some specific cases like Dr. Besant Road and Pycrofts road, the sidewalks were encroached by streets vendors, eateries and parked vehicles, making them inaccessible to pedestrians.

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Fig. 7: Barriers to Walking in Triplicane, Chennai, Tamil Nadu. (Source: Author)

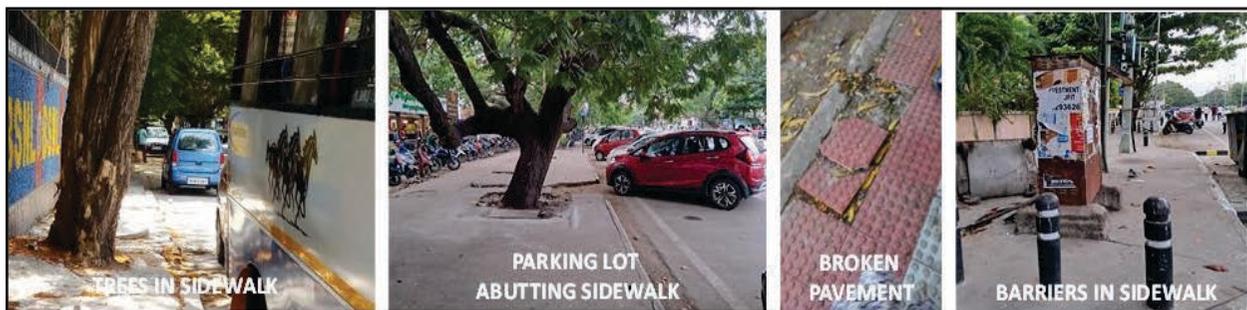


Fig. 8: Barriers to Walking in Anna Nagar, Chennai, Tamil Nadu. (Source: Author)

Anna Nagar is a planned settlement with lesser density and a gridiron pattern of street network. The streets were categorized as avenues, main roads and local streets. Though the shaded avenues provided a pleasant walking experience, they had certain shortfalls. The sidewalks in the avenues and main roads had walkability barriers like parking lots abutting sidewalks, uneven sidewalks, trees, electrical transformers and hawkers (Figure 8). Anna Nagar is known for its high car ownership rate per household. Thus, residents park their cars in residential streets, posing a hindrance to pedestrians.

### CONCLUSION

This study investigated the relationship between street configuration and walkability potentials in two different neighbourhoods in Chennai, Tamil Nadu. The study utilised Space Syntax as a research tool, to identify streets, that are well connected and integrated and hence their walkability potential. The results were confirmed through an on-site survey that examined the actual site conditions. The findings showed that the two areas, Triplicane and Anna Nagar, with contrasting spatial configurations, exhibited varied connectivity and integration values. This method

had some limitations, though. This evaluation procedure was primarily based on the geometric and topological configuration of the street network. Thus, streets were categorised as well connected and integrated, but, it did not reflect the important on-site conditions which impact walking behaviour and walkability. For example, the width of streets, sidewalk availability and continuity, traffic conditions and pedestrian safety levels also have a bearing on the walkability of a built environment. To arrive at holistic outcomes and recommendations for developing long-term planning strategies, the space syntax methodology should be combined with on-site evaluation studies that consider microscale-built environment factors.

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