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The fragile/resilience city represents a topic that collects itself all the issues related to the urban risks and referred to the different impacts that an urban system has to face with. Studies useful to improve the urban conditions of resilience are particularly welcome. Main topics to consider could be issues of water, soil, energy, etc..

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THE RESILIENCE CITY / THE FRAGILE CITY. METHODS, TOOLS AND BEST PRACTICES.

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Laboratory of Land Use Mobility and Environment
DICEA - Department of Civil, Architectural and Environmental Engineering
University of Naples "Federico II"
Piazzale Tecchio, 80
80125 Naples
web: www.tema.unina.it
e-mail: redazione.tema@unina.it

Cover Image by Maria Rosa Tremiterra of Am Sandtorkai, one of the main streets of HafenCity, a new district located on the waterfront of the City of Hamburg. HafenCity can be considered "a city in the city" and one of the most resilient urban areas in the world to the flooding events thanks to its urban redevelopment strategy.

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The Resilience City/The Fragile City.
Methods, tools and best practices.

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- new consideration of the planning standards, blue and green networks as a way to mitigate urban risks and increase city resilience;
- the territorial risks and fragilities related to mobility of people, goods, knowledge, etc.;
- the housing issue and the need of urban regeneration of the built heritage;
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ANALYSING THE SPATIAL STRUCTURE OF THE STREET NETWORK TO UNDERSTAND THE MOBILITY PATTERN AND LANDUSE- A CASE OF AN INDIAN CITY - MYSORE

HARCHARAN PAPPU

Assistant Professor, Sri Venkateshwara College of Architecture, Hyderabad, India.
e-mail: harcharanreddy@gmail.com

ABSTRACT

Settlements grow and develop their unique spatial structure, subject to the factors (cultural, political, religious, etc.) influencing them. In course of time, the spatial structure starts influencing different aspects in the settlement like mobility, land-use, crime pattern, land values, etc. To understand the influences of spatial structure in a rational way, a scientific approach is required. So, space syntax techniques are chosen as the principal theoretical postulates for analysis, because of its quantitative and scientific approach. In this paper, an attempt has been made to analyse the spatial structure of the street network in an Indian city – Mysore – by a comprehensive application of space syntax techniques. The study has been conducted by breaking down the structure into components and by analysing the use of different measures, like integration and choice, using Depthmap software (Turner, 2012). The analysis is then related to the existing mobility pattern and land-use to construe how the spatial structure influences the mobility pattern and land-use.

KEYWORDS:
Spatial structure; Built environment; Urban street network; Mobility pattern; Space syntax; Patterns of movement.

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以了解出行方式和土地使用为目的的街道网络空间结构分析

研究对象：印度城市迈索尔

HARCHARAN PAPPU

Assistant Professor, Sri Venkateshwara College of Architecture, Hyderabad, India.
e-mail: harcharanreddy@gmail.com

摘要

人类定居点在逐渐增长的过程中，发展出其独特的空间结构，受到各种影响因素的制约。随之，空间结构开始对定居点的各种功能——如出行、土地使用、空间扩展等——产生影响。要合理了解这种空间结构及其影响的动态变化，有必要开展科学分析。因此，选用了具有定量科学方法的空间型构法则，作为分析的主要原理。本文试图通过综合性应用一种空间型构技术，来分析印度城市迈索尔的街道网络的空间结构。本研究中，作为研究对象的结构被拆解为多个部件，使用 软件通过不同方法——如整合与选择——实现分析。随后，将分析结果与现有的出行方式和土地使用相关联，以解释空间结构如何影响出行方式和土地使用。

关键词：
空间结构；建成环境；城市街道网络；出行方式；空间型构法则；运动方式。

1 INTRODUCTION

Built environments are human-made space in which people live, work, and recreate on a day-to-day basis. They are purely the creations of humans, subject to the existing factors and influences at any given time. Thus, collectively, the products and processes of human creation are called 'built environments' (McClure, Bartuska & Bartuska, 2007). Mobility spaces in any built environment can be visualised in two parts: (1) The space in and around the building where movement is associated with that building. Here, mobility has no effect on its surrounding areas; (2) The pathways that are connecting different buildings, which are called 'streets', form the basis for mobility from one building to another (City Form Lab, 2012). These individual streets are then connected to one another to form a network called 'street network' of the built environment. This street network forms the base in deciding the mobility pattern of a settlement. Movement is the essence of any settlement, and it creates the dense patterns of human contact (Tim Stonor, 2011). Patterns of movement and space use are fundamentally influenced by the configuration of space and by the location of activity generators and attractors (Space Syntax, 2011), and are also…shaped by the geometry of the street network, which, in turn, shapes the patterns of land-use. Patterns of crime and of land value are similarly affected (Tim Stonor, 2009a). So, there is a need to understand the inherent and composite relationships between 'street network' and 'pattern of movement'. Historic cities organise themselves (by) mixing land-uses in a natural way that people understand intuitively (Tim Stonor, 2010). Mysore is one of such cities which have physical, cultural, social, political and religious factors influencing the spatial structure of the settlement.

According to Mysore Urban Development Authority, Mysore is the second largest city in the State of Karnataka, India, with a population of more than 8 million, as per the 2011 census (MUDA, 2016a). It was the State capital and headquarters of the Princely State of Mysore (1399-1950). The city, built at the foot of the Chamundi Hill, boasts of natural and built heritage. The city's focal point for its punctilious planning and proportionate axis is the Ambavilas Palace which is the most magnificent and imposing building in Mysore. The well-defined central axis and long boulevards radiating from it are one of the finest examples of meticulous planning of those days (MUDA, 2016a).

Lack of scientific study of the urban street network creates a huge gap in understanding the relationship between form-mobility-landuse, and their impact on patterns of movement, land-use, land values, crime pattern, safety and spatial expansion. Streets with high mobility create points of land-use attractions since they attract more mobility and add more traffic to the existing ones, thereby generating a variety of problems related to congestion and mobility. Generally, problems arise with streets of lesser width attracting greater volumes of movement. In order to accommodate high volumes of mobility, these streets need to be widened; however, widening of the narrow streets may not be the solution in every case. In the case of fully-developed urban precincts/areas, road widening may not be a feasible solution because of physical, economic, political or historical constraints. So, here, there is the need to explore alternative solutions like flyovers or underpasses, etc., which are again major issues to consider. But, in newly-developing or partially-grown urban areas, anticipating high mobility on certain streets and, consequently, widening them and developing the related infrastructure, like parking facilities, etc., to meet future needs, will genuinely help in solving the problems arising from greater mobility. Restructuring the street network with necessary connectivity or detachments of streets might be a solution to change the preference for certain routes, but this has its own problems (Parthasarathi, 2014).

'Space syntax has the ability in capturing the trends of vehicular travel demands merely by analysing roadway accessibility embedded in urban morphology' (Penn et al., 1998; Karimi and Mohamed, 2003; Dawson, 2003, and many others). Research shows that 60-80% of the movement flows are due to the structure of the network, measured by spatial accessibility (Tim Stonor, 2014). Human movement was spatially guided by

geometrical and topological rather than metric factors (Hillier & lida, 2005). Lower movement-sensitive land-uses locate around the corner, higher movement-sensitive land-uses locate on movement-rich streets (Hillier & Vaughan ,2007). As cities evolve, land-uses exploit spatial accessibility (Tim Stonor, 2009b). Streets with high choice value will tend to attract higher mobility than the streets with less choice value, irrespective of the width of the road. This is due to the syntactical position of streets in the street network.

2 STUDY AREA

The study area shown in Figure 1 (MUDA, 2016b) includes Mysore city – an area of about 150 sq km. It includes the old city and the new neighbourhood extensions. To understand the evolution of the city in a better way, the spatial structure of Mysore city has been studied by collecting maps of the city as it was in 1865 (Karnataka Archives, 1865), 1897 (Rice. & B. Lewis, 1897), 1930 (Parsons & Constance, 1930) and 1976 (MUDA, 2016a).

Fig. 1: Study Area

2.1 GROWTH OF MYSORE CITY FROM 1865 TO 2016

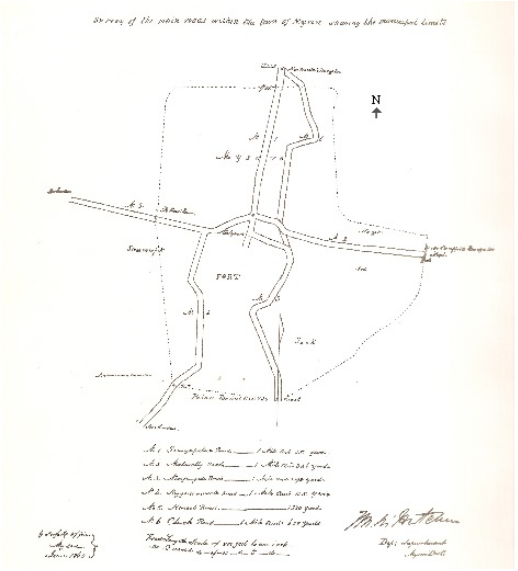


Fig. 2: Mysore City Map in 1865

Fig. 3: Mysore City Map in 1897

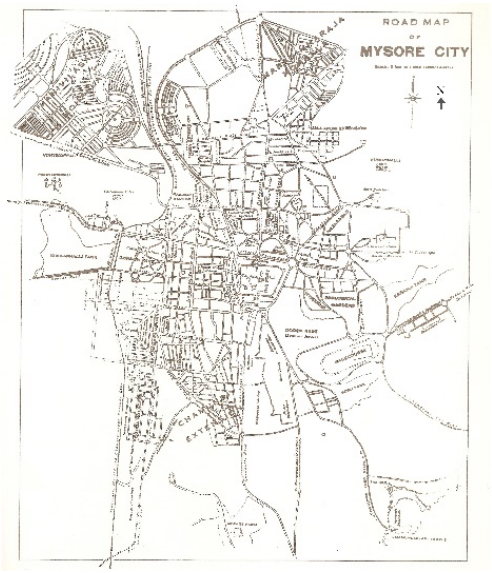


Fig. 4: Mysore City Map in 1930

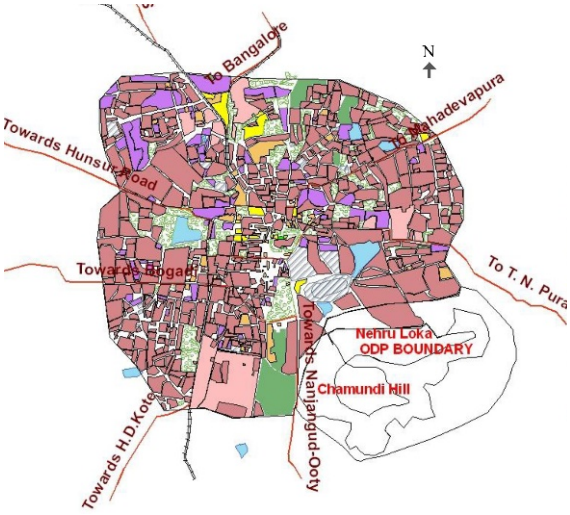


Fig. 5: Mysore Land-use Map in 1976

3 METHODOLOGY

The adopted methodology includes:

- To calculate the integration and choice graphs of the urban street network, using space syntax techniques;
- To investigate and analyse these graphs with the existing mobility and land-use;
- To determine the inter-relationship between the structure of the street network, mobility and land-use.

Space syntax is a set of techniques for analysing spatial layouts and human activity patterns in urban areas. It is also a set of theories linking space and society. Space syntax addresses where the people are, how they move, how they adapt, how they develop, and how they talk about it. (UCL Space Syntax,2017). It helps in explaining the relationship between the built environment and human behaviour. Depthmap is a software platform originally developed by Alasdair Turner at University College London (UCL) to perform a set of spatial network analyses designed to understand the social processes within the built environment (Space Syntax Network, 2017). Depthmap can demonstrate the spatial configuration of the street network in the vocabulary of Graphs and Data which makes it easy in interpreting the street network.

The integration and choice graphs of the urban street network of Mysore city are calculated using Space Syntax techniques in Depthmap software. Integration is a normalised measure of distance from any space of origin to all others in a system. In general, it calculates how close the origin space is to all other spaces, and can be seen as the measure of relative asymmetry (Hillier, B. & Hanson, J., 1984).

Choice measures how likely an axial line or a street segment it is to be passed through on all shortest routes from all spaces to all other spaces in the entire system or within a predetermined distance (radius) from each segment (Hillier et al.,1987). The integration and choice graphs generated are then investigated and analysed with the existing mobility and land-use. This helps in understanding the impact of street network on mobility pattern and land-use in a rational way. With the empirical study carried out, the inter-relationship between the structure of the street network, mobility and land-use can be established.

4 RESULTS

Integration and Choice Graphs of Mysore city from 1865 to 2016.

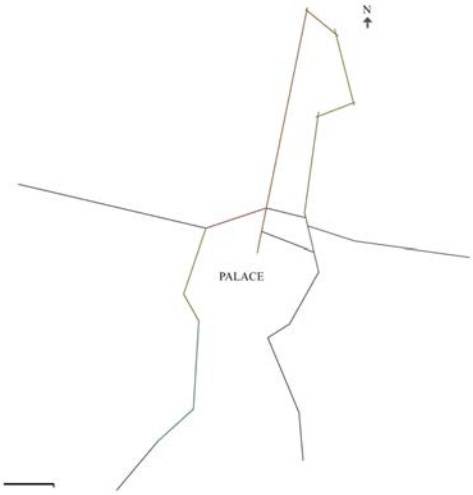


Fig. 6a: Integration - 1865

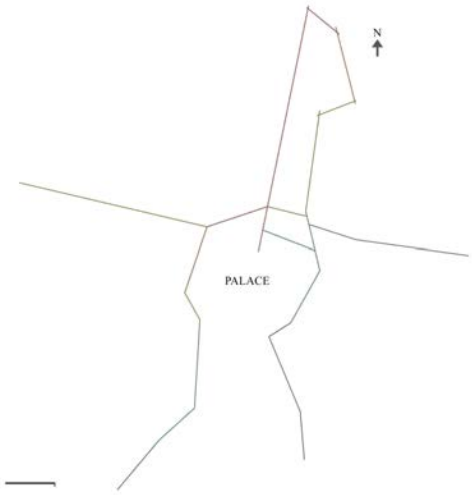


Fig. 6b: Choice - 1865

Fig.6a and Fig.6b show the Integration and Choice Graphs of Mysore City during 1865. The settlement started around the palace. Roads spread out in all four directions from the palace and they formed the initial base for the street network of the city.

Fig. 7a: Integration - 1897

Fig. 7b: Choice – 1897

Because of the Chamundi Hill on the south-east side, the city started growing towards the north and the west. Many public buildings, agraharas, and mohallas were constructed in the northern and western sides of the palace; so, roads leading towards these directions gained importance because of high choice and strong integration values (Fig.7a and Fig.7b).

Fig. 8a: Integration - 1930

Fig. 8b: Choice – 1930

Since the city is landlocked on the south-eastern side, it started growing towards the northern side with new extension layouts, but no such expansion is seen towards the southern or western sides (Fig.8a and Fig.8b).

Fig. 9a: Integration – 1976

Fig. 9b: Choice – 1976

Distinguished precincts were apparent by the streets with high integration to low integration value. The adjacent precinct towards the north of the palace has high integration value (Fig.9a). Hence, this precinct became the centre for many commercial and retail activities of the city, leading to formation of the Central Business District (CBD) of the city. Roads connecting the different precincts gained high choice value (Fig.9b) and gave the basis for the future direction of growth.

Fig. 10a: Integration Graph of Mysore City in 2016

Fig. 10b: Choice Graph of Mysore City in 2016

In 2016, the precinct located towards the north of the palace (which formed the base for the CBD) lost its high integration value as the city expanded (Fig.10a). So, the CBD area is not the most integrated area in the city. It seems that the integration power of the CBD area had slowly shifted towards the north-west side of the palace. The area is named as Centre C1. It includes the neighbourhoods of Vanivilas, Jaylakshmipuram, and Gokulam 2nd Stage area (Fig.10a and Fig.10b).

5 DISCUSSIONS

5.1 CBD AREA

The city started growing from this place. During the 1970s, the CBD area was the most integrated part of the city, but by 2016, the average integration value of the streets in the CBD had gone down (Fig.10a). However, it still retained its commercial land-use (Fig.11c) because of the previously established activities and the mobility pattern. 80% of the commercial land-use in the CBD area concentrated mainly on a few roads (Fig.11c and Tab.2).

The level of relative integration power percentage to that of the city can be calculated in the following way:

$$\text{Percentage of Relative Integration Power of CBD} = \frac{Average\ Integration\ of\ CBD}{Average\ Integration\ of\ Entire\ City}\ x\ 100 \qquad [1]$$

The average integration power of the CBD with that of the city was 14.8% stronger than the city in 1976, while in 2016, it was only 4.8% stronger (Tab. 1). This is because, as the city expanded, the structure of the street network changed; and hence, the lower integration power.

YEAR	AVERAGE INTEGRATION VALUE IN 2016	AVERAGE INTEGRATION VALUE IN 1976
CBD Area	4449	2596
Centre 1	5436	2288
Entire City	4244	2262

Tab.1: Integration values in 1976 and 2016

Much of the interior parts of the CBD area still have residential land-use (Fig.11c). This is because the interior roads are not much integrated with the street network, (Fig.11a) which makes accessibility difficult. The major commercial activities are happening on roads listed in Table 2 which have high integration and choice value. Apart from the few public and semi-public land-uses, 80% of the land abutting these roads have commercial land-use.

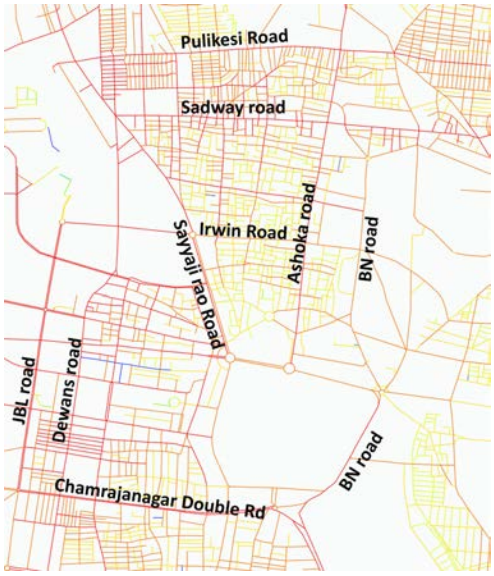


Fig. 11a: CBD Integration Graph

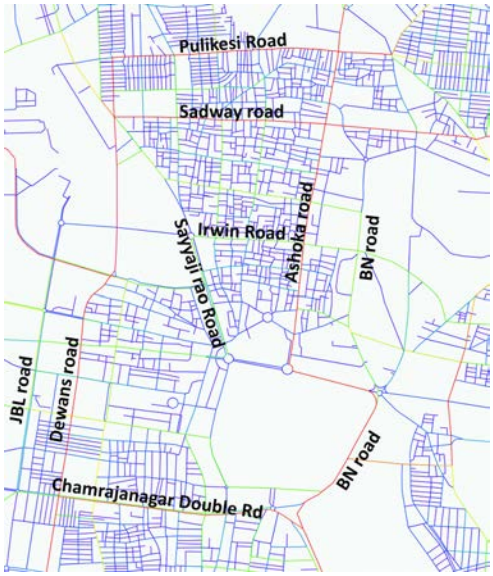


Fig. 11b: CBD Choice Graph

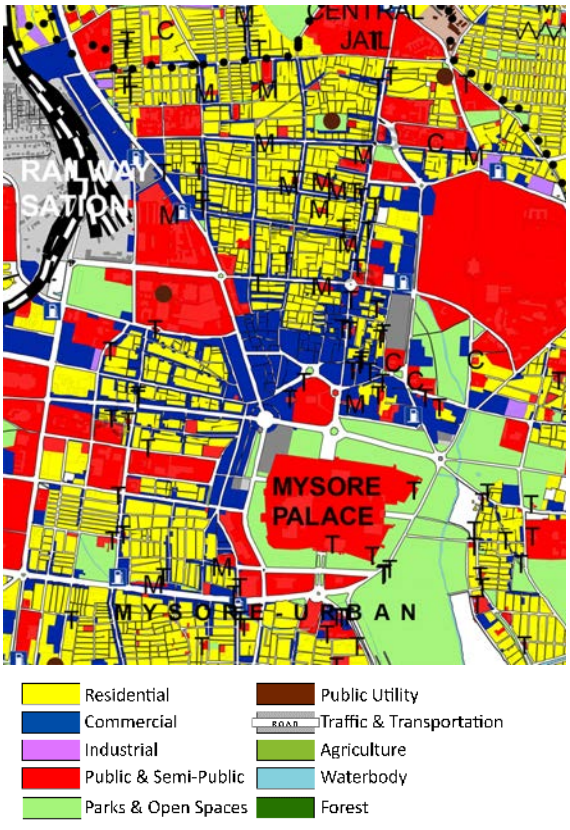


Fig. 11c: CBD Land-use Map (MUDA, 2016c)

Fig. 11d: CBD Circulation Map (MUDA, 2016b)

	STREETS	INTEGRATION VALUE	CHOICE VALUE	MAJOR LAND-USE
1	Irwin Road	5671	$1.84938\ X\ 10^8$	Commercial
2	Sawday Road	5333	$5.15944\ X\ 10^7$	Commercial
3	Ashoka Road	5383	$5.15742\ X\ 10^7$	Commercial
4	Sayyajirao Road	5221	$8.33283\ X\ 10^6$	Commercial + public & semi-public land-use
5	JLB Road	5167	$1.28762\ X\ 10^8$	Commercial + public & semi-public land-use
6	Dewan Road	5626	$1.50939\ X\ 10^7$	Commercial
7	Chamrajanagar Double Road	5239	$2.36761\ X\ 10^7$	Commercial

Tab.2: Integration Value, Choice Value and Land-use of important roads in CBD during 2016

5.2 CENTER 1

The most integrated area in the city, Centre C1 (Fig. 10a), has a much higher integration value than that of the CBD area. By 2016, it is 22% more integrated than the CBD area, which made it the most accessible centre from anywhere in the city (Fig. 10a and Tab.1). It has three strong choice routes (Fig.12b) passing through it. They are the Gokulam Road, the Maternity Road and the Kalidasa Road.

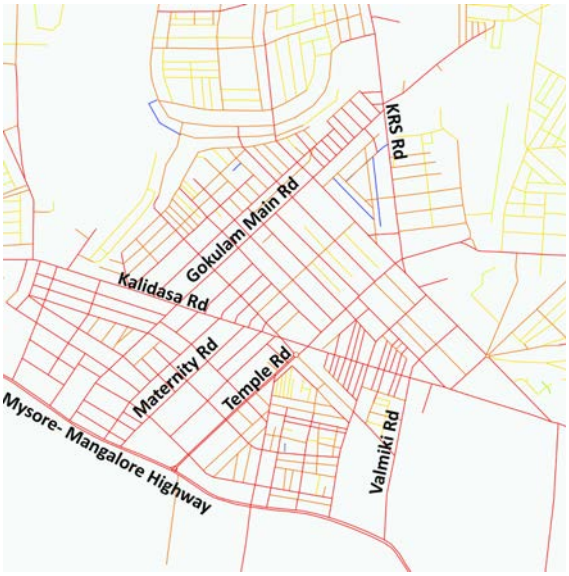


Fig. 12a: Centre C1 Integration Graph

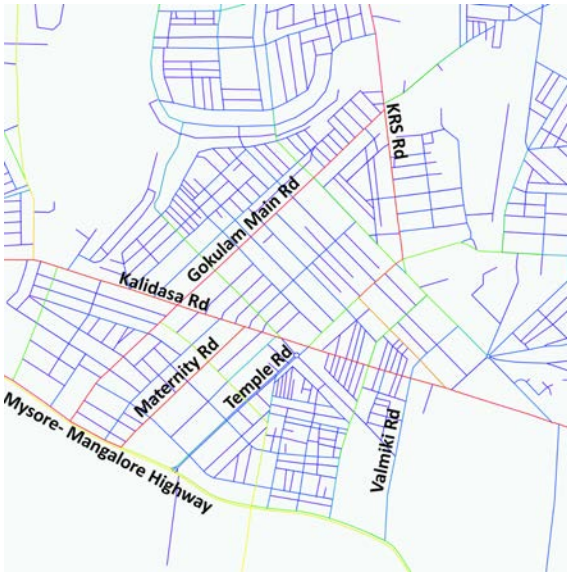


Fig. 12b: Centre C1 Choice Graph

The average integration of Centre C1 area was only 1% higher than that of the average integration value of the entire city in 1976, but in 2016 it was 28% higher, which is a very steep jump in value (Tab.1). This implies that the structure of the street network of this area (Centre C1) is strongly integrated with the rest of the city. The proposed intermediate ring road and two radial roads also passes through this area (Fig 12d). Because of the high integration power of this area, around 50% of which is under residential land-use at present (Fig.12c), it has the potential to attract more mobility and thereby get transformed to a movement-sensitive land-use in future.

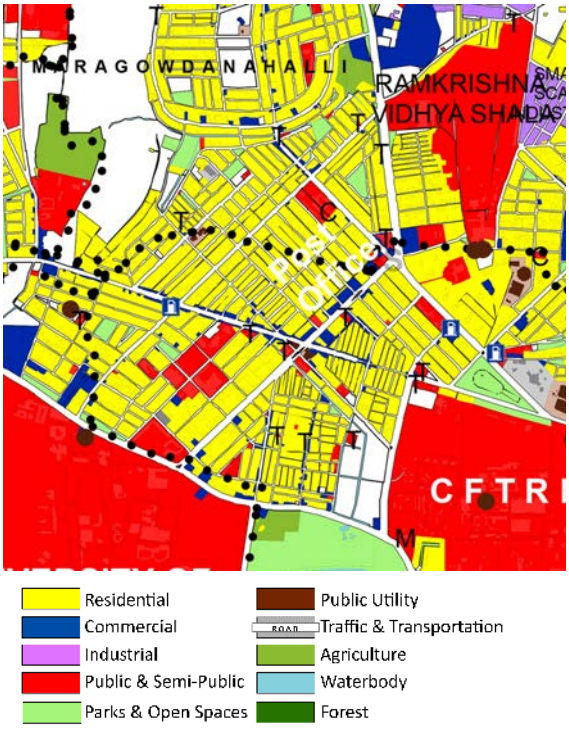


Fig.12c: Centre C1 Land-use Map (MUDA, 2016c)

Fig.12d: Centre C1 Circulation Map (MUDA, 2016b)

6 THEORY TO PRACTICE

Kumbar Koppal Road and Tenali Rama Road are good examples to demonstrate how the syntactical position of streets in the street network affects mobility and land-use. In the proposed Master Plan Report of Mysore 2031, Kumbar Koppal Road is not marked as an important road (MUDA, 2016 c) while Tenali Rama Road is marked as such, although actual mobility and land-use speak differently (Tab.4 and Tab.5).

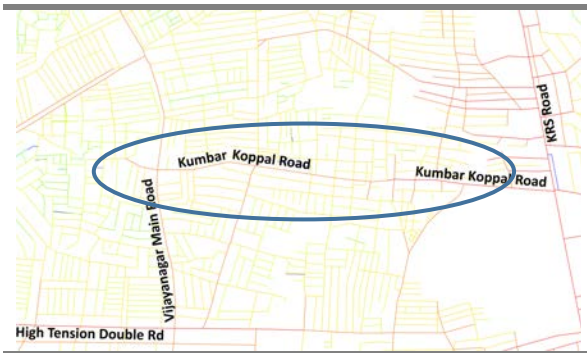
Kumbar Koppal Road which has 10% higher integration value and 10% higher choice value than Tenali Rama Road, has 67% more mobility volume (Tab.3). The land-use of Kumbar Koppal Road has 80% commercial, and 20% public and semi-public land-use, while Tenali Rama Road has 20% commercial and 80% residential land-use (Tab.4 and Tab.5).

The comparative analysis of Kumbar Koppal Road and Tenali Rama Road:

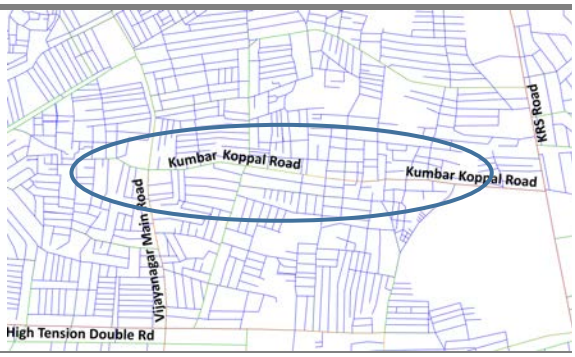
	KUMBAR KOPPAL ROAD	TENALI RAMA ROAD
Integration Value	5,047	4,580
Choice Value	1.93879 X 10^7	1.91876 X 10^6
Average Road Width (in metres)	15	21
Mobility Volume (Motor Vehicle Count)	5000 (approx.)	3000 (approx..)
Major Land-Use	Commercial	Residential

Tab.3: Comparative Analyses of Kumbar Koppal Road and Tenali Rama Road

INTEGRATION

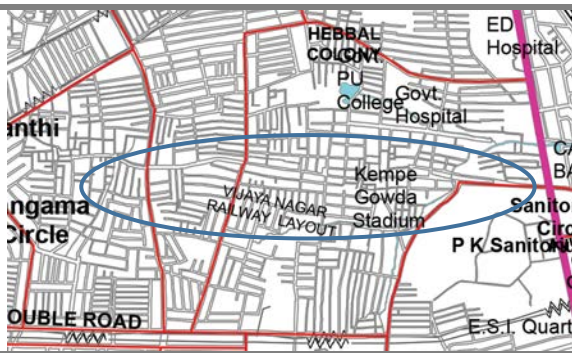


CHOICE



LAND USE

CONNECTIVITY



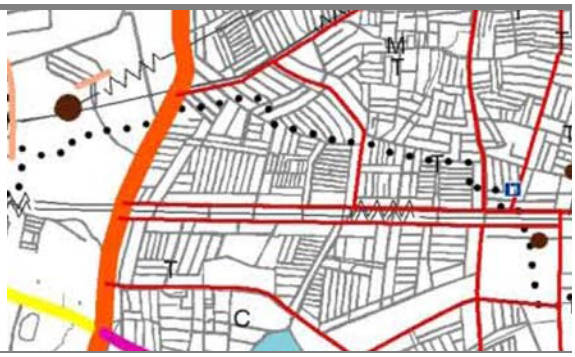
Tab.4: Kumbar Koppal Road's Integration Graph, Choice Graph, Land-use Map and Connectivity Map (MUDA, 2016b and MUDA 2016c)

INTEGRATION

CHOICE

LAND USE

CONNECTIVITY



Tab.5: Tenali Rama Road's Integration Graph, Choice Graph, Land-use Map and Connectivity Map (MUDA 2016b and MUDA 2016c)

Fig. 13a: Traffic at Kumbar Koppal Road, Mysore. May 18, 2016

Fig. 13b: Traffic at Tenali Rama Road, Mysore. May 18, 2016

7 CONCLUSION

The structure of the street network influences humans to take up the choicest route to reach their destinations. The choicest route is decided on the basis of the syntactical position of the streets in the street network. Hence, it can be concluded that the structure of the street network has an immediate effect on the mobility pattern and the land-use. This is confirmed by the above study and analysis. Two roads, Kumbar Koppal Road and Tenali Rama Road, each with a different syntactical position on the street network of Mysore, have different land-use and mobility.

In any city, a precinct with strong integration power with the rest of the city, potentially becomes the centre for business activities. This is generally observed in many historical cities, where the Central Business District (CBD) witnesses high mobility and business activity. But, as and when the city expands, with consequent change in the structure of the street network, the preferable destination will also get altered, thereby creating new precincts as the most preferable destinations because of their higher integration value. This phenomenon can potentially affect the mobility pattern and the land-use. It is evident from the above study that the CBD area, which was once the most integrated area in the city, lost this position to Centre C1 as the city started expanding.

It can, therefore, be safely concluded that a scientific analysis of the spatial structure of the street network using space syntax techniques, helps in understanding the influence of street network on mobility pattern and land-use.

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IMAGE AND TABLE SOURCES

Fig. 1: Mysore Urban Development Authority (2016)

Fig. 2: Karnataka Archives (1865)

Fig. 3: Rice, Benjamin Lewis (1897)

Fig. 4: Constance E Parson (1930)

Fig. 5: Mysore Urban Development Authority (2016)

Fig. 6a: Integration Graph of Mysore city in 1865, generated by author using Depthmap software.

Fig. 6b: Choice Graph of Mysore city in 1865, generated by author using Depthmap software.

Fig. 7a: Integration Graph of Mysore city in 1897, generated by author using Depthmap software.

Fig. 7b: Choice Graph of Mysore city in 1930, generated by author using Depthmap software.

Fig. 8a: Integration Graph of Mysore city in 1930, generated by author using Depthmap software.

Fig. 8b: Choice Graph of Mysore city in 1865, generated by author using Depthmap software.

Fig. 9a: Integration Graph of Mysore city in 1976, generated by author using Depthmap software.

Fig. 9b: Choice Graph of Mysore city in 1976, generated by author using Depthmap software.

Fig. 10a: Integration Graph of Mysore city in 2016, generated by author using Depthmap software

Fig. 10b: Choice Graph of Mysore city in 2016, generated by author using Depthmap software.

Fig. 11a: CBD Integration Graph in 2016, generated by author using Depthmap software.

Fig. 11b: CBD Choice Graph in 2016, generated by author using Depthmap software.

AUTHOR'S PROFILE

Pappu Harcharan. Architect and Urban Planner; Assistant Professor at Sri Venkateshwara College of Architecture, Hyderabad, India. During his Bachelor's studies at School of Planning and Architecture Vijayawada, he was a recipient of the Prime Minister's Scholarship for academic excellence. He received his Master's degree in Urban and Regional Planning from School of Planning and Architecture, University of Mysore. His research interests lie in Space Syntax, Spatial Planning, Urban Studies and Environmental Planning.