



## Application of space syntax methodology to predict spontaneous commercial areas and to develop strategic decision-making tool: a study on Kolkata

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### Abstract

Spontaneous commercial urban development is becoming strategically significant for the urban designers and policy makers for developing strategies for inclusive growth, managing traffic, allocating resources and developing infrastructure. The developments of such areas may be an excellent indicator of urban vitality, but they also create visual imbalance and adversely affect historical patterns and create difficulty in managing urban infrastructure. This study employs axial line analysis of space syntax to establish the relationship between spatial configuration and development of spontaneous commercial areas. The integration value generated from the axial line analysis and the metric measure of road width are used to generate a strategic decision-making grid in classifying street segments for assessing their potential in becoming spontaneous urban commercial spaces. This strategic grid operates from both the ends on conservative and generative use of space by maintaining the pattern or through suggesting changes as per the actual requirement and condition.

**Keywords:** Axial line Analysis; Commercial space; Integration; Movement; Space Syntax.

### 1. Introduction

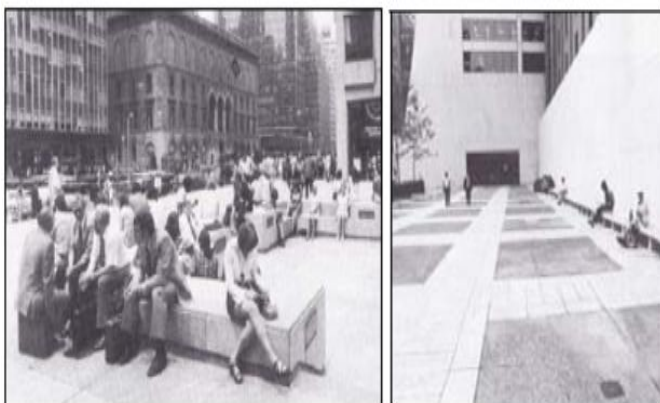
Spontaneous urban commercial spaces are becoming significantly important in recent research (Hossain, 2014) as they develop organically, sometimes even without any formal planning or approval. These spontaneous urban commercial spaces represent urban economic vitality and significantly mark a contrast with the historical characteristics of the urban area. Jane Jacobs ascribed the reason for urban vitality to the spontaneous informal commercial developments in her seminal work, "Death and Life of Great American Cities" (Gómez-Varo et al., 2022; Laurence, 2006). But this kind of development results in safety issues, affect visual coherence and develop hindrance in managing[1] urban resources and infrastructure (Natividade - Jesus et al., 2019). Moreover, it even leads to visual imbalance and adversely affects the historical pattern (Kara &

Iranmanesh, 2022). These areas are less structured and regulated compared to the planned commercial areas. Why is a particular part of a city becoming more vibrant than the other? Why does a calm neighborhood exist near the hustle bustle of a street lined with commercial establishments? This question haunts urban thinkers and Urban designers, architects and sociologists who try to understand the logic behind that. Sometimes, people do behave in a particular way while our natural understanding of space suggests otherwise. Pruitt - Igoe is a classic example (Bristol, 1991; Salihoglu, 2022; Allen & Wendl, 2014) of failure of an architect's perception of space and induced human behavior. The same is true for the study on good and bad plaza (Whyte, 2012; 2013) (Figure 1). Why people prefer a particular space over another is a spatial question

which also has strategic ramifications. This preference to a particular space over others leads to the development of these informal spontaneous commercial spaces (Schertz et al., 2022; Yan & Qi, 2022; Slaev et al., 2022). The basic objective of any enquiry in the field of social science is to understand the pattern behind chaos. Every human being is different but when they work in a group, some kind of pattern is discernible and once we identify the pattern, it is easier for us to do strategic decision making. This pattern identification is important for foreseeing the outcome. In traditional discourse, a space is described qualitatively therefore is prone to error caused by subjective judgement. This identification of the reason behind the development of the spontaneous commercial areas is becoming more significant considering the sustainable development goals (SDG) adopted by United Nations in 2015 (Russell, 2018) and for the philosophy of National Urban Policy Framework, Govt, of India (Vaidya & Vaidya, 2024). The identification will lead to mapping of activities, developing strategies for inclusive growth, addressing conflict with traffic patterns, assessing requirement of infrastructure, planning resource allocation, resolving conflicts between formal development and spontaneous development. Understanding of the logic behind such occurrences will also help in retaining and reclaiming or managing historical areas (El-belkasy & Wahieb, 2022; Alosan et al., 2024). As shown in Figure 1.

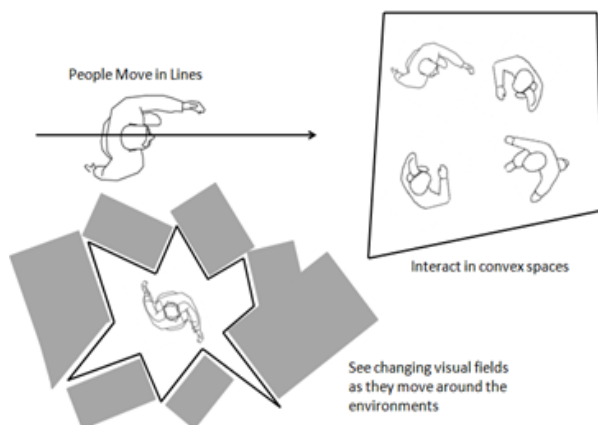
## 2. Materials and Methods

Development of spontaneous commercial spaces in an urban area depends on the preference for a particular space over others and is mostly reflected by increased pedestrian and vehicular movement through that space. Therefore, movement is one of the significant anthropogenic variables that can explain the emergence[2] of spontaneous commercial spaces. Space is traditionally explained in qualitative terms in architectural or urban design discourse making it difficult to explain the presence or absence of any anthropogenic activities. Anthropogenic activities can be expressed in numbers and therefore spatial configuration also needs numeric tags for establishing correlation. Space influences behaviour is essentially a truism, but establishing a functional relationship between spatial configuration and behavioural outcome is paramount for strategic decision making. Analysis of spatial configuration is therefore of immense significance. Space syntax methodology was developed as an application of graph theory as a configurational analysis in the Bartlett School of Architecture, University College of London[3]. Configuration can be described as a set of rules that distinguishes a spatial arrangement and is defined as: "... A set of relationships among things all of which interdependent in an overall structure of some kind" (Hillier, 1996) The purpose of space syntax is to analyse a spatial configuration and provide numeric tags to the constituent units. This numeric tag is universal and objective. It is not clouded by the subjectivity of the enquirer. The social meaning of any spatial configuration is guided by varied anthropogenic activities. These anthropogenic activities are measurable and can also have numeric tags. Therefore, it is easier to establish a causal relationship between spatial configuration and anthropogenic variables. The space syntax theory thus provides a social meaning of spatial configuration (Hillier & Hanson, 1997)[4 - 10]. Space syntax methodology is implemented on the two-dimensional abstraction of an architectural space or urban layout. It is done through the breaking up of the space into constituent units. Depending on the level of enquiry, the abstraction can represent movement, interaction and visibility (e.g. Klarqvist,



**Figure 1** New York City Plazas (The “Good” Plaza and the “Bad” one, Whyte, 1980) and their use during the lunch time; some are full off activities (left) while some are deserted (right)

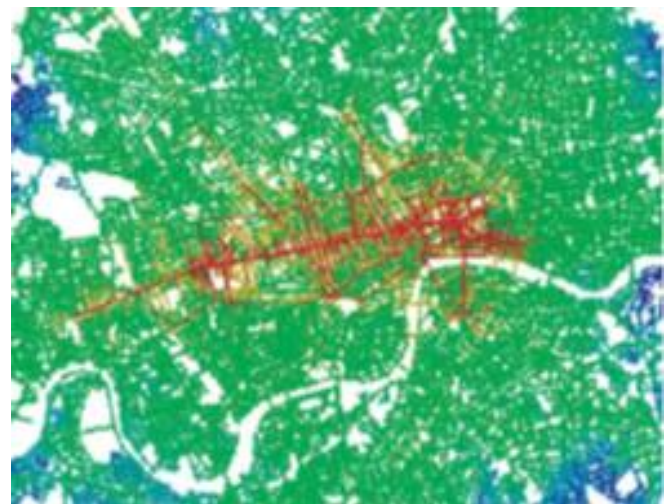
2015) (Figure 2). Longest lines of sight represent visual connection in a spatial configuration. The built space under consideration is broken down into a map of the minimum number of longest lines of sight (Turner, 2007; Batty, 2004). The underlying configuration is the interrelationship between the lines of sight, known as axial lines. Considering the unit of enquiry, the analysis is known as axial line analysis[11]. This analysis is common in urban scale where the parameter of enquiry is movement. High degree of correlation is visible between the syntactical measure of the axial lines and movements along it. As shown in Figure 2.



**Figure 2** Three geometric ideas for spatial representations, Linearity, Convex space and Isovist

Similarly, convex space analysis is employed where the parameter for study is interaction and related anthropogenic activities (footfall, purchase, pollution etc.). Similar to the axial line analysis, the name convex space analysis is derived from the unit of enquiry, i.e., convex space. A convex space is a polygon without any obtuse angle in it. The basic philosophy behind this shape is that every point in a convex space should be visible from all the points in that convex space[17 – 20]. Therefore, it relies on the concept of intervisibility. This type of space is instrumental in influencing interaction. For the analysis, the space under consideration is broken down into mutually exclusive and collectively exhaustive convex spaces. The space syntax analysis depends on the logic of arrangement of the convex units. The third level of abstraction is called isovist or

visibility polygons. Though, the concept of visibility is implicitly imbibed in the conceptualization of the two other space syntax methods. The visibility analysis depends on the definition of isovist. An isovist is a visibility polygon generated by obstruction to visibility from a given vantage point considering a 3600 field of view. These constituent units are analysed using graph theory to generate universal unambiguous measurements. The analysis can be done both at the global and local scale depending on the entirety or part of a space. The most common measure is called “integration” which is a normalized measure of a configuration, and it symbolizes the syntactic distance from other constituent units in the configuration[12 – 16]. The higher the integration value, the better the connection of that particular unit with other units of the system and vice versa. The significant correlation between integration value of an axial line and the magnitude of traffic, vehicular movement through it is established in several research (Hillier et al., 1993; Hillier, 1996; Peponis et al., 1997; Penn et al., 1999). Therefore, movement can be predicted with space syntax measures. As shown in Figure 3.



**Figure 3** Axial analysis of central London (Hillier, 1998). Oxford Street is most integrated (red)

The integration value of a particular road segment influences the traffic volume through it and therefore the road segment with higher integration value generates higher traffic volumes. A study was conducted on the neighbourhood of Oxford Street in

Central London, and it is found that the local integration value of the particular street segment is significantly higher (Figure 3) than its neighbouring street segments (Hillier, 2009). That justifies the commercial establishments and busyness of the Road. One of the classical cases where axial line analysis is employed to justify and predict movement is the improvement of public realm in central London between Parliament square and Trafalgar square (Dursun, 2007) (Figure 4). Trafalgar square was literally disconnected from the surrounding areas. In that project Sir Norman Foster took the help of Space syntax laboratory. SSL studied the environment and plotted movement pattern around that area and ran axial analysis of that space to find a high degree of correlation between integration value and movement. They ascribed the reason for the disintegration as the low level of connectivity [21 – 25]. The condition was improved through increasing the integration value through incorporating new axial lines (Figure 5). Spatial interventions were made such as to support the formation of axial lines. As Shown in Figure 4 & 5.

(Dursun, 2007)

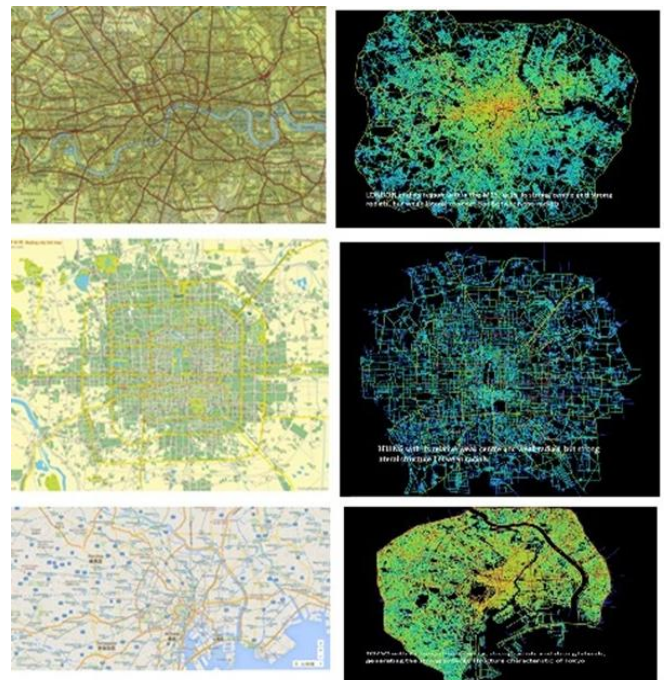


**Figure 5 The Trafalgar Square: before (left) and after (right) design interventions**

The designer acknowledged the input from space syntax analysis as: “I would just mention that the sources of our proposals have an interactive relationship with each other. Many have emerged from these experiences; but they have also come out of the brief. They have resulted from our observations, but the same time here is constant crosschecking between those findings and public consultation. It is this symbiosis which demonstrates to me what a very creative tool the space syntax theory is” (Foster, 1997, quoted in Dursun, 2007, p. 56-6). As shown in Figure 6.



**Figure 4 Trafalgar Square: Axial analysis and movement traces before and after the design interventions of Norman Foster. The strong relationship between integration of axial lines and movement traces is clearly visible (Source:**



**Figure 6 The Trafalgar Square: before (left) and after (right) design interventions**

Streets are network that connect the built spaces in a city. The street layout alone is insufficient in

describing the character of a city. The left side of the Figure 6 depicts street layout of London, Beijing and Tokyo. It is difficult to comment on the characteristic difference between them. The axial line analysis on the right-hand side depicts a different story altogether. London has a strong core and strong radials but relatively weak connection between radials. That fits well with the historical development of the London city. The Beijing city has weak core and radial but comparatively strong radials which conceptually correlate with the concept of forbidden city (weak core). Tokyo reflects its strong sub-urban structure through its strong core, strong laterals and strong radials.

### 3. Study

Kolkata as a city has a long history. With an insignificant starting as an amalgamation of three villages it grew to be the capital of the colonial India, declined to be the capital of West Bengal and is still the third largest metropolis of India after only Delhi and Mumbai. It is still known as the cultural capital of India. Different streets have different stories to narrate. We have taken 6 streets from three parts of Kolkata. Neemtala Ghar Road and Ahiritola are in the northern part of the city and dates back to the colonial era. Though rich in heritage, they suffer from lack of infrastructure, traffic congestion and limited modern amenities. In spite of the sorry conditions, they are strongly woven with the cultural fabric of the city with the ghats, temples and buildings dating back to the British era. In contrast, Rash Behari Avenue and Southern Avenue are representative of the growth of the city during mid-20th century. On the southwestern edge of the city, we have identified Biren Roy Road and Roy Bahadur Road representative of post-colonial era sub-urban growth. The metric categorization of a road can be done by the width of the road (which dictate the FSI of the plots abutting it). We have applied axial line analysis on the street segments in the vicinity (3 sets). The axial line analysis of the neighbourhood of the three sets of roads are done with Depthmap X, a spatial network analysis software by importing .dxf files of the street layouts of Kolkata. The attribute map of Integration is shown in the following three maps where Red represents highest integration and blue represents the

lowest value. As Shown in Figure 7, 8 & 9.



**Figure 7** The Attribute map of integration of the Axial line analysis of the Ahiritola and Neemtala Ghat Street



**Figure 8** Attribute map of integration of the Axial line analysis of the Biren Roy Road, Roy Bahadur Road



**Figure 9** Attribute map of integration of the Axial line analysis of the Rash Behari Avenue



### and Southern Avenue

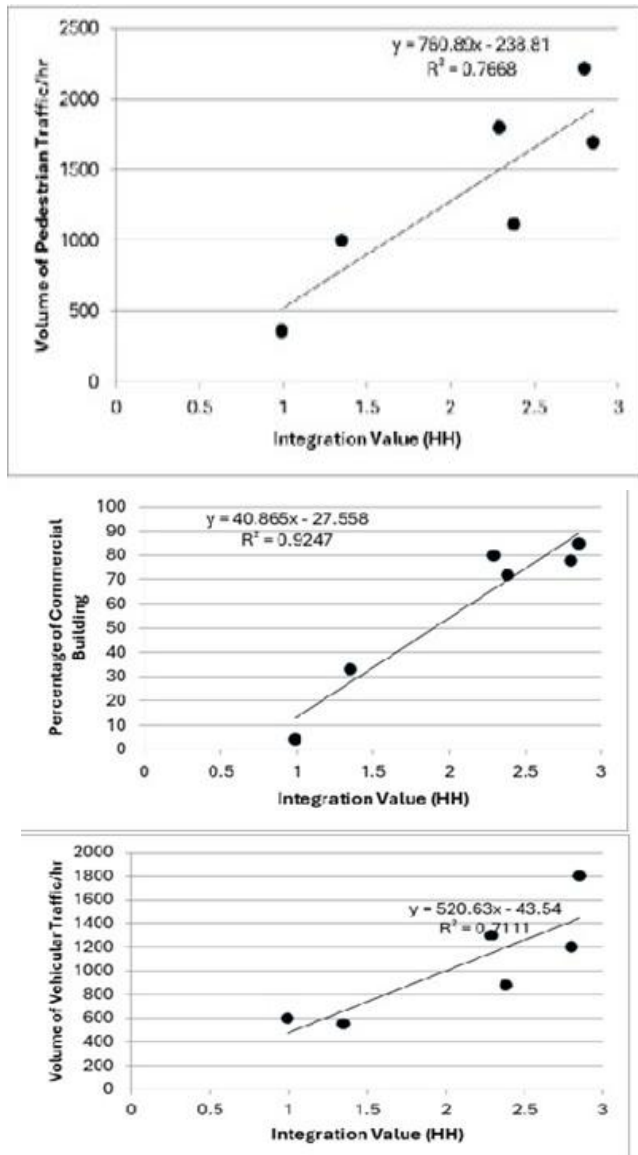
A brief Survey was conducted in the three sets of road segments and apart from the integration value another metric measure of the road was taken, i.e., road width. Apart from that Percentage of commercial building of

the road was assessed along with the average volume of pedestrian and vehicular traffic through it. The integration value is obtained from the Axial line analysis. The findings are summarised in the following Table 1.

**Table 1 Summary of the survey findings on the 6 Roads in Kolkata**

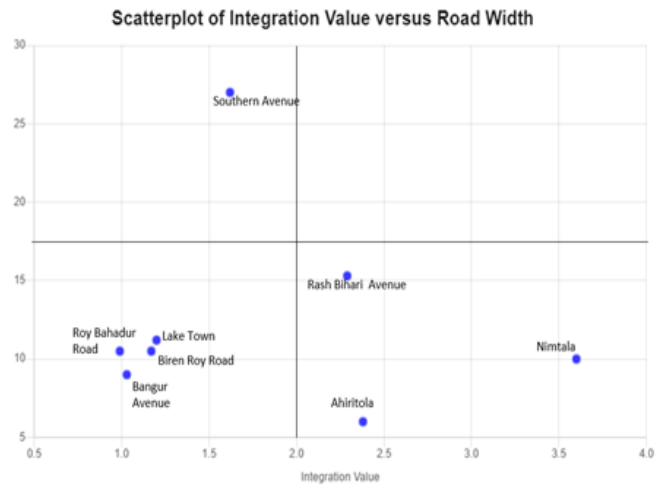
Street name	Width (Avg)m	Integration HH	Percentage of Commercial Building	Volume of vehicular Traffic/hr	Vol of Pedestrian traffic/hr
Ahirtola Street	6	2.38	72	880	1120
Neemtala Ghat Street	10	3.6	78	2100	2220
Biren Roy Road	10.5	1.17	85	550	1050
Roy Bahadur Road	10.5	0.99	33	600	1000
Rashbihari Avenue	15.3	2.29	80	3000	1800
Southern Avenue	27	1.62	2	1440	360

The volume of pedestrian traffic, vehicular traffic and percentage of commercial building can be expressed as a function of integration value where  $r^2$  is significant ( $r^2 > 0.5$ ). Therefore, it can be concluded that integration value of a road can predict the development of spontaneous commercial areas and influences traffic movement (both pedestrian and vehicular) through it. The Road width on the other hand influences the building height in the particular road segment through the differences in permissible FSI. The two measures provide a good starting point in categorization of roads on the basis of road width and integration values. As Shown in Figure 10 & 11.



**Figure 10** Expressing percentage of commercial buildings, volume of Vehicular traffic/ hr and Volume of Pedestrian traffic/hr in terms of

### Integration value



**Figure 11** Categorization of Road based on integration value and road width

### 4. Conclusions and Recommendation

The study leads to the development of a general categorization of roads on the basis of their width and integration value. Based on that, the roads can be categorized into four major types depending on the high and low values of both the parameters, integration value and road width. The road segments, irrespective of their locational differences, in a cell exhibit similar characteristics. Therefore, it is easier to identify the pattern in a city and develop strategies accordingly. The same grid can be broken down into 4 cells employing the same logic. The tool provides guidelines for strategic decision-making regarding traffic intervention, resource allocation or managing clutter based on its location in the grid. As Shown in Figure 12.

Road width	High	<p>Characteristics: Quiet Residential Districts, Less commercial activities Features: Lesser pedestrian and vehicular traffic Higher building heights Can accommodate selective commercial and business uses Lesser problem with parking</p>	<p>Characteristics: Busy and thriving Streets/ Requires proper design and attention Features: High volume of vehicular and pedestrian traffic Building height more Can accommodate business uses Encroachment may be an issue</p>
	Low	<p>Characteristics: Small neighborhood streets Feature: Less building height Problem of parking Predominantly residential use with small shops</p>	<p>Characteristics: Commercial/ Mixed use streets with high level of encroachment on road Feature: High Traffic leading to congestion Lower building height Predominant mixed-use</p>
		Low	High

Integration value

**Figure 12 Strategic decision making grid for decision making**

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