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## Spatial Sustainability as A Contextual Tool to Code Emerging Urban Patterns of Cities

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### Abstract

As cities grow, the urban system expands and the contribution of each architect or urban designer into the system is different. Every increment is unique in its own character and expresses the attitude of the designer through it. Hence any increment into the system should be a continuation of what was existing before and should give due values to the existing condition without which the system tends to break. Doing so can lead to formation of a spatially sustainable fabric or city but to attain this kind of sustainability, every type of fabrics in every cities should follow a set of codes which are unique to themselves because spatial sustainability depends upon the spatial and social organization of spaces, geometric and configurational ordering of the space, culture and way of life in a city. Space syntax and spatial cognition were the methods used to identify parameters that contribute to spatial sustainability.

**Keywords:** Spatial Sustainability; Space Syntax; Urban Fabric; Patterns.

### 1. Introduction

Sustainability in cities is achieved through a development that meets the needs of the present without compromising the ability of future generations to meet their own (Thomsen C, 2013). Out of the three domains of sustainability – social, economic and environment, the latter deals with a sub field of spatial organization of fabrics in a city. How sustainable are our urban fabrics that are either self-formed or created is to be thought of. The spatial aspect of sustainability explains how sustainable the geometric and configurational ordering of space in the city is (Hillier, 2009).

As a primary case, the city of Coimbatore in India was chosen and two fabrics from the older and newer developments were taken as sample fabrics and compared to derive what are the sustainable features present in the fabrics and what more can be done so that the space becomes spatially sustainable. The function of the chosen fabrics had to be similar, so sample fabrics from two CBDs (old and new functioning) of the city were chosen. The conclusion of the study was to derive codes that can be followed by any future development projects (case of fabrics in CBD) in Coimbatore so that these developments will pertain to be spatially sustainable.

#### 1.1. Framework

##### 1.1.1. Aim

To code the urban patterns of the city for sustainable spatial development by defining the existing spatial functions, patterns and configurations.

##### 1.1.2 Objective

- i. To identify the parameters contributing to spatial sustainability in existing fabrics and to apply them to newer fabrics within the city.
- ii. To map the spatial, functional and social roles of the selected fabrics.
- iii. To understand the spatial configurations in the fabrics and to assess how sustainable the space is (through space syntax).
- iv. To devise a framework to code urban fabrics of a city based on spatial sustainability.

##### 1.1.3. Research Question

Are the existing fabrics of the city of Coimbatore spatially sustainable?

If not, to conclude on the parameters leading to spatial sustainability of the city as a whole, by deriving the same from its older fabrics.

##### 1.1.4. Need of the Study

There exists a relationship between the spatial components of an urban system. It is essential to evaluate if the city as a whole has preserved its spatial structure. Modern streets and developments tend to dominate and fracture the organic spatial structure of cities. Cities have to change, but the change has to be analogous to the existing urban

structure. By identifying the aspects and parameters that contribute to the sustainability of an urban fabric, a framework can be developed for the newer developments.

### 1.1.5. Research Gap

Research studies are available on reversing the decline of an urban fabric due to low spatial sustainability, but not on planning the newer developments considering the same.

### 1.1.6 Research Methodology

The three domains of sustainability exist hand in hand, hence the aspects leading to spatial sustainability are spatial, functional and social in nature. The parameters that come under these aspects are narrowed down from literature reviews and case studies. The first step was to understand the reasoning behind the concern mentioned by reading the books on space and spatial configurations. Books such as the New Theory of Urban Design by Christopher Alexander was studied in detail to understand the importance of the relationship between the various spatial components in an urban system and the sustainability of the same.

A framework was later formed to conduct a theoretical study and then a literature review was done on 2 broad areas – spatial sustainability and organization of spaces. To carry forward the research, mixed methods were to be used because the spatial, social and functional roles of the study area have to be mapped.

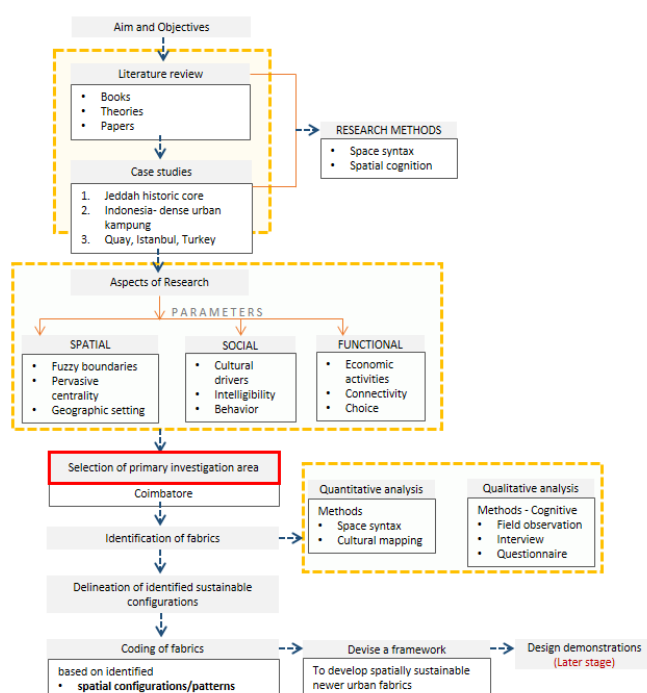


Figure 1. Research Methodology

The next stage was to go through cases that has similar concern. Jeddah's historic core has been reviewed by Bill Hillier for spatial sustainability (Hillier, 2009) by analyzing the issues for its disintegration from the urban system and a spatial quality assessment was carried out through which an evidence based design has been developed using the theories of space syntax and the software - DepthmapX-0.8.0.

Another case of Urban Kampongs/villages in Indonesia (Desiyana, 2018) was studied in understanding the spatial sustainability of the place. In this case two fabrics were chosen from the investigation area and the evolution of the space over time due to various cultural, economic and social drivers was studied to understand the varying spatial configurations and change in patterns over time.

A third study on Quays-port bays in Turkey (Dizdaroglu & Yigiter, 2018) has been studied as this case deals with the social, cultural and historic factors apart from the spatial organizations. Hence this study helps in understanding the role of social and cultural aspects in the formation, organization and arrangement of spaces.

From the literature and case studies, the spatial, social and functional parameters contributing to spatial sustainability has been identified. The parameters were grouped under the above 3 aspects and were studied using mixed methods because some of the parameters were syntactic in nature and the others were qualitative in nature. The next step was to select a primary investigation area where the parameters can be tested. A city which has an active older core and fast growing newer developments was required so that a comparative analysis can be done by taking 2 sample fabrics from both the areas and deriving spatially sustainable codes from them. The limitation was

that the sample fabrics should be from similar districts or areas with similar functions. Hence the city of Coimbatore was chosen as the study area and Coimbatore currently has 3 CBDs – older city core, CBD in the infill developments and the emerging new CBD. The next step was to choose 2 fabrics from the first 2 formed CBDs of Coimbatore and to test the identified parameters on the fabrics to understand what the spatially sustainable configurations within these fabrics are and what more has to be done to increase the spatial sustainability of these spaces. This analysis can be coded based on the identified spatial configurations and patterns and can be used to design spatially sustainable newer fabrics of the same function. The research is concluded by devising a framework for developing spatially sustainable newer fabrics and codes derived from the primary study for the newer fabrics of Coimbatore.

**2. Literature Review**

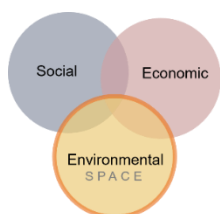
**2.1. Spatial Theories**

In the book, *New Theory of urban Space* (Alexander, 1987) Christopher argues that, wholeness doesn't exist in newer developments because they tend to grow as parts and are not in respect with any of its existing counterparts. This results in a lack of sustainability within the spatial configurations of a city that in turn affects the design in micro level. The city is always created as a piecemeal because each time an architect or urban designer inserts an increment into the urban system, they hardly merge together and exist as whole. Hence Christopher proposes seven rules of growth, which brings a coherence between various urban fabrics and patterns that co-exists within a city. Yet, the spatial sustainability of a single fabric is not addressed, though the element of wholeness is stressed upon. An urban fabric can possess the quality of sustainability only when the fabric functions well, with its inmates being socially and culturally rich with the right spatial usage and configurations (Agboola et al., 2018). Hence the spatial, social and functional aspects coexists to bring spatial sustainability within any given fabric of a city.

**Table 1.** Rules of Growth, Christopher Alexander

	RULES	FUNDAMENTALS
1	The whole grows piecemeal	<ul style="list-style-type: none"> <li>No increment may be too large</li> <li>Reasonable distribution(mix) of functions</li> </ul>
2	The growth of larger wholes	<ul style="list-style-type: none"> <li>Every increment plays a role</li> <li>Any small increment should be a part of the larger whole</li> </ul>
3	Authentic vision - content & character of individual increment	Any increment to arise from a vision to heal the existing structure, not from an intellectually formed concept
4	Positive Urban Space	<ul style="list-style-type: none"> <li>Building must create coherent and well shaped public space</li> <li>Current urban spaces are negative – the leftover after buildings are built</li> </ul>
5	Layout of Large Buildings	Buildings should be well ordered, and well integrated to bring wholeness in the city
6	Construction	<ul style="list-style-type: none"> <li>Every building must generate smaller wholes</li> <li>Exterior of the building will be in harmony with the exterior public space.</li> </ul>
7	Formation of Centers	<ul style="list-style-type: none"> <li>Deals with the geometric shape of all the wholes, at all scales within the process</li> <li>Every whole must be a 'center' in itself, and must also produce a system of centers around it</li> </ul>

The erosion of urban spaces as addressed in the book, *Urban Space* (Krier, 1975) takes place in all the urban areas post 20th century. Rapid construction and organization of spaces in the urban areas, to achieve maximum usage leads to economic oriented developments, thus reducing the spatial quality and values of the fabrics. This applies to both existing and newer developments in the current situation as of 2021 which in turn reduces the sustainability index of the space especially through the 3rd domain i.e., Environment (Space).



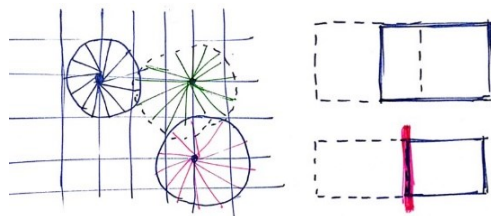
Domains of sustainability

**2.2. Spatial Sustainability**

Spatial sustainability can be referred as the geometric and configurational ordering of space in the city to achieve sustainability of the 3rd domain i.e. Space (Hillier, 2009). Bill Hillier arrived at two parameters that contributes to spatial sustainability –

**Pervasive centrality** – where the function of centrality in cities pervades the urban grid in a more intricate way than has been thought (Hillier, 2009).

**Fuzzy boundaries** – Urban areas get created through spatial differentiation, so maintaining inter-accessibility between areas is important rather than through well-defined boundaries which limit inter-accessibility (Hillier, 2009). Hillier infers that high degree of interaccessibility is necessary for a centre to act as a location for inter-dependent activities.



**Figure 2.** Pervasive centrality, Fuzzy boundaries

### 2.3. Spatial Configurations

In (Hasgül, 2015), the relation between the physical formation of space and the social experience of the human is analysed, and a relation between the patterns of space and culture is studied using space syntax.

The research conveys that initially there is a physical formation of the space – i.e. the origins of spatial order. Next the space is configured by the ordering of relations between people and the space i.e. socially identified groups vs. spatial domains. Addition to this is the structuring of the social activities in the physical environment i.e. Patterns of use and social activities.

## 3. Research Methods

### 3.1. Space Syntax

Space syntax has been used as a quantitative method by Bill Hillier to test sustainability in organic cities. Space syntax is a set of theories and methods for the analysis of spatial configurations of all kinds and at all scales. Hence for further research, some of the fundamental links between spatial layout vs. social, economic and functional aspects are to be established using space syntax. The syntactic parameters such as connectivity, integration, intelligibility and choice contribute to spatial sustainability (Hasgül, 2015).

### 3.2. Spatial Cognition

Parameters which are qualitative in nature are analysed using spatial cognition theories which includes social theory of space, mental operations - perception, attention and memory. Behaviour, culture, geographical setting, economic activities, density and compactness are the factors that has a direct effect on spatial sustainability (Sasanpour, 2017). Spatial cognition method on site is done through cultural mapping, field observations, and interviews.

### 3.3. Identified Parameters

The parameters identified from the literature review and case studies that contribute to spatial sustainability are listed. The syntactic parameters are tested using a software ‘DepthmapX-0.8.0’ developed by Alasdair Turner.

The other parameters like spatial arrangements, configurations, urban patterns, density and compactness, geographical setting, fuzzy boundaries and pervasive centrality can be analyzed through field observations and by using quantitative data. Social Parameters like way of life, behavior of people, culture, economic activities, and interaction levels can be analyzed by talking to the people, understanding their culture and through interviews and field observations.

**Table 2.** Identified parameters

ASPECTS → ↓ METHODOLOGY	SPATIAL PARAMETERS	SOCIAL PARAMETERS	FUNCTIONAL PARAMETERS
SPACE SYNTAX	Integration/ Local integration		
	Intelligibility		Interaccessibility
	Pervasive centrality		Choice
	Fuzzy boundaries		
SPATIAL COGNITION	Geographical setting		
	Urban pattern	Historical Influences	
	Density & Compactness	Cultural drivers	Economic activities
	Spatial configurations	Behavior of people	Density & Compactness

### 3.4. Selection of Primary Investigation Area

The city of Coimbatore in Southern state of Tamil Nadu in India has been going through several transformations due to increased urbanization resulting it to develop as a multinuclear city with 3 fully functioning CBDs. Hence for this study, sample fabrics from the first formed 2 CBDs are tested for spatial sustainability and the results are analyzed to come up with spatially sustainable urban codes for newer developments in the future CBDs of the city. The selected fabrics predominantly include residential and commercial usages and the arrangement of different functions within the fabrics is studied.

#### 3.4.1. About Coimbatore

The settlements in Coimbatore dates back to Sangam period and by 8<sup>th</sup> C.E. the Cholas took over power and built their settlements across the Noyyal River which is a tributary of Cauvery. The Cholas built their Kottai (fort area) and Pettai (market area) on the banks of Periyakulam which then became the first CBD of the modern Coimbatore by 1900s that still continues to be.

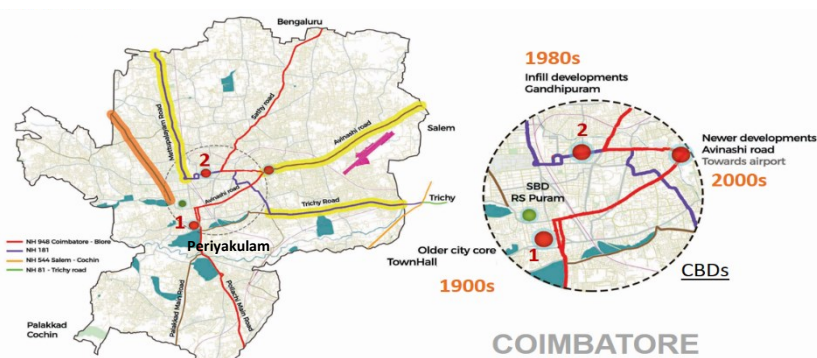


Figure 3. Coimbatore City Limits

By 1960, industrial developments came up and then on, a new CBD has been developing in Gandhipuram to support the above said trade and businesses.

Later in 1972, there was an increase in educational institutions like colleges which required larger land for their infrastructure. Hence these institutions developed across the then formed major roads of the city like Avinashi road. Due to the presence of these institutions and the access to Airport, Avinashi road gained status of the 3<sup>rd</sup> new CBD of the city which was formed after 1980s.

#### 3.4.2. Sample Fabric 1 – Older CBD of Coimbatore (Town Hall)

The existence of Town Hall dates back to the 9<sup>th</sup> C.E when the Cholas ruled Coimbatore and set up their market area on the banks of Periyakulam which is now called as Town Hall. From then until date, the fabric continues to serve as the CBD of Coimbatore with retail and whole sale businesses. The chosen area from the CBD has mainly commercial streets like Oppanakara Street, Raja Street, Big Bazar Street and Vysial Street.

##### Spatial Pattern in Town Hall

Oppanakara Street can be considered as the nerve centre of the fabric which has predominantly commercial buildings of various scales. Once a shopping street with G and G+1 buildings, now the street has expanded vertically and has grown up to G+4, thereby changing the scale of the street. Commercial developments grew on either side of the Oppanakara Street giving rise to equally prominent Secondary Streets - Big Bazar Street and Vysial Street on the west. Raja Street has marked its existence much before the formation of any other streets in the locality and it is also the first formed street in the city as part of trade and business which still functions with the same hustle and bustle it used to possess.



Figure 4. Town Hall - First formed CBD of Coimbatore

### 3.4.3. Sample Fabric 2 – Second Developed CBD of Coimbatore (Gandhipuram)

The second developed CBD of Coimbatore was in Gandhipuram, and it had a contrast in configurations and arrangement as compared to its counterpart. The patterns are much planned with a central substation also known as the ‘power house’ that receives electricity from Pykara power plant and supplies to the Corporation area. Six roads radiate from the power house and the city blocks are arranged horizontally across these radiating roads. Dr. Nanjappa road that goes parallel on the eastern side of the power house can be considered as the nerve centre of Gandhipuram with lots of commercial establishments. Gandhipuram is highly connected and accessible to the rest of the city but the spatial sustainability of the fabric is to be questioned because in the case of its counterpart Town hall, which was once a holistic fabric has now undergone rigorous development pressure and the change has created unsustainable spatial conditions.



Figure 5. Gandhipuram - Second formed CBD of Coimbatore

## 4. Testing of Spatial Parameters

In the following session, all the identified spatial parameters are analysed as to how much of it is contributed by the fabric towards spatial sustainability. Hence a comparative analysis of both the cases is done to understand what are the sustainable patterns and configurations possible in the city of Coimbatore by considering the social, cultural and functional individuality of the city which is exclusive only to Coimbatore.

### 4.1. Geographical Setting and Connectivity

The reason for the settlements or the development of the fabric plays a vital role in establishing the existence of the fabric in the particular setting (Rahbarianyazd, 2017). Factors such as topography of the site, and climatic features help shape a settlement the way it is and to develop sustainable patterns, configurations and arrangements of functions.

#### 4.1.1. Inference

In the case of Town Hall and Gandhipuram, the former had a strong historical reference as to why the settlement is how it is today and the latter's existence is strongly dependent on the accessibility factor. Hence both the fabrics justify its existence.

#### 4.2. Urban Pattern

Urban pattern refers to the way how different functions and elements of the settlement form are distributed and mixed together spatially (Lynch, 1981). The arrangement of blocks and the street networks can be studied under urban patterns of the city and the reasoning for their formation is important in understanding the sustainability of the formed patterns.

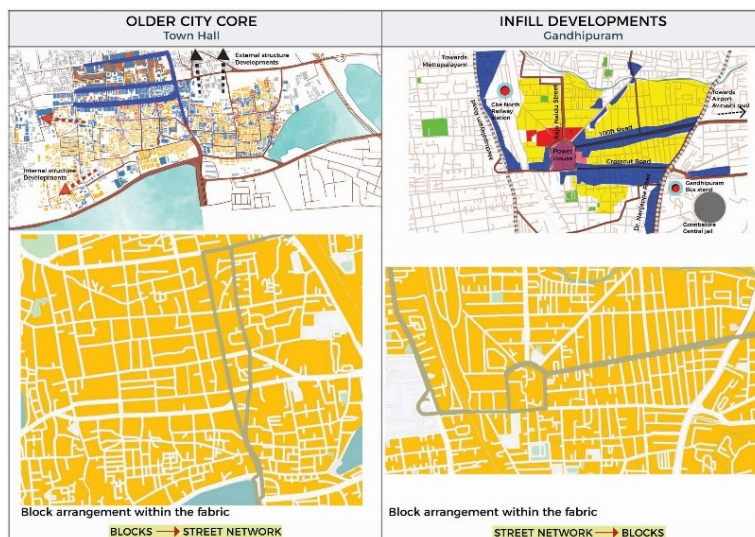


Figure 6. Urban Pattern

##### 4.2.1. Analysis of Town Hall

Town hall was developed in an unplanned manner and hence the settlements came up first followed by the streets and their networks. When the Pettai (market area) of the Cholas came up first, they built their houses and shops together with shared walls and in close proximities. Later as the settlement made its way through time, the streets developed around these shops for connectivity and later the Municipality managed to lay roads based on the existing network. Hence irregular rectangular blocks paved way for irregular street network.

##### 4.2.2. Analysis of Gandhipuram

A much more planned development with roads radiating from the central power house and the blocks are arranged perpendicular to the radiating roads. Since it was a planned fabric the street networks came first and then the blocks contrary to its counterpart fabric of Town Hall.

In this case the commercial shops came up along the Cross cut road, 100 ft road and Dr. Nanjappa road and the perpendicular blocks on the north had spacious residential units and wider streets abducting them providing space for vegetation and pedestrian pavements along the roads. Whereas in the case of Town Hall, the residential units were cramped and had lesser or no setbacks.

##### 4.2.3. Inference

In terms of urban patterns, Gandhipuram is more spatially sustainable because the planned development has left room for future expansion and has considered the inflating population needs thereby creating wider streets and roads.

#### 4.3. Global Integration

Global integration is a syntactic parameter which shows how each street is connected to all others in a whole city in terms of the maximum possible direction change (Nes et al., 2010). It also shows the internal (chosen fabric) to external (urban system or the city) connectivity levels (Omer & Zafrir-Reuven, 2010).

The same can be analysed using the maps generated by DepthmapX-0.8.0. Color value are given to each segment of the road or street to understand their allotted values – red being on the higher side and blue on the lower side. The red lines show the streets with the highest integration values, while the blue ones shows the most segregated ones (Nes et al., 2010).



Figure 7. Global Integration

#### 4.3.1. Analysis of Town Hall

When the software is run for Global integration in Town Hall, the derived map shows that the fabric is connected to nearby fabrics via roads and streets but the connection is not strong. Hence the fabric exists as a part rather than having a harmonious integration with the neighboring fabrics or the city. This in turn reduces the spatial sustainability levels in the fabric because fabrics with higher values of global integration tend to be more spatially sustainable.

#### 4.3.2. Analysis of Gandhipuram

In the case of Gandhipuram the segment lines are mostly yellow or green in color indicating higher global integration levels. The radial roads have higher values (green) and the perpendicular minor roads in between them are next in hierarchy (blue) indicating that these segments of roads are globally integrated with the neighboring fabrics.

#### 4.3.3. Inference

This indicates that the Town Hall to an extent, exists as a part in the urban system and is isolated in the system whereas the newer CBD- Gandhipuram exists as a whole with the rest of the system.

#### 4.3.4. Derived Guideline

Higher global integration values indicate easy access to other places. Hence a fabric should be stitched into the urban system in such a way that it seams in with the system and doesn't exist as a part. For this the global integration levels of any taken fabric should be higher in a city so that the fabric is spatially sustainable.

#### 4.4. Local Integration

Local integration shows how each street is connected to its vicinity in terms of three times direction changes (Nes et al., 2010). I.e. these syntactic values show how each street of a fabric is connected within the fabric amongst other streets.

##### 4.4.1. Analysis of Town Hall

In the older core it is seen that the local integration values for majority of the segments are high which implicates that the segments are interconnected with each other very well. This in turn improves the functionality of the fabric as the function can pervade through the fabric.

##### 4.4.2. Analysis of Gandhipuram

On the contrast, the segments within Gandhipuram exhibits very lower local integration values leading to poor internal structure of the fabric. When a fabric's internal connection is poor, it affects its spatial sustainability.

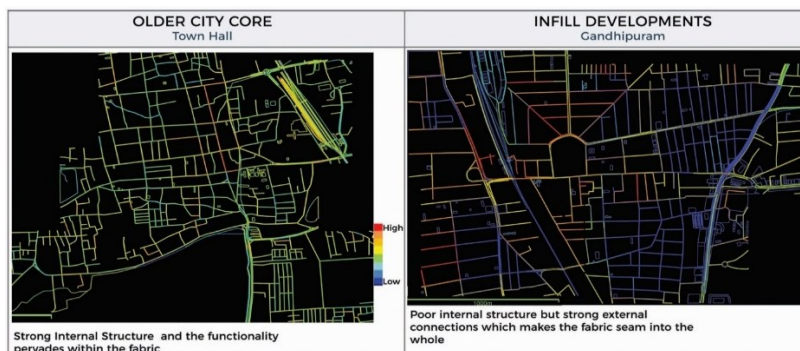


Figure 8. Local Integration



#### 4.4.3. Inference

Poor local integration in Gandhipuram can be the result of arrangement of functions or land use in the fabric because the residential and commercial exists as separate entities whereas in the case of Town hall, the functions and land uses are all mixed up and as a result the local integration within the fabric is high because of the interconnectedness it provides.

#### 4.4.4. Derived Guideline

Higher local integration increases the spatial depths which makes the internal structure of the fabrics within the system stronger.

#### 4.5. Intelligibility

Intelligibility can be defined as the correlation between connectivity and global integration. This correlation demonstrates how clean an urban system is for its users because the degree to which what can be seen and experienced locally in the system allows the large scale system to be learnt without conscious effort (Ugalde et al., 2009).

High Intelligibility indicates a strong correspondence between the distributions of connectivity and global Integration values (Valipour et al., 2017). This means that the degree of connection between individual spaces - the urban space that can be seen and experienced synchronically - provides a good guide to the integration of that space into the system as a whole at the global level (the urban space that cannot be directly seen and experienced). An intelligible system is one in which well-connected spaces also tend to be well-integrated spaces (Omer & Zafrir-Reuven, 2010). For this study the syntactic values for intelligibility are taken at 40 m and 400m radii are compared. Using this information, the following parameters such as the pervasive centrality and fuzzy boundaries can also be studied.

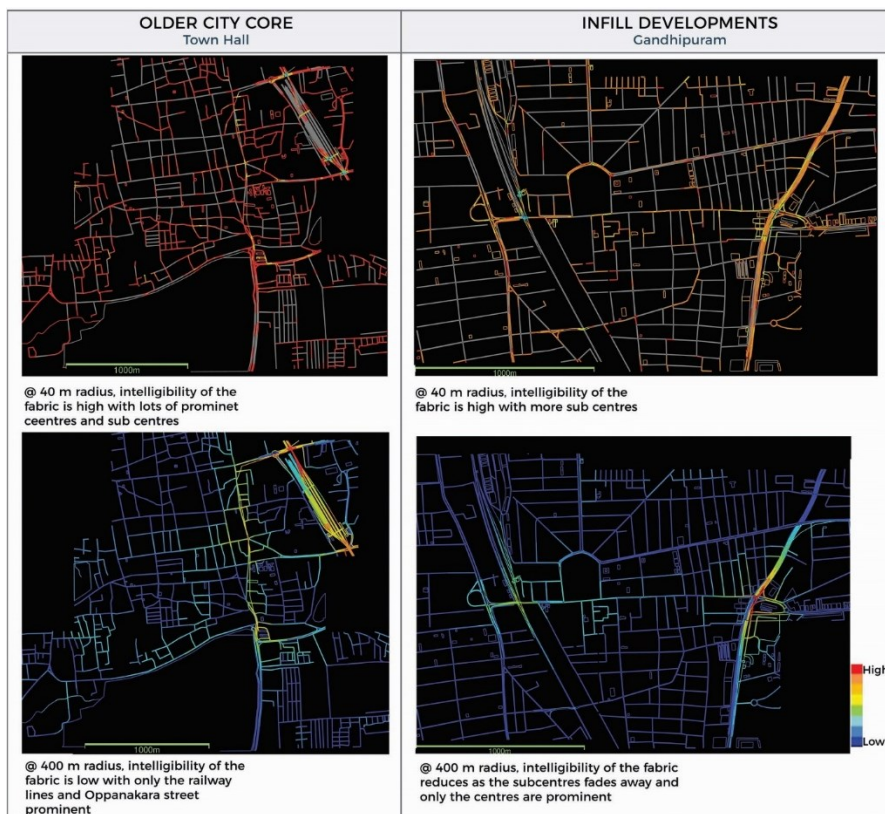


Figure 9. Intelligibility

#### 4.5.1. Analysis of Town Hall

When the simulation for 40m radius is run for Town Hall, it is found that lots of prominent centres and sub centres appear (red concentrations in the intelligibility map). These centres are the results of concentration of commercial activities in the fabric. Hence the intelligibility values seems to be higher which makes the fabric locally functioning well and when it is seen as part of the larger urban system it does a positive role in getting integrated into the system seamlessly. But when the same fabric is simulated for 400m radius the prominent centres or sub centres disappear except for the railway terminal and the Oppanakara Street.

#### 4.5.2. Analysis of Gandhipuram

At 40m radius the intelligibility of the fabric is high with prominent centres along the Power House, Cross cut road, Mettupalayam Road and Dr. Nanjappa road and at 400m radius all the sub centres fade away and only the centres are prominent. Hence this reveals that the fabric has spaces which are highly connected internally and externally but the level of integration within the urban system i.e. at 400m radius is comparatively poorer.

#### 4.5.3. Inference

In both the fabrics the intelligibility levels are higher at smaller radii, but as the radii increases i.e. as the urban system expands, the intelligibility values are lower indicating lesser integration of the fabrics into the urban system.

#### 4.5.4. Derived Guideline

The intelligibility values should be higher so that the fabric is spatially sustainable. This also helps us to make decisions in the case of newer developments. For example, activities are to be placed in highly integrated streets rather than the primary or the major roads otherwise they become segregated from the system.

#### 4.6. Pervasive Centrality

Pervasive centrality suggests that the function of centrality in cities pervades the urban grid in a more intricate way than that has been thought, and that multi scale centrality should be seen as a pervasive function in cities, with clear spatial correlations, and not simply as a hierarchy of locations (Hillier, 2009).

It means that in an urban system or fabric at any given point, the user should always be closer to a small local centre and not far from much larger one. This character of the urban fabric increases the spatial sustainability levels in the fabrics.

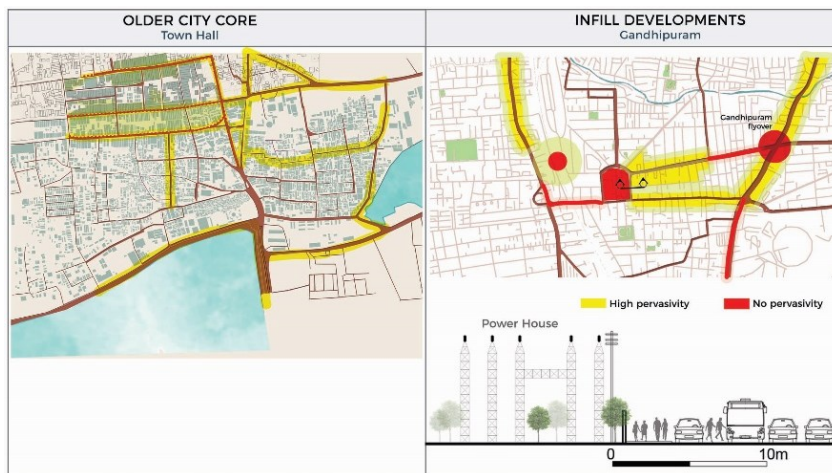


Figure 10. Pervasive centrality

##### 4.6.1. Analysis of Town Hall

In the above map, the areas marked in yellow contributes to pervasive centrality in the fabric. For example the Oppanakara Street, Raja Street, Vysial Street and Big Bazar Street have high functionality in terms of commercial businesses. This function of these streets pervade into the smaller adjacent and perpendicular streets converting them into commercial streets of lower orders. Hence an urban user at any point in this area feels closer to a small local centre (any major commercial node in this case) and is at any point not too far from the higher order commercial streets.

##### 4.6.2. Analysis of Gandhipuram

In the case of Gandhipuram, the character of pervasive centrality is seen along Dr. Nanjappa road and it pervades to some segments of Cross cut road, 100ft Road and Mettupalayam road. But the arrangement of these roads creates huge blocks between the roads therefore the nature of pervasiveness reduces in this fabric. Through field observation it is also noticed that there is an isolation amongst the residential and commercial functions which proves the pervasive theory.

##### 4.6.3. Inference

Land uses have a direct effect on the functioning of the fabric and hence proper land uses must be allotted considering the land use of the adjacent site. If not, this can lead to unsustainable spatial conditions due to spatial isolation of the functions which in turn leads to reduced pervasive centrality of a place.

#### 4.7. Fuzzy Boundaries

The concept of fuzzy boundaries conveys that urban areas are created through spatial differentiation, so maintaining inter-accessibility between areas, rather than through well-defined boundaries which limit inter-accessibility is important in achieving spatial sustainability (Hillier, 2009). Fuzzy boundaries hence can be avoided by increasing the pervasive centrality of a space.

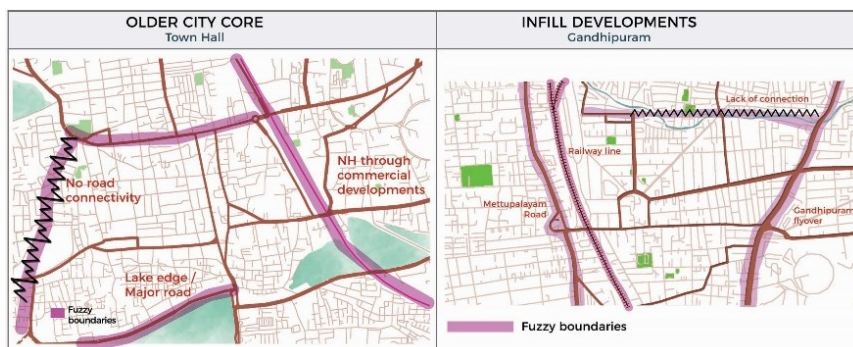


Figure 11. Fuzzy Boundaries

##### 4.7.1. Analysis of Town Hall

In the case of Town hall, the lake on the south and railway track on the east of the fabrics act as fuzzy boundaries because they define a boundary for the fabric which in turn can make the fabric exist as a part in the urban system. Also no connectedness towards the east due to absence of roads can also act as a fuzzy boundary because accessibility is denied to that particular area or absence of function in that zone reduces the frequency of it being interacted by the rest of the fabric.

##### 4.7.2. Analysis of Gandhipuram

In Gandhipuram, the Mettupalayam road on the west which is also a primary road stops the functionality of Gandhipuram to abruptly stop within itself. Within the fabric, the Power house in the centre stands as a secluded function with its surrounding hence reducing the interconnectedness within the fabric. Also there is a lack of prime connection towards the North therefore the CBD abruptly stops its growth or pervasiveness towards the North. On the contrary, the fabric is pervasive in its function towards the East and it is taken over by Dr. Nanjappa road which increases the pervasivity further more.

##### 4.7.3. Inference

Hence fuzzy boundaries can create a lack of interconnectedness between spaces within the fabric and also can create it with a fabric and the rest of the urban system. So when adding any increment into the urban system care should be taken to see that the increment doesn't turn into a fuzzy boundary for the nearby fabrics rather should act as a catalyst to increase the pervasiveness.

##### 4.7.4. Derived Guideline

Interaccessibility between areas to be promoted rather than well-defined boundaries. This can be explained through certain techniques like Grid intensification which will be explained in the following chapter.

#### 4.8. Spatial Configurations

Spatial configuration refers to the spatial pattern of patches in a landscape by taking into consideration the patch size, density, shape, connectivity and fractal dimensions (Brown, 1997). They are highly dependent upon the physical formation of the space and it is studied to understand the social logic of a settlement (Nikoofam & Mobaraki, 2017). Spatial configurations deals with the structuring of social activities in the physical environment and the spatial usage (Nia & Suleiman, 2018). The morphology derived from the usage of space includes size, shape and arrangements of blocks and spaces within the fabrics. Spatial configurations can be the resultant of the morphological evolution of the spaces and the urban players within the fabric plays a major role in shaping it.

##### 4.8.1 Patterns of space

###### Analysis of Town Hall

The arrangement of space prevailing in this CBD is a result of how the people had used the spaces before. This fabric being one of the first settlements in the city, the people arranged their shops together with shared walls rather than having enough setbacks. They chose elongated rectangular shops placed vertical to the streets (case of Big Bazar Street) with shared walls so that majority of the shops gets the frontage. Hence the shop sizes were ideally (2m x 6m) and the shop owners resided in the rear part of the shop. This resulted in majority of the street fronts having

commercial land uses and following a mixed use pattern with no separate residential areas. So when more developments came up in this CBD, need of residential areas increased but lesser space was available leading to cramped organization of residential colonies with slum like environments. The spaces were not adequate for the growing families and hence majority of their activities spilled out into the abducting alleys and the existing housing buildings were growing horizontally and even vertically. But there was an increased bond between the communities and the arrangement of spaces provided room for high interaction levels.

**Present Condition:** Now the condition is that in Town Hall, there is no more room for further developments whereas the function of the CBD is still fresh and is growing. But the usage and organization of spaces by the people based on their culture and needs could be identified from the study. Hence while planning a newer development the same organizational levels can be used for arrangement of spaces within the fabric.

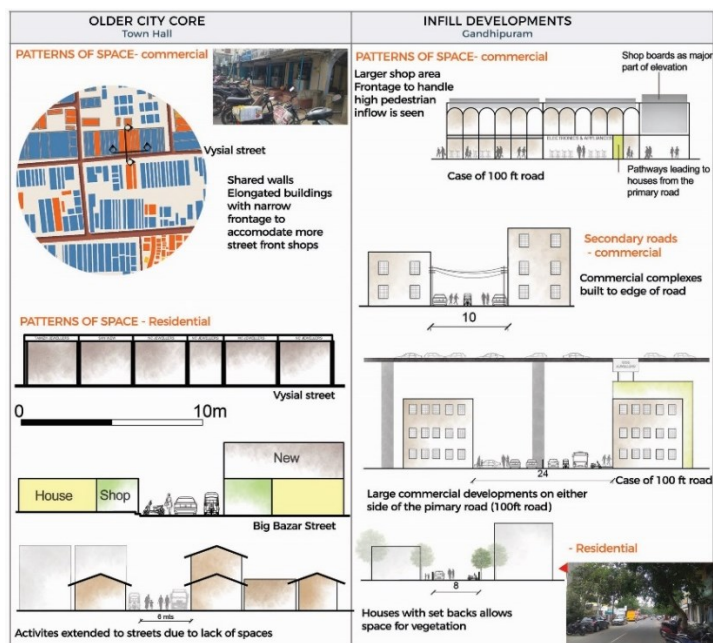


Figure 12. Patterns of space

### Analysis of Gandhipuram

Gandhipuram being a much planned area has larger area for their shops with good frontages to handle high pedestrian inflow. Most of the commercial shops were present on the primary roads of the fabric and the remaining space was filled up by the residential units. In case of secondary roads, the commercial shops are built to edge of the street leaving no set backs or buffer zones, whereas in the case of residential units in the secondary roads, the plot sizes are much bigger and hence there is enough setbacks as per byelaws and also ample buffer space between the houses and the street edges. The buffer space in the front are usually covered with trees and plants providing a quality for the streets and as a result these streets are walkable. The size of the commercial establishments are bigger in the primary roads (e.g. the ones in Cross cut road) and there is a scope for expansion to withstand the future growth.

### Inference

It is to be questioned if the spaces are configured according to patterns of culture or does the configured spaces start to define our cultural living patterns. Hence while planning for a newer development room for expansion is to be provided so that at any given point in future, the spaces remain sustainable thereby providing quality spaces to its inmates.

### 4.8.2. Arrangement of space

#### Analysis of Town Hall

Rearrangement of spaces are presently taking place in this fabric because the previous needs and functions are changing. Also the increasing population and the increasing need of commercial and residential buildings in this fabric has led to division of the buildings and also adaptive reuse of the old unused buildings.

As the age of this fabric is really old, many of the buildings have crossed their lifespan limits and are either in dilapidated conditions or in unusable state. Some buildings can undergo adaptive reuse whereas some buildings had to be torn down to create better buildings for satisfying the needs of the fabric.

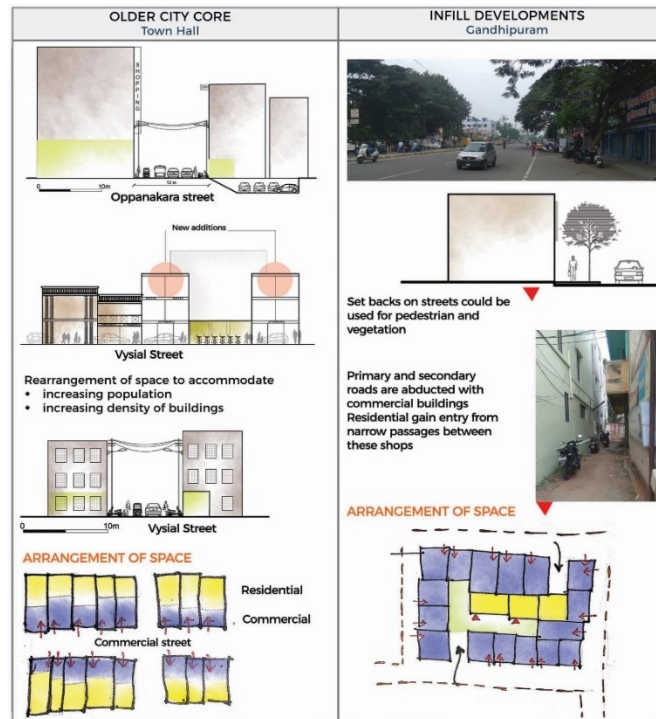


Figure 13. Arrangement of space

### Analysis of Gandhipuram

In Gandhipuram, primary and secondary roads are abutted with commercial buildings and the residential units gain entry from narrow passages in between these shops. But these kind of housings are also spacious enough with adequate setbacks.

### Inference

The spatial configurations of a fabric can be formed due to various reasons. They can be the result of culture and the predominant functions of the space. Similarly, these configurations are also affected by all the decisions the planners and urban designers take. Hence care should be provided at the planning level itself to arrange the land uses, functions and spaces in a fabric in such a way that the spaces and the fabric will be spatially sustainable.

### 5. Coding of Fabrics

By studying the fabrics through the lens of various parameters which are required for a space to be sustainable, a set of codes has been derived, which can be followed for the newer developments of the same city. The limitation is that these codes can be used only for the particular fabric type that has been studied (CBD in this case).

Listed below are the derived codes that can be used to develop a newer CBD (case of the 3<sup>rd</sup> developing CBD – Avinashi Road) in the city of Coimbatore.

#### 5.1. CODE 1 – Geographical and historical setting

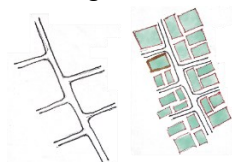
A newly developing fabric should have a geographic or strategic significance without which the fabric will fail to justify its function in the urban system.

Hence the spatial spirit of the city which enabled the old city to function and inspires the modern city to adapt itself with the historic core has to be maintained.

*In the case of new CBDs in Coimbatore, considering Avinashi Road as a case, the strategic location of the area, that is its accessibility to airport and other districts like Salem, Palakkad, Trichy and Bangalore makes it an apt location for the newer CBD. Hence this significance should always be taken care off by developing the fabric without compromising the importance of its emergence.*

#### 5.2. CODE 2 – Urban Pattern

Planning of the street network and then placing the blocks creates a more sustainable spatial network.



When a new CBD is to be planned on a Greenfield area, it is important to decide the connecting networks first and then place the blocks because the analysis shows that doing so increases the spatial sustainability of the fabric.

### 5.3. CODE 3 – To achieve Intelligibility

A fabric should be stitched into the urban system in such a way that it seems in with the system and doesn't exist as a part. Every increment in the city level should be part of a larger whole and should create smaller wholes in itself. These smaller wholes in turn makes the internal structure of the system stronger.

Any increment to the urban system should

- Contribute to a harmonious growth
- Create more sub centres
- Be part of the whole and should not exist as a part
- Should not fracture the urban system

When a new CBD is planned for the city of Coimbatore the above code must be followed so that each increment to the fabric is checked for its contribution into the system and the increments shouldn't exist as a part but should merge into the system. This leads to an intelligible fabric which is high in spatial sustainability

### 5.4. CODE 4 – Global and local integration

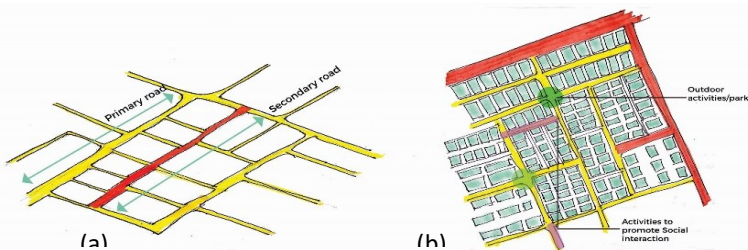
Activities to be placed in highly integrated streets otherwise they become segregated from the system. Residential neighbourhoods contribute to the poor internal structure of the fabric, hence inducing outdoor activities, social interaction and playing can increase the local integration.

#### 5.4.1. Strategies

(a) Placing of economy generators or commercial zones in highly integrated roads rather than the primary roads will help to accentuate the effect of the economy or activity generators rather than placing them based on the hierarchical importance of the road.

(b) Increasing the local integration values of residential neighborhoods by inducing activities.

In the case of residential areas the local integration values were found very low mainly due to the reason that they get secluded in the fabric and no activity happens in that area. This makes residential areas to get separated from the whole and such areas exists in isolation. So, inducing activities for the neighborhoods, and provision of parks and play grounds makes the area more active.



### 5.5. CODE 5 – Pervasive Centrality

The function of the centrality should pervade through the urban grid. Any increment into the urban grid should be tested for pervasive centrality to check if the increment would fracture the whole.

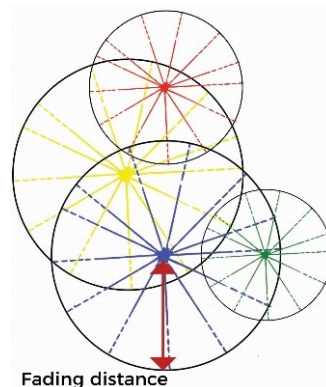


Figure 14. Pervasive centrality

### 5.5.1. Strategies - Formation of centre

Smaller centres develop in an urban fabric when they are at the focus of a local intensified grid and when they are at an intersection. Hence new centres to be formed within the fading distance of the previous centre. This can be achieved by adding economic or development magnets which will act as a location for interdependent activities. Here fading distance can be defined as the radius up to which the effect of a centre pervades. Hence before the effect of the centre stops pervading, another new centre should be installed so that no negative or isolated spaces occur in the system.

### 5.6. CODE 6 – Reduce fuzzy boundaries

The inter accessibility between the areas can lead to a spatially sustainable fabric. For an area to have its own character or character district, isolation of the area is not required. An identity or uniqueness can be given for an urban fabric through spatial differentiation rather than through well-defined boundaries.

#### 5.6.1. Strategies

##### Grid Intensification

Reducing the scale of the grid can increase interaccessibility and can also spark the development of a centre. This can be achieved by reducing the size of the blocks.

So when a centre is formed within the fabric it doesn't get dissolved into just one block but pervades between many blocks. Only then can the function of the centre reach more area and doesn't restrict to just one block.

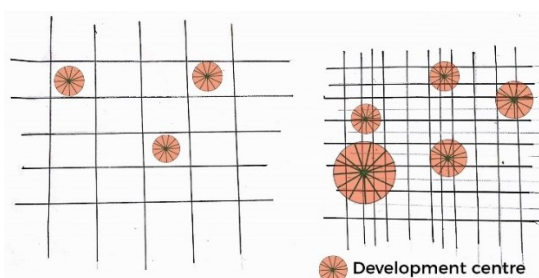


Figure 15. Grid Intensification

Hence all the districts within the fabric will be inter accessible and this same feature should be followed while planning to achieve interconnection between fabrics. Hence through this method of grid intensification, spatial sustainability is achieved.

*Reduced block sizes to be planned for the newer CBD in Coimbatore so that the pervasiveness of the centre is more.*

### 5.7. CODE 7 - Social and functional aspects

- Provision for expansion of spaces horizontally and vertically
- Provision for vegetation and pedestrian movement to be included in the planning stage of newer fabrics
- Spaces are to be configured in a fabric considering the cultural living patterns of the place.

*In the newer CBD scope for future development and expansion should be provided so that the fabric doesn't get congested as in the case of other 2 CBDs. The culture and way of life of the people of Coimbatore are to be considered while designing a newer fabric for them.*

## 6. Conclusion

The syntactic, spatial and social parameters were tested on 2 fabrics taken from the older and newer CBD of Coimbatore city and it was found that some of the parameters that would contribute to spatial sustainability in a fabric is seen at the existing fabrics. They were further analyzed to check for the indicators that would lead to spatial sustainability in Coimbatore, so that the same can be applied to the newly developing CBDs in Coimbatore. Some of the parameters tested negative in the case of Coimbatore but its positive aspect should be followed in the case of newer developments.

The framework followed can be used to derive at what would contribute to spatial sustainability in a city especially in the case of newer developments. The codes derived from the framework is unique for the selected city because the social and functional aspects of each city varies from each other resulting in unique spatial ordering and configurations for the city.

The primary study of the fabrics compared the parameters under the spatial and social aspects identified from the literature study. Each parameter (example global integration) was looked in detail for both the fabrics and an analysis was made on if the parameter in this case leads to spatial sustainability. If the parameter was tested positive i.e. there is good global integration in the chosen fabrics then what were the reasons that lead to good global integration

is to be analysed and converted to codes that can be used for new CBDs. Similarly if the local integration is tested to be poor in the selected fabrics, then what can be done to improve local integration is to be analysed and coded.

Since two sample fabrics had been studied, a comparative derivation can be made from the same. The social parameters were studied to analyse the pattern of living and usage of spaces by the people of Coimbatore and to anticipate what would be the future of the city in terms of social relations. By studying this, the same can be considered while designing new fabrics for the city. This helps to hold on to the spatial spirit of the city which helped the old fabrics to function successfully and to rectify the possible spatial errors in the case of newer development by developing spatially sustainable fabrics. The obtained results has been coded which can be used while designing any new increment in the city (case of CBDs).

The global integration levels in Town Hall were poor but high in Gandhipuram and through literature study it is understood that the higher global integration values lead to spatially sustainable fabrics. So the factors leading global integration in the case of Gandhipuram is studied in detail and the inference is transformed into codes.

Similarly, the social parameters like cultural drivers, behaviour of people, economic livelihood, way of life etc. are analysed so that spatial, cultural and economic needs of the people of the city can be understood so that people friendly designs can be brought up in the future.

The future scope is that in the case of Coimbatore, the derived codes can be used to design the newer developing CBDs of the city and more spatially sustainable codes can be developed for varying types of fabrics in the city. In the wider arena, the framework can be used to develop generic codes which can be followed to derive spatial sustainability in other cities.

The functional aspects also have a direct relation as to how sustainable the space can be but was less explored in this research. The functional aspects can be unique for each fabrics in a city but their livelihood, way of living etc. can be studied to derive what is necessary to be followed in the future developments.

Hence the research has been completed by using spatial sustainability as a contextual tool to code emerging urban patterns of cities. The output being spatial codes that can be followed for the development of fabrics in the emerging CBDs of Coimbatore and a framework on how to derive spatial codes for producing spatially sustainable fabrics in cities.

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#### **Conflict of Interests**

The authors declare no conflict of interest.

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