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Urban Roads Insight on Weighing Parametric Analysis with Fractal Dimension to Assess the Level of Service of Causative Convergence

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Abstract
Urban Traffic Congestion continuing to be major problem in urban areas and is being considered as a perineal issue for transport planners and traffic engineers for designing the mitigation measure and strategy to counter. For any mitigation measure to be proposed or designed, it is necessary to measure the congestion and identify the factors that are causing the congestion. The urban road network and the factors causing the urban traffic congestion are no more characteristic in nature. Instead, they are inconsistent and irregular in characteristics, exhibiting the scale variance when measured on smaller scales. The capacities of the road lanes are falling too short for the traffic to handle efficiently. The actual capacities of the lanes are much lower than the practical capacities. The approach of fractal analysis best fits for the analysis of features showing such characteristics. Hence, this paper presents a study where an existing link in urban road network is analyzed by the concept of fractal geometry and fractal dimensions. The complete link is divided into smaller segments and fractal dimensions are calculated for lane capacities. The fractal dimensions so determined shows that the lane capacity within a link is inconsistent and irregular.

Keywords: *Urban Traffic Congestion, Landuse, Supportive Infrastructure, Stationed Vehicles*

1. Introduction
Urban Traffic Congestion is becoming a bottleneck for further development of nation's economy, if it is not addressed amicably. The essential infrastructures for the development of the city and also to meet the travel demands of the people an efficient road network is desired in an urban area. In the current scenario of the traffic in many parts of the world the road users are facing problems of traffic congestion as it is causing wastage of time, money, energy beside creating pollution of environment. Hence it is having an adverse effect on the society. This is mainly due to the cities, which are growing at a rapid rate with reference to Business, Commercial, Educational and technological aspects, the land use pattern is also getting promoted to decentralized activities of business, educational and residential. Due to this the functionality of the road is changing but then the geometrical condition remains same which leads to many urban traffic issues. In short, the traffic has become dynamic but the network characteristics remains static. Traffic congestions are caused due to many factors which can be categorized into two main aspects – one if from the traffic side and other is from the Urban Road Network. Traffic side constitutes the nature, trend and composition of traffic. Urban Road Network constitutes many factors like Continuously changing Landuse, Deficiency in Network Connectivity, Poor Network Accessibility, Inconsistent Pedestrians, Discontinued Footpaths, Violation of Right of Way. All these factors are having adverse effects on traffic and urban road network.

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Traffic volumes have become dynamic but the urban road network remains to be static. These are seriously affecting the capacities of road. This paper presents a study wherein capacities of a link in an urban road network is analyzed by the method of fractal geometry. Fractal analysis is a concept which was first described by (Mandelbrut 1967), where he presented an analysis to measure a coast line in a city. Fractal analysis can be applied to the features which do not remain constant, regular and similar. It can be effectively used for the factors which are inconsistent, irregular and dissimilar over space and time. The Traffic composition, traffic volume, Features of Road Network, Landuse and other important factors that lies in an urban area are no more characteristic in network but keep on changing if we observed the on smaller scales. The fractal analysis has been used effectively for such factors and the same concept can be applied to the analysis of urban road network and the factors influencing the same. The Complete Road link under study is divided into segments and fractal dimensions of each segment in terms of road capacity is determined and studied for its similarity. The capacities of each segment can be used to predict the different factor leading to the congestions in segment and accordingly correlations can be drawn about the major factors that are causing the congestions in the Link. The detailed analysis and results and discussions are provided in the subsequent chapters.

2. Literature Review

Road networks are important part of an urban city which provided vital movements of vehicles and other freight services. Studies conducted in the past has shown that the researchers have mostly concentrated on traditional factors like operating speed, travel time and road width as a single factor and has presented a mathematical model for quantification of congestions. In recent times fractal geometry has been used to analyze the urban traffic congestion in urban road networks. The following literature review gives a broad picture of the work done in recent past. (Mandelbrot and Cannon 2013) presented a study which has shown the application of fractal analysis for the features which cannot be used to model by the conventional Euclidian Geometry. The paper proposed that for a feature which is not a point, line, or a cube the dimension will be an integer. It may be between 1 and 2 based on the scale variance feature that it exhibits. (Mirza Vilayath Ali Baig and Professor Dr. K. M. Lakshmana Rao 2024) delineated a road network using digitization and studied the actual influencing factors – Stationed Vehicle, Violation of Right of Way, Landuse, Pedestrians, Network Accessibility, Network Connectivity, Road Density and Traffic Volume and presented their transitional trends in network. It is shown that the traffic congestion caused due to multi-factors have certain trends and probabilistic values which has to be determined for quantification of congestion. (Wen, Zhang, and Deng 2023) presented a study based on the fractal analysis and measured the evaluation index of urban road network layout and internal structure characteristics to guide the optimization and adjustment of the urban road network, which is of great significance for guiding urban land use, effectively utilizing geospatial space, and promoting sustainable urban development, and attempts to apply the fractal analysis concept to evaluate the urban road network in Harbin, China. It is found that there is a good relationship between the length of the urban road network and the build-up area. Therefore, fractal analysis is used to reasonably determine the spatial demand of incremental road networks, considering the impact of road network increase on development mode. (Vilayath, Baig, and Rao 2024) proposed a study where study area was taken and complete road network was delineated and studied in terms of different influencing factors with the orientation of links. Major influencing factors causing the traffic congestions in the study area were identified with the mitigation measures and policy was proposed to address the problem of congestion. (Purevtseren et al. 2018) Presented a study that summarizes the land use and city expansion, as well as the dynamics of urbanization, over recent years in Ulaanbaatar city, Mongolia. The study applies fractal

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geometry to describe land uses in Ulaanbaatar city using a mathematical procedure and geographic information system (GIS) urban analysis, and measures urban sprawl using an index relation of area and perimeter. (Thomas and Frankhauser 2013) Compared the fractal dimension measured on built-up spaces with the fractal dimension measured on the street network in an urban environment. The differences are demonstrated theoretically and empirically. Fractal dimensions, curves of scaling behavior, and concordance analyses are computed for the city region of Antwerp. It is clear that the fractal dimension measured on built-up spaces is a quantity that indicates how uniformly buildings fill space when zooming to ever finer scales, while the fractal dimension measured on networks indicates the extent to which street segments are uniformly distributed in the study area (Dasari and Gupta 2020) attempted the concept of fractal analysis in evaluation of urban road networks for a small city Karimnagar city in the state of Telangana in South India. The study observed that there exists a good relation between the road network lengths and built-up area in the city and thereby using fractal analysis makes a case to rationally identify the requirements of incremental road network spatially considering the likely impact of road network augmentation on the development patterns. The paper concludes that fractal analysis is a great potential tool for road network evaluation including addressing the issue of inequity in supply of road networks within urban areas and it is very appropriate as an interactive planning tool to incrementally build road networks in urban situations particularly in developing environments where resources for such investments are scarce. (Chen and Huang 2019) employed an experimental method to find parametric models for the growth curves of fractal dimension of Chinese urban form. By statistical analysis, numerical analysis, and comparative analysis, it was found that quadratic Boltzmann equation and quadratic logistic function can be used to characterize how the fractal dimension of the urban land-use pattern of Beijing increases in the course of time. The models are also suitable for many cities in the north of China. The developed models were utilized to predict the rate and upper limitation of Chinese urban growth. In particular, the models can be employed to reveal the similarities and differences between the fractal growth of Chinese cities and that of the cities in western countries. (Chen and Jiang 2018) presented that hierarchies can be modelled by a set of exponential functions, from which a set of power laws indicative of scaling can be derived. The solution to a scaling relation equation is always a power law. The scaling laws are followed by many natural and social phenomena such as cities, earthquakes, and rivers. The cities of America, Britain, France, and Germany were taken as examples to make empirical analyses. The hierarchical scaling relations was well fitted to the data points within the scaling ranges of the size and area of the natural cities. The size-number and area-number scaling exponents were found to be close to 1, and the allometric scaling exponent is slightly less than 1. The results showed that natural cities follow hierarchical scaling laws and hierarchical conservation law very well. The hierarchical scaling law proved to be derived from entropy maximization principle, and further suggested that the evolution of natural cities is dominated by entropy maximization laws. (Boeing 2018) developed a typology of measures and indicators for assessing the physical complexity of the built environment at the scale of urban design. It extends quantitative measures from city planning, network science, ecosystems studies, fractal geometry, statistical physics, and information theory to the analysis of urban form and qualitative human experience. The typology developed here applies to empirical research of various neighborhood types and design standards. It includes temporal, visual, spatial, scaling, and connectivity measures of the urban form. (Vilayath and Lakshmana Rao 2016) proposed a fractal study in which the complete road network is divided into smaller segments and all the links are studied for its orientation. It was stated that, if the network is analyzed on smaller scale, it proves to be fractal. But if

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Page No: 16-23

the network is viewed overall, it shows non-fractal in nature. Longitudinal corridors and transverse corridors were proposed to enhance the capacity of the arterial and sub-arterial roads by avoiding the direct access of collector streets to sub arterial roads and sub-arterial roads to arterial roads. (Vilayath, Baig, Sridhar, et al. 2024) studied the road network characteristics and the effect of Pavement Surface and Road Width and presented a study for traffic congestion. The effect of Pavement Surface Condition and Road way width was studied in detail and proper mitigation measures are proposed at the end. These studies focus more on the fractal nature of a specific element of urban transportation network which have given formulations and empirical results revealing the fractal nature of urban road network, they are not systematic in the sense that cities were not selected according to population, size or extent. In view of this we can say that the results are not complete and less useful in urban networks and it is evident that the fractal dimension has been an integral part of fractal geometry in particular to the distribution of road network. [1-5]

3. Methodology

The methodology of the proposed study is shown in flow chart below

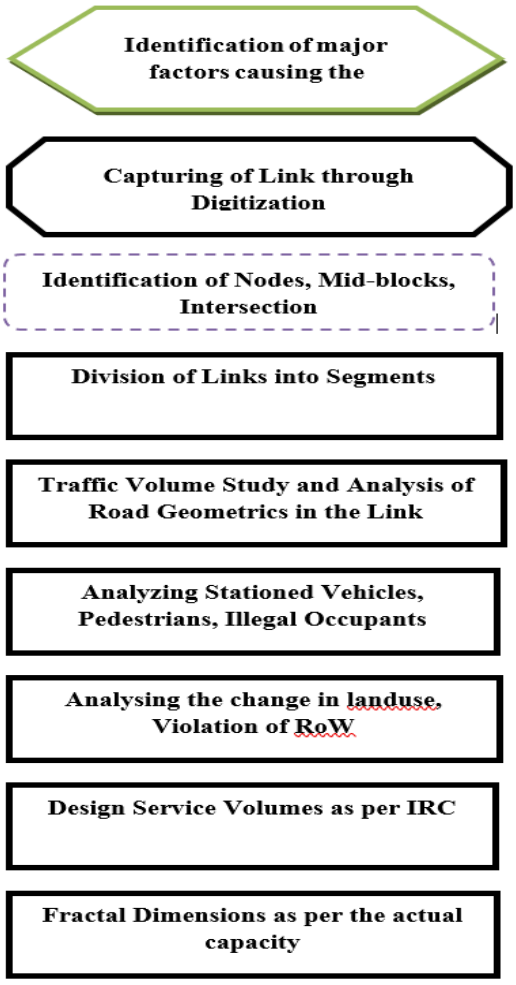

Figure 1 Proposed Structure of Research Methodology

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Page No: 16-23

4. Data Collection and Data Processing

Tolichowki is an urban area in city of Hyderabad in Telangana State. A Sub-Arterial Link is of length 1.5 Km is taken as the study area. The link is divided into 6 Segments (to and fro of the link) of 500m length. Video graphic surveys, Manual Surveys and Data Analysis from the Road map is done to capture the data.

Table 1 Segments in the Road Link

Link	Segment	From	To	Length
Tolichowki Junction to 7 tombs	**1**	Tolichowki X Roads	Ratnadeep Supermarket	500
	2	Ratnadeep Supermarket	Hyderabad Express Restaurant	500
	3	Hyderabad Express Restaurant	Al Saba Dairy	500
7 Tombs to Tolichowki Junction	**1**	Al Saba Dairy	Hyderabad Express Restaurant	500
	2	Hyderabad Express Restaurant	Ratnadeep Supermarket	500
	3	Ratnadeep Supermarket	Tolichowki X Roads	500

Table 2 Features in the Segment

Segment -1, 500m Long from Tolichowki Junction to Ratnadeep Supermarket	
Influencing factor	**Condition Prevailing in the Segment**
Traffic Composition	Slow Moving Vehicle = 668
	Fast Moving Vehicle = 4544
Stationed Vehicles	Car = 11, 2W=140, Auto=15, LCV=1
Landuse	Total Built-up area up to 50m adjacent of Road Line is 500 X 50 X3 = 75000 Sq m
Right of Way Violation	1) ROW available along the length but utilized for parking.
	2) Road Side Shops - 32 No's @ 5m X 5m each
	3)Footpath is available in the last 200m stretch.
Road Geometrics	1) Average Road width of the segment is taken = 6.925m
	2) Shoulder Not Available
	3) Pavement Surface - Smooth and Even

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5. Results and Discussions

Table 3 Fractal Dimensions of Capacities in Link

Fractal Dimensions for Lane Capacities								
Sl. No.	**Name of Road**	**Segment Number**	**Area Sq.Km**	**No of Lanes in Segment**	**Design Capacity as per IRC 60**	**Actual Capacity**	**Fractal Dimension**	**Average Fractal Dimension**
1	Tolichowki Junction to 7 Tombs Road and 7 Tombs Road to Tolichowki Junction	**1**	0.175	2	1200	2400	0.53	**4.68**
2		**2**	0.265	2	1200	2400	0.53	
3		**3**	0.128	2	1200	2400	0.53	
4		**4**	0.192	2	1200	2400	8.84	
5		**5**	0.113	2	1200	2400	8.84	
6		**6**	0.175	2	1200	2400	8.84	

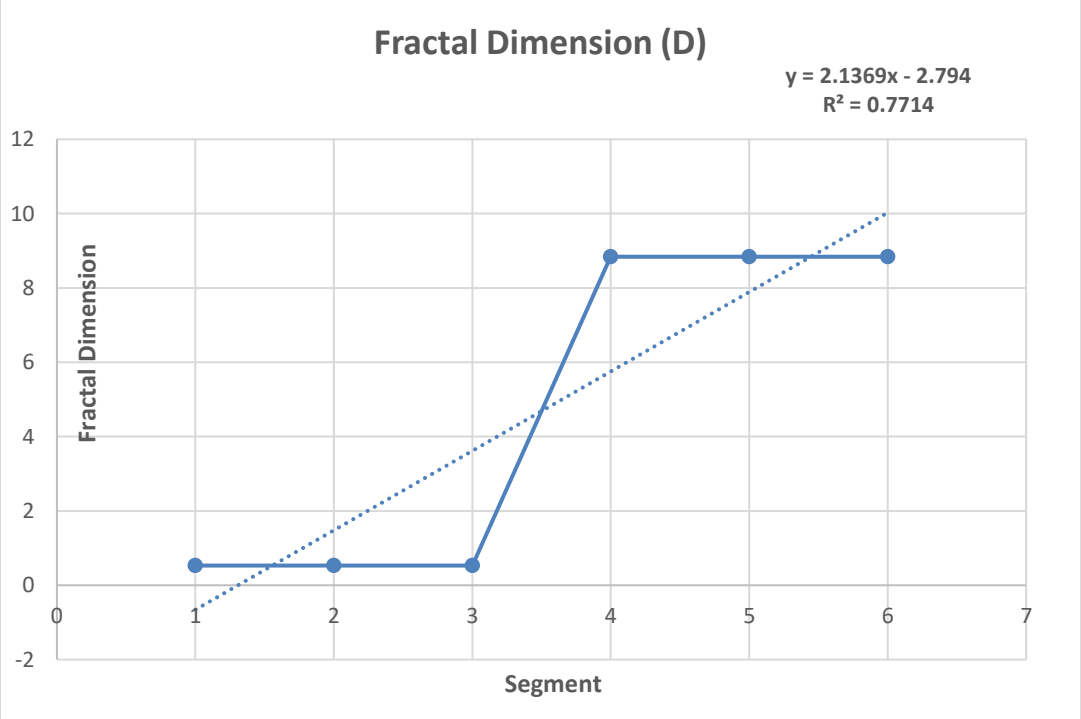

Figure 1 Fractal Dimension

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Page No: 16-23

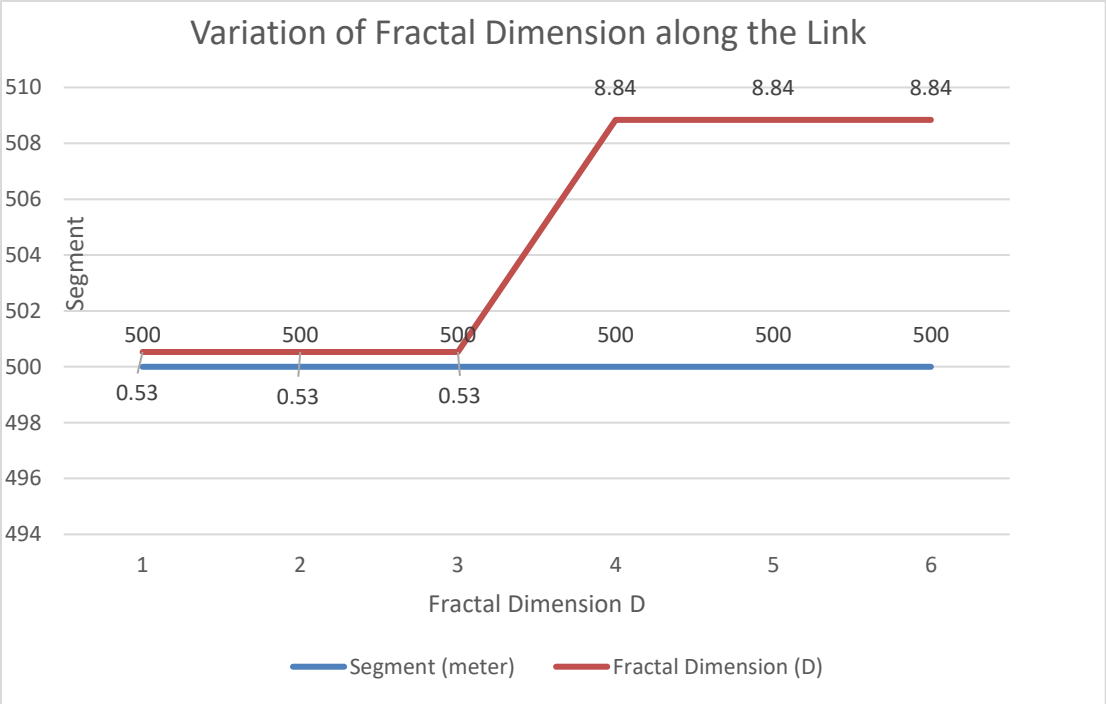

Figure 2 Variation of Fractal Dimension Along the Link

Conclusion

Fractal Dimension determined for the capacities are constant, similar, and regular in single direction of flow. But if viewed overall the fractal dimension for both the direction are not same but varies with a high margin. This is due to the presence of local influencing factors – Violation of Right of way, Presence of Stationed Vehicles, Inconsistent Pedestrians and Dis-continuous Sidewalk. Average fractal dimension of the link is 4.68, which shows that the link has high tortuous features which makes all the influencing factors very distinct, irregular and inconsistent which are decreasing the capacities of the segment. Fractal Dimension for Tolichowki Junction to 7-Tombs Road for capacities are 0.53 which shows that the link efficiency for the movement of traffic is very low and on the other hand the Fractal Dimension for capacity for 7-Tombs to Tolichowki Junction is 8.84, which shows that the conditions are very severe and influencing factors actually causing the traffic congestions shall be identified and addressed before designing the mitigation measures. The link is undivided 2 lane road with non-uniform width throughout the link length and is characterized by violation of Right of Way and intrusion of business activities on carriage way width. The Right of Way has to be cordoned and screening of psychological behavior of road users shall be done as part of mitigation measure in the link. [6-12]

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Page No: 16-23

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