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EVALUATION OF URBAN AREAS THROUGH SPATIAL ANALYSIS: A CASE STUDY

C. S. R. K. Prasad, *Dept. of Civil Engineering, Regional Engineering College, Warangal*
N. Srinivasa Reddy, *Dept. of Civil Engineering, Regional Engineering College, Warangal*
N. V. Ramamoorthy, *Dept of Civil Engineering, Regional Engineering College, Warangal*

ABSTRACT

Urbanization is a perpetual process. Due to urbanization the kind of urbanization taking place in most of the Indian cities is in an unplanned manner. To identify areas of potential development and also to plan investment for civic and transport infrastructure, understanding of city form, structure and size is a prerequisite. Spatial density functions in terms of five parameters such as population density, land values, commercial floor area, number of commuters visiting activity center and automobile volumes are represented as a function of distance from core to the periphery, for the evaluation of urban areas through a case study. Probability contours are drawn for the identified CBD's to establish movement pattern with in the urban area. Shape of the urban agglomeration and directional growth of city are established for decision-making process.

INTRODUCTION

Urbanization and industrialization are the two causative factors making people to migrate from rural to urban areas. Urbanization is a necessary condition for economic development of a nation, but the kind of development taking place in Indian cities and towns is marked by population growth with inadequate civic and transport infrastructure resulting in traffic congestion and deterioration of urban environment. Activity, housing and transportation are the three important components of complex urban system. The interaction between the place of residence and place of activity is brought about by transportation facilities such as roads or rail.

Urban planners are concerned with the most appropriate arrangement of these sub systems to yield an integrated urban structure. As it is recognized that urban travel demand is a function of urban size, urban form and urban structure, the integration of urban form and urban structure should be such that they will minimize travel demand through manipulation of land use activity. Different urban forms and structures lead to definite travel patterns. In India, urban form and urban structure of most of the cities is the result of ribbon extension along arterial roads with high concentration of population at city core (CBD) area. Problems arising out of an unbalanced urban form are increased traffic congestion with compounding land property values.

Urban form may be defined as an articulation and arrangement of central business district (CBD), the place where all economic /trade /commerce and administrative activity located. Various urban forms generally found in metropolitan areas are central CBD (mono nucleus), multiple CBD (poly nucleus) and eccentric CBD. The formation of CBD generally taking place in the core of the city is in consistent with the evolution of urban area. To plan the future development of these cities, it is necessary to understand the existing city form and

structure. Understanding of city form and structure through its evaluation is helpful for framing policy decisions for future growth strategies.

LITERATURE REVIEW

Eminent town planners proposed various theories and concepts related to urban form. Ebenezer Howard (1898) proposed garden city concept with low density and large open areas. Lecorbousier (1922) proposed City core with high density and open areas surrounded by green belt. Various city structures proposed/existing for urban development are grid type, linear type directional grid and centripetal. These theories were followed while master plan proposals were drafted for various development policy options.

To explain the changes in land use, land value micro economic theories were proposed by Vanthunen, Alonso and others. Vonthunen developed location bid rent curves for different agriculture cropping pattern. The ideas of Vonthunen have been formally applied in the urban context by William Alonso (W.Alonso, 1964.). Population density models were developed by Clark (1957), and later on modified by Tanner and Shrett (1961) and New Lings (1969) to show spatial variation of land use from city core to periphery. Mhmassoni Hani S et al (1988) suggested cubic spline estimation method for evaluation of urban form. Black J.A et al (1988) gave classification of city structure for various forms and they developed urban consolidation index to explain city parameters such as city form structure and shape.

There are about 329 small and medium cities in India with population range from 0.1 million to one million plus. Unorganized development and growth of these cities necessitates a methodology for the evolution and evaluation of urban areas, for their growth management using available land use theories and modeling techniques. Hence in this technical paper, an attempt is made to formulate methodology for the evolution and evaluation of urban areas through a case study of Vijayawada city.

VIJAYAWADA URBAN AREA

Vijayawada is one of the oldest urban settlements of Andhra Pradesh located in Krishna District on the Krishna river bank. It is the third largest city in the state after Hyderabad and Visakhapatnam. Administrative, trade, commerce and educational facilities located in the urban area are attracting the people in the surrounding districts. This causative factor has made Vijayawada a most happening place in the state.

Demographic Growth

Population of Vijayawada city has grown from 24,224 in 1901 to 9.3 lakh in 2001 and accounts for 15% of the state population and 27% of the district urban population. The population of the city is also increased due to migration from neighboring districts mostly from East Godavari, Guntur and Prakasam.

Land Use Pattern

Vijayawada Urban area within the municipal corporation limits has mixed land use with industrial, residential and commercial activities. The core area of the city is bound by the river Krishna on the South, Indrakiladri Hill on the West, railway line to Chennai in the East and Gandhi Hill in the North. Because of these geographical constraints, the city core area is

densely populated. Geographical area of the city is increased from 30.38sq.km in 1961 to 55.58sq.km with 50 zones in 21 Revenue Wards in the year 2001. Population density of the city varies from 1545 persons per hectare at the city core to 234 near the periphery. Existing land use pattern of Vijayawada urban area is presented in Table 1.

Traffic-Transportation Scenario

The city of Vijayawada is the divisional head quarter of south central railway and is connected by National Highway (NH) 5, NH 9 and a State Highway. There are five arterial roads which define the movement pattern of the city namely Bandar road, Eluru road, NH9, Byepass road and road from Kaleswara Rao (KR) Market to Panja centre. In recent years, the City has experienced tremendous growth in two wheelers and three wheelers (auto's). At present there are about 57600 two wheelers and 14000 three wheelers, contributing about 94% of total traffic. Besides this, considerable number of cycle rickshaws also exists. Composition and model share of traffic are presented in Tables 2 and 3. These personalized vehicles and intermediate public transport cause traffic and transportation problems during peak hour.

METHODOLOGY

Identification of economic activity (CBD), which defines the city form, is prerequisite to establish movement pattern in urban areas. For identification of CBD'S and also to study the spatial variation of land use from city core to periphery, the following parameters are used.

Population Density
Land Values
Commercial Floor area
Number of commuters traversing the corridor
Traffic volumes along the corridors

The above listed parameters are represented as a function of distance from city core to periphery along the corridor. The variation parameter explains the change in land use and there by the intensity of development from core to periphery.

Population Density

Clark (1957) first provided exponential empirical function to specify land use pattern in terms of population density from core to periphery. Clark model was modified by Tanner and Shrett (1961) and suggested that population density decreases exponentially with square of the distance from CBD. Later NewLings (1969) suggested quadratic exponential model for the variation of land use. Mathematical presentation of the models is given below.

Sl. No	Model	Exponential Form	Logarithmic Form
1	Clark	$D_d = D_0 \times e^{-bd}$	$\ln D_d = \ln D_0 - bd$
2	Tanner and Shrett	$D_d = D_0 \times e^{-bd^2}$	$\ln D_d = \ln D_0 - bd^2$
3	New Lings	$D_d = D_0 \times e^{bd - cd^2}$	$\ln D_d = \ln D_0 - (bd - cd^2)$

Where D_d : Population density at a distance 'd' from the core to the periphery
D_0 : Population density at core
d: distance from the city core
b, c : are constants

Land Values

Land values decrease with increasing distance from CBD. Various models were attempted to explain the variation of land use in terms of land values (Alonso). In the present study, land value is represented in the form of power function and the same is given below.

$$LV = a \times d^{-b} \quad \text{Power function} \quad (1)$$

$$LV = \ln a - b \times \log d \quad \text{Logarithmic form} \quad (2)$$

Where LV : Land value
d : Distance from CBD
a, b : constants

Other Parameters

Other parameters such as commercial floor area, number of commuters traversing the corridor, and total traffic volume are analyzed in the similar fashion as explained above, for the evaluation of Vijayawada urban area.

DELIMITATION OF CBD AREA

Through Probability Contours

The methodology adopted for delimitation of trade area (CBD) is by drawing probability contours as suggested by Huff (1964). The probability contours represent the influence of activity (CBD) centre over the space in urban areas. The probability contours for two hypothetical activity centers (CBD) in an urban area are shown Figure 1.

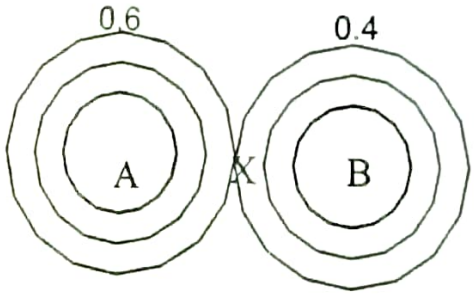

Figure 1 CBD Areas Represented by Probability Contours

A person located at X in an urban area has the probability of 0.6 commuting to CBD A and probability of 0.4 commuting to CBD B. To create such probability contours, data pertaining to commuter visiting each CBD from different residential zones are required, which was obtained through commuter attitudinal survey .The following mathematical expression is used to represent probability values.

$$D_p = D_n \times \frac{\alpha_i}{\alpha_n} \quad (3)$$

Where

D_p : Distance from CBD at which p% commuters visiting CBD

D_n: Normalized distance for p% of commuters

$_i$: weight age associated with corridor i

$_n$: weightage associated with normalized corridor.

A hypothetical CBD connected by three corridors as shown in Figure2 is taken as an example to explain the above-mentioned equation (3).

Figure 2 Number of Commuters Visiting CBD From Different Corridors

In the above Figure 2, let 500, 300 and 200 be the number of commuters visiting the CBD along the corridors 1, 2 and 3 respectively. Cumulative percentage of commuters visiting the CBD is represented at different distances is shown in Figure 3.

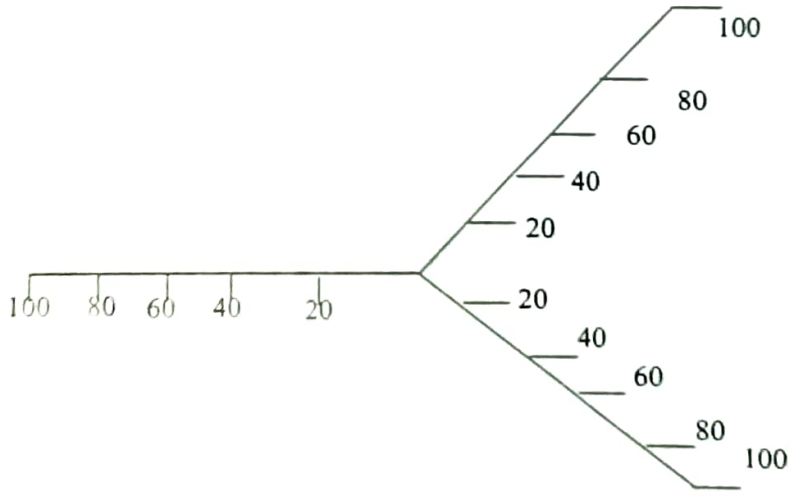

Figure 3 Cumulative of Commuters Visiting the CBD Along the Corridor

The corridor with maximum number of commuters visiting the CBD is taken for normalization and the distance corresponding to100th cumulative percentage is taken for normalization. In the above example corridor –I with 500 commuters is taken for normalization. Further a curve is drawn between distance from CBD and cumulative percentage of commuters, from

which 98th, 85th percentile distance is estimated to represent normalized distance D_n using the Equation (3).

The same methodology, as explained above, is followed to establish the influence of urban agglomeration area by taking Vijayawada city as a single system. The methodology presented will facilitate to arrive the shape of Vijayawada urban agglomeration and there by to establish the directional growth of Vijayawada city.

Model Development

A probabilistic model which is similar to singly constrained gravity model is developed for prediction of probability of a worker working in CBD $_j$ and living in zone i, is represented as

$$P_{ij} = \frac{U_j}{\sum U_j} \tag{4}$$

$$U_{ij} = \frac{S_j}{d_{ij}^{\,b}} \tag{5}$$

$$P_{ij} = \frac{S_j / d_{ij}^{\,b}}{\sum \left[S_j / d_{ij}^{\,b} \right]} \tag{6}$$

Where
P_{ij} : probability of worker working in CBD_j and living in zone i
S_j : size of the CBD_j measured in terms of commercial floor area
d_{ij} : aerial distance from CBD_j to zone centre i
b : distance deterrence factor to be calibrated.

DATA COLLECTION

Population Data

Population data pertaining to 50 zones in 21 Revenue Wards for the last three decades were obtained through population census tracks.

Land Use Data

Land use data was obtained from Vijayawada Municipal Corporation and Vijayawada – Guntur – Tenali - Mangalagiri Urban Development Authority (VGTM UDA).

Land Values

Current land values pertaining to 50zones and also the variationof land value along the identified arterials were obtained from real estate and private land developers and Municipal Revenue records.

Commercial Floor Areas

Commercial floor areas along the corridors were extracted from revenue records of Vijayawada Municipal Corporation.

Traffic Volumes

Traffic volume count surveys were conducted on the identified arterial roads of Vijayawada to obtain classified traffic volumes.

Number of Commuters

Number of commuters, traversing the corridor, was obtained through vehicle occupancy survey. Also commuter attitudinal survey was conducted in Vijayawada City to obtain the information pertaining to origin, destination, and mode of travel, frequency of travel and socio-economic characteristics of the commuter through a structured questionnaire. For this a total of 7,000 samples were collected in Vijayawada urban area at different locations such as bus stations, commercial areas, administrative offices etc.

DATA ANALYSIS AND RESULTS

Urban travel patterns are intrinsically related to land use and urban form. Spatial analysis of the selected parameters is useful in characterization and quantification of land use activity. For this five corridors were identified in Vijayawada urban area, which defines the movement pattern in the city. The diagrammatic representation of corridors is shown in Figure 4. They are

Corridor-I : K.R.Market-Modern Super Market-Veterinary Hospital-Hotel Khandari-Benz Circle-
Eenadu Office-Siris Drugs-Kamayya Thopu-Poranki (Bandar Road).
Corridor-II: K.R.Market-Mamata Hotel-Brindavan Hotel-Governor Pet-Mysore Café-SRR College-
Gundala-Ramavarapadu.(Eluru Road).
Corridor-III: K.R.Market-Swathi Theatre-Bhavani Puram.-Ibrahim Patnam(NH9-Hyderabad road)
Corridor-IV: K.R.Market-Barrage-RTC Bus Station-Guntur Bye Pass.(Bye Pass Road)
Corridor-V: K.R.Market-Hindu School-Panja Centre- KBN College-Chitti Nagar.

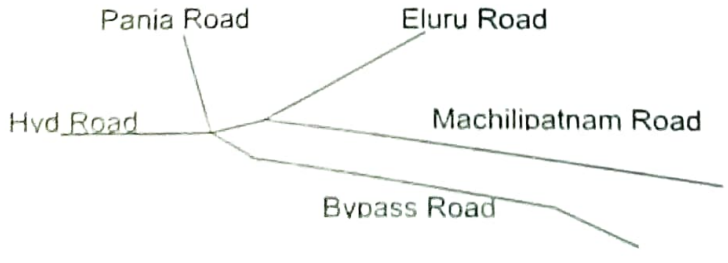

Figure 4 Diagrammatic Representations of Corridors

Using the above proposed methodology spatial and temporal analysis of the selected parameters was carried out for the five identified corridors of Vijayawada urban area. Results of the data analysis are presented in the following Tables 4 to 8.

Table1 Land Use Pattern in Vijayawada City

Land Use	1961(areasinhectare)	1996(areasinhectare)
Residential	575(44)	1457(47.24)
Commercial	66.(5.1)	170(5.51)
Industrial	37(2.9)	125(4.05)
Public and Semi public	128(10).	322(10.45)
Transport and Communications	444.(34.9)	875(28.37)
Parks and Open Spaces	27.(3.1)	103(3.34)
Public Utility	NA	32(1.04)
Total Development Area	1279(100.0)	3084(100.)
Vacant	334.	376
Others	1424.33	2098
Total	3038.00	5558

Note: Figures in parenthesis represent % of total developed area

Table 2 Composition of Slow Moving Traffic In Vijayawada City

Location	Cycles	Cycle Rickshaws
Hyderabad Road	584	131
Bandar Road	13080	4916
Alankar Bridge Road	20670	13026
Eluru Road	13258	6568
Ring Road	3895	1209

Table 3 Composition of Fast Moving Traffic in Vijayawada City

Type of vehicle	Number
Two Wheelers	57600
Three Wheelers	14325
Car, Jeep, Taxi	2854
Bus	1050
Truck	4260
Tractor	1390
Others	300
Total	81829

Table 4 Variations of Land Values Along the Corridors In Vijayawada City

Corridor	Model Form	R^2
I	$LV = 34468 \times d^{-0.69}$	0.76
II	$LV = 40242 \times d^{-0.97}$	0.84
III	$LV = 26787 \times d^{-1.543}$	0.94
IV	$LV = 27945 \times d^{-1.89}$	0.83
V	$LV = 31391 \times d^{-1.009}$	0.94

LV :Land value

Table 5 Spatial Variation of Commercial Floor Area From Core to Periphery In Vijayawada City

Corridor	Model Form	R^2
I	$\ln F.A_d = 11.434 - (0.065d + 0.01d^2)$	0.93
II	$\ln F.A_d = 11.434 - (0.1059d + 0.009d^2)$	0.96
III	$\ln F.A_d = 11.434 - 0.274d$	0.98
IV	$\ln F.A_d = 11.434 - 0.28d$	0.85
V	$\ln F.A_d = 11.434 - 0.344d$	0.96

$F.A_d$: commercial floor area at a distance 'd' from the core

Table 6 Decadal Spatial Variation of Population Density Along the Corridors

Year	Corridor	Model Form	R^2
1981	I	$\ln D_d = 6.733 - 0.1856d$	0.97
	II	$\ln D_d = 6.733 - 0.186d$	0.98
	III	$\ln D_d = 6.733 - 0.262d$	0.95
	IV	$\ln D_d = 6.733 - 0.267d$	0.94
	V	$\ln D_d = 6.733 - 0.55d$	0.96
1991	I	$\ln D_d = 7.16 - 0.0192d^2$	0.93
	II	$\ln D_d = 7.16 - 0.0169d^2$	0.98
	III	$\ln D_d = 7.16 - 0.0207d$	0.96
	IV	$\ln D_d = 7.16 - 0.22d$	0.92
	V	$\ln D_d = 7.16 - 0.55d$	0.94
2001	I	$\ln D_d = 7.34 - (0.0785d + 0.00035d^2)$	0.88
	II	$\ln D_d = 7.34 - (0.096d - 0.0118d^2)$	0.91
	III	$\ln D_d = 7.34 - 0.189d$	0.94
	IV	$\ln D_d = 7.34 - 0.215d$	0.92
	V	$\ln D_d = 7.34 - 0.27d$	0.94

D_d: Population density at a distance d from the core

Table 7 Spatial Variation of Commuters Traversing the Corridor In Vijayawada City

Corridor	Model Form	R^2
I	$\ln Comm_d = 11.320 - (0.0574d + 0.0012d^2)$	0.62
II	$\ln Comm_d = 11.320 - (0.104d - 0.00082d^2)$	0.90
III	$\ln Comm_d = 11.320 - 0.276d$	0.96
IV	$\ln Comm_d = 11.320 - 0.2395d$	0.97
V	$\ln Comm_d = 11.320 - 0.568d$	0.94

$Comm_d$: Commuters traversing at a distance'd' from the core

Table 8 Spatial Variation of Traffic Volumes From Core to The Periphery In Vijayawada City

Corridor	Model Form	R^2
I	$\ln TV_d = 11.192 - (0.144d - 0.0025d^2)$	0.69
II	$\ln TV_d = 11.192 - 0.019d^2$	0.76
III	$\ln TV_d = 11.192 - 0.146d$	0.84
IV	$\ln TV_d = 11.192 - 0.1078d$	0.77
V	$\ln TV_d = 11.192 - 0.278d$	0.90

$T.V_d$: Traffic volumes at a distance 'd' from the core

PROBABILITY CONTOURS

Probability contours are drawn for the identified activity centers (CBD) to represent work trip movement pattern using the Equation (3).

DIRECTIONAL GROWTH OF VIJAYWADA URBAN AREA

Using mofussil commuter attitudinal survey data, probability values were obtained by using the equation (3) for Vijayawada urban area and urban agglomeration for its directional growth and thereby the shape of Vijayawada urban area as well as urban agglomeration is arrived. From the analysis of moffusil commuter attitudinal surveys, it is found that in Vijayawada urban area, continuous urban sprawl is extended up to 34Km in corridor –I, 26Km in corridor-II, 18Km in corridor-III, and 14Km in corridor-IV respectively.

DISCUSSIONS AND CONCLUDING COMMENTS

The principal aim of this technical paper is to illustrate the importance of spatial density function in terms of population, total traffic volumes, land values, commercial floor area and commuters visiting CBD for characterization of urban structure. Represented at different locations along the corridors, the function helps in understanding the land use and development pattern in urban areas, which describe the evaluation of urban form for which Vijayawada city is taken as a case study.

Corridor analysis of the five identified parameters facilitates evaluation of urban form and it can be concluded that Vijayawada urban area is having K.R.Market as the major CBD, Governor Pet and Benz Circle as an intermediate CBD's of second order and Swathi theatre Center on corridor III and Krishna Lanka on corridor IV as minor CBD of third order.

Further the parameters illustrate spatial and temporal variation, away from the urban core affecting the demand for transportation in urban areas. The parameters population density, commercial floor areas, automobile volumes and number of commuters are represented in exponential form for the five corridors and it is found that the variation of the parameters are in similar fashion and decreases from city core. The variation of the four parameters for corridor –I and II follow New Ling's model, representing the matured stage and shift of economic activity from the City core, where as the variation of the parameters on corridor – III, IV and corridor-V follow Clark model representing youthful stage indicating the scope for further development.

The spatial variation of land values are represented in power function form and explain how land value dictates land use in urban areas. The parameter land value helps in fixing the extent of Municipality boundary limits along the corridors, and there by to redefine City boundary limits. In addition to the above, probability contours are drawn for Vijayawada urban area to represent spatial influence of each CBD, which are useful in understanding the movement patterns and also for calibration distance deterrence function, in predicting future travel patterns. Probability contours drawn for Vijaywada urban and urban agglomeration areas facilitate in fixing the shape and also establishes the directional growth for Vijaywada city. Using the probability values distance deterrence factor is calibrated for work trips and is found to be 1.74 for Vijayawada urban area.

The methodology demonstrated is quite helpful for identifying potential development and investment opportunities in urban areas. The methodology described in this paper is well known among geographers and regional planners, but here an attempt is made for its adoption in land use transportation planning for effective policy decision-making process.

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ROAD TRANSPORTATION IN INDIA: EMERGING TRENDS AND TECHNIQUES

Volume 2

K. SUDHAKAR REDDY
BHARGAB MAITRA