Evolution of Spatial Structure of World Heritage City of Kandy, Sri Lanka: An Analysis of Population Density Change

RJM Uduporuwa, L Manawadu

Abstract—Urban population density is one of prime determinants and a measure of spatial structure of a city. Theoretically and empirically shown general trend of growth of cities over time is that they are becoming more 'flat' decentralizing its residential population and have a tendency for suburbanization. This paper examines the evolution of spatial structure of world heritage city of Kandy, Sri Lanka focusing its growth phases, spatio-temporal change of population density distribution and testing the general hypothesis of world city expansion for its future planning considerations. A series of concentric zonal density maps were produced by using population density statistics with the help of ARCGIS 10.2 version to visualize population density shifting process over the time. Negative exponential growth model was employed to quantify the density gradients over the time. Results reveal that high density concentric zones are closer to the city center until 1991 and gradually shifting to the periphery starting in 2001 and further in 2011. Density gradient was peak in 1957(-0.24) and has progressively reduced up to -0.06 in 2001 and further 0.3 in 2011. After 2001 the city is being experiencing the stationary phase and it exhibits the 'maturity' of urban growth. Density analysis clearly confirms the two hypotheses of world city expansion exhibiting the density declining with increasing distance from the city centre and its flattening nature through time. This spatio-temporal change of residential population of the Kandy city is a sign of decentralization of population which lead the suburbanization trend of the city.

Keywords—Urban structure, Population density, Density gradient.

I. Introduction

Spatial structure of a city is an extremely complex and constantly evolving spatial phenomenon and is contributed by a number of interplaying factors of human as well as physical. As defined by Harrison and Kain [1] urban spatial structure is the location and density of residential and non-residential activities in an urban area and their spatial linkages. According to Isard [2] it is the 'spatio physiognomy' of urbanization. It is the physical outcome of complex interaction over centuries between factors such as land market and topography, infrastructure, regulations and taxation.

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Despite the fact that understanding of spatial trend of development of a city is extremely significant in the context of urban planning and management, it is not often monitored especially in developing countries.

Monitoring spatial trend of development of a city is significant due to several factors. Spatial aspect of urban development can have important impact on economic efficiency and quality of the urban environment. From the economic point of view, city is a large labour and consumer market. Larger the size of the city lower the cost of transaction and more prosperous is the economy. A deficient spatial structure leads the less efficient market fragmenting labour and consumer market into smaller parts, contribute to high transaction cost by unnecessarily increasing distance between people and places. A deficient spatial structure can negatively impact on city's productivity as well. From an environmental point of view a deficient spatial structure can decrease quality of urban life increasing the time spent on transport, by increasing air pollution and contributing to the unnecessary expansion of urban areas on natural space. Poor environmental condition also reduces the city's productivity. Therefore, it is important Municipalities to monitor the spatial trend of development with the help of spatial indicators and take regulatory remedial actions if the city growth is not in the proper manner.

Urban population density analysis which describes population density as a function of the distance (relationship between population density and distance) is a widely relevant and used technique in understanding the evolution of urban spatial structure of a city since the population is the prime determinant and a measure of the urban spatial structure. Population density refers to the value of concentration of people in an urban area and is measured per unit of area. It examines the spatial distribution of population within urban areas and is a best measure of understanding the concentration of population and territorial expansion of a city over the urban space.

The classical study undertaken by Colin Clark [3] is one of most popular functional forms(Negative exponential model) of urban population density analysis explains how population density distribution pattern changes with increasing distance from the city center(*Fig*. 1). The model proposed two general hypotheses, (1) Population density declines exponentially with a linear function of distance from the city center and (11) in most cities time passes and density decreases in the central

area and increases in the periphery (suburbs), thus producing a territorial expansion of the city. According to the first hypotheses the density (intensity of space use) to be at a peak at the center (the optimum total- access point) where the poor,
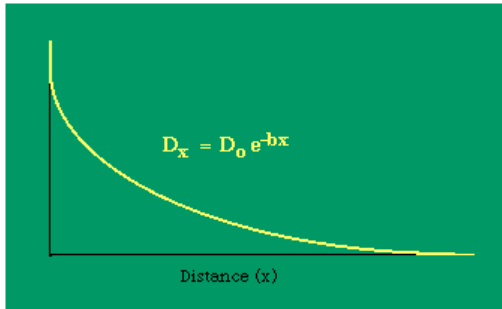
x: Distance from city center
D_x : Population density at distance x
D_o: Central density
b: Population density gradient (slop)

Figure 1.Negative Exponential Growth Model
(Urban Population Distance-Decay Curve)

who need a central location in order to reduce the cost of the journey to work, live on small areas of valuable land, or where building densities are high in order to cover high land costs. Densities decline with distance from the centre as the rich, who can afford higher travel costs, locate at the periphery and use large areas of cheaper land. Such a tendency can be described by a 'density gradient' (b), where density is a negative function of radial distance.

As the second hypotheses suggest over an extended period of time density gradient gradually declines and cities are becoming more 'flat' decentralizing its residential population and have a tendency for suburbanization. This reflects the evolution of spatial structure over the time. Studies done by Clark [3][4], Muth [5] and Mills [6] in cities in United State, Brush [7] in cities in India and Wong and Zhou [8] in China were some of notable early work which confirmed this model.

In this context, this study attempts to examine the evolution of urban spatial structure of world heritage city of Kandy, Sri Lanka focusing on its change of population density distribution pattern over time and testing the general hypothesis of world city expansion. Kandy city is the second largest city in Sri Lanka in terms of its population and has a great national important since it is being the major cultural, commercial, administrative and transport center of the hill country during the last 600 years history since its established as the capital of the Kandyan Kingdom in the 15th Century. The most significant cultural character of the Kandy city is the location of the Sacred Tooth Relic Temple along with its surrounding which is recognized as a monument of World Heritage city in 1986 by UNESCO. It was shaped by different ruling periods of local and colonial and is world renowned

because of the university of Peredeniya and Peredeniya botanical garden too.

II. Data and Methodology

This paper depends on secondary data of population in Kandy city. Ward wise data in years of 1943, 1957, 1971, 1981, 1991, 2001 and 2011 were used for the analysis. These data were collected from Kandy Municipal Council, Department of Census and Statistics in Sri Lanka and Urban Development Authority, regional office, Kandy.

Arithmetic density of population which is number of persons per Square kilometer was employed and a series of concentric zone density maps with 0.5 Kilometer concentric circles were constructed with the help of ARCGIS 10.2 version and summarized with the help of Zonal Statistic tool in ARCGIS 10.2 to visualize the change of population density distribution over the corresponding time periods. Negative exponential growth model derived by Clark [3] was used to quantify the density change from the city center to the periphery (gradients) in corresponding time periods.

III. Results and Discussion

A. Growth Phases of Kandy City

From 1594 Kandy was invaded by Portuguese (1594) Dutch (1802) and British (1815) and affected by their socioeconomic and cultural setting. This influence led to a change from Kandyan architecture in the city to modern architecture. In 1832 British made changes to the inner city by making it an administrative city. The residencies of elite class who lived in the city center were converted to bungalows of the British administrates and some were converted in to offices and hotels. All the blocks within grid pattern were subdivided for various commercial activities during the British era. These plots were given to established sales departments. For the last 100 years the city has developed part by part adding new commercial activities to the city in an adhoc manner. All these characters religious, historic, cultural and environment have made the city of Kandy an attractive place for not only living but also the other activities such as tourism.

As historically recorded the population of Kandy city appears to have more or less stagnant from the 17th century up to end of the 19th century has been around 2500 and after British occupation in the city in 1815 it has risen to 3000 [9]. This, by the year 1871 which is the first national Census has increased to 16881 recording an annual increase of 8.3 percent in relation to the base year of 3000. As shown in the F*ig*. 2 population growth of Kandy city over the last 140 years of period has grown progressively and exhibits the characteristic of 'S-shaped curve' of population growth. According to the available data period before 1891 is evident as the lag phase of growth while the 80 years of period from 1891 to 1971 confirms the natural exponential growth of the population.

After 1971 growth of the population of the city is being experiencing with a slow rate of growth adding less amount of population. It is an indication that the city is in the stationary phase on one hand and exhibits the 'maturity' of growth on the other.

The most important growth phase of the city is the exponential growth phase which occurred during the period from 1891 to 1971. This phase also is characterized with two distinct growth stages which are British colonial period and the period after independence. British colonial period from 1815 extended up to 1946 and which was the initial stimulus of exponential growth of the city.
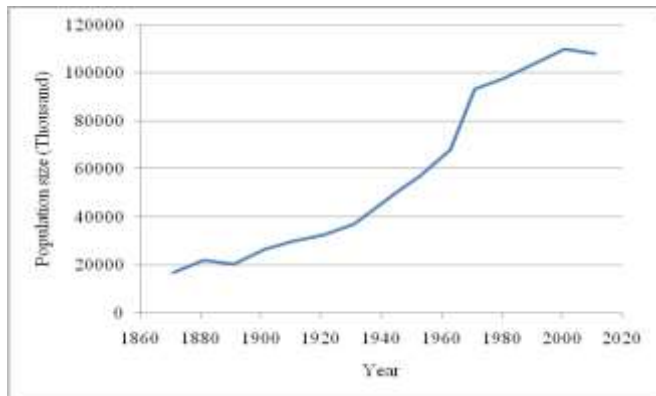

Figure 2. Growth of Population in Kandy City

In 1815 Kandy fall into British Colonial hands and started a new era of development satisfying the needs of the colonial administrators. Various kinds of development efforts and structural changers launched by the British government in the period of British rule absolutely affected the population influx to the Kandy. Improving communication by linking Kandy city with Colombo and other provincial cities in the country was one of the prime objectives of British and it improved the Kandy as the main center for the colonial administration in the hill country in the one hand and the economic growth of the province permitted the British to open up the areas for the coffee plantation. Kandy was linked to Colombo, Trincomalle, Kurunagala and Badulla in the British period. Further construction of railway lines linking Kandy and Colombo and Kandy-Matale allowed communication and transportation very much easy.

The construction of roads and a railway line caused a drastic change in the urban form of the Kandy. The location of the railway station resulted a new entrance to the city. It created a new demands for accommodation facilities, hotels for visitors and guests who came from Colombo and plantation areas and British Constructed three large hotels (Grand hotel, Queens's hotel and Swiss hotel). Contraction of these large buildings brought a new impact on the overall scale of the city. Another important establishment by the British is the Municipal Council as a local authority to look after the management and services in the city in 1829. This progress

and attractiveness of Kandy in the British era gradually created an increasing demand for housing as well the commercial buildings. Due to the limited availability of land within the city for these increasing constructions British brought a drastic change to the city by draining off the Bogambara Lake, filling a major portion of it and extending Dalada Veediya up to Katukale creating new land within the city for housing and other buildings. These alterations in land use and construction of Bogambara Prison in the city added a new configuration in to city. With these increasing demands and alterations the Kandyan upper-class families who first lived in the city center moved out to their homes towns and villages giving rooms to English and Kandy based commercial establishments in the city. Nearly 60 % of the building within the densely built Central Business Areas has constructed between 1856-1950s [10].

Second stage of exponential growth phase which begun after 1948 has future motivated the city growth. As data shows in figure 05 after 1948 net addition the city population and Annual Average Growth Rate have increased than before it. After independence the rapid demand on administration and commercial activities resulted in haphazard uncontrolled physical development in the city. In addition, to the natural growth and the influx to the city boundary extension also remarkably contributed the increase of city population. Total population in the Kandy city has remarkably increased in two occasions since the administrative area of the city has been enlarged. Administrative boundary of the city was enlarged in 1930 in the British era and its impacts are evidently seen in 1946 in which a year with net addition to the population is high. In this occasion city was added 6 new administrative units (Wards) and after independence in 1967 [11] it was added 8 wards subdividing some large units and including relatively developed new areas located northern part of the city. Due to this administrative area expansion, in 1971 city was gained the largest net addition recorded in the 140 years period experiencing a 4.6 percent of Annual Growth Rate.

As data confirm period after 1971 exhibits the stationary nature of the population growth flattening the growth curve. The development concern of the government after independence is accountable for this change. After the independence the successive government carried out the city development programs preserving its own identity as a religious center, historically and architecturally important buildings and acknowledging their contribution to the built form of the city.

With the introduction of open economic policy, economic boom accelerated by private sector participation in the latter part of 1980 and early 1990 created rapid constructions within the city area for commercial, administrative and other uses. This rapid construction on administration and commercial activities resulted in haphazard uncontrolled physical development in the city. Unauthorized constructions with cheaper building materials and modern technology generally

have not been consistent with the world heritage city concept. Along with the development trend many vehicles were brought to the city center and aggravated the problem of the city congestion. Focusing this problematic situation in the city relevant authorities have taken several actions to guide, control and regularize the development occurring haphazardly in the Kandy city.

In this context, Kandy city has been declared as an urban Development area under the law of Urban Development Authority in 1979 [12] and a land use and zoning plan have been prepared in 1981. In addition, with the inauguration of the Kandy project of the UNESCO- Sri Lanka Central Cultural Triangle in 1986s the Kandy was declared as World Heritage city. An Advisory committee was formed after Kandy was declared as a world heritage city to guide and control the future development and a Master Plan for 1995-2005 was prepared by this committee to conserve and protect the city in a proper manner establishing a balanced growth between the "old" and "new" in the light of contemporary needs.

Development plan is the basis for the physical development of a city. It greatly contributes to regularize the development of a city with a proper land use pattern. Development plans which are prepared by Urban Development Authority guide and control the development in the city. Plans which were prepared in 1995-2005 and 2005-2015 have imposed a set of land use zoning regulations focusing its religious importance, historic and architectural value, natural elements and beauty and environmentally sensitiveness and those controlling regulations have greatly contributes the limit of residential activities within the city.

B. Population Density Change in Kandy City

Concentric zonal density maps prepared for visualization of density distribution pattern and change of density gradient over time of Kandy city are presented in *fig*.3, *fig 4*, *fig* 05 and Table 1 obviously demonstrate that the high density zones are found close to the city center from the year 1943 to 1991 indicating the continuous growth of the core. In this period density was high at the city core and its proximity and density is relatively low at the peripheral areas. Central density of the city has increased 2598 persons per sq km from 1943 to 6744 persons per sq km in 1991.This highly compacted nature existed for nearly 50 year period in the city has changed after 1991 shifting high density zones in to the periphery indicating density flattening nature.
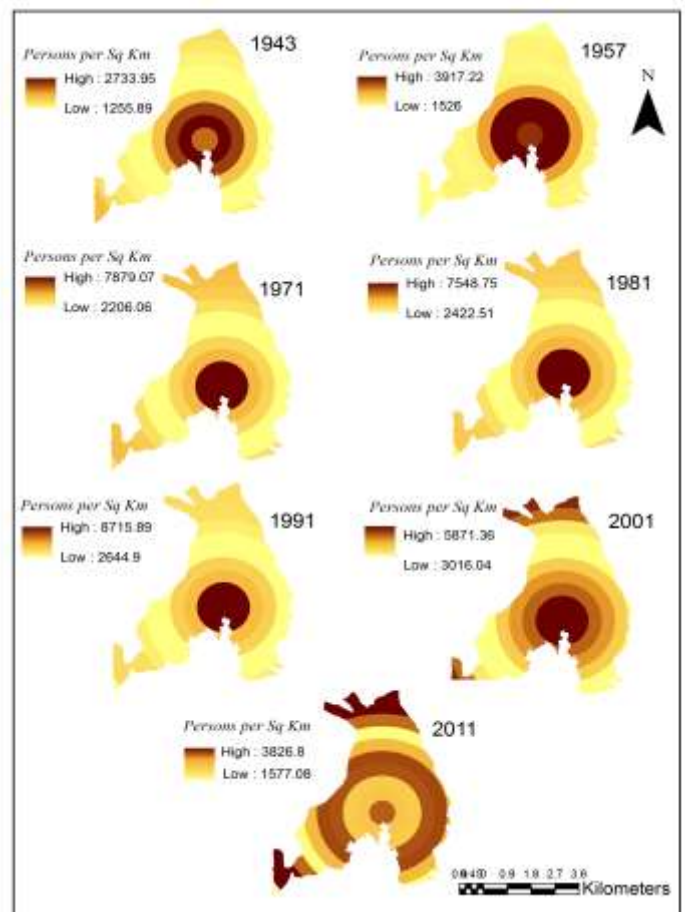

Figure 3. Visualization of Spatio-temporal Density Shifting in Kandy City, 1943-2011
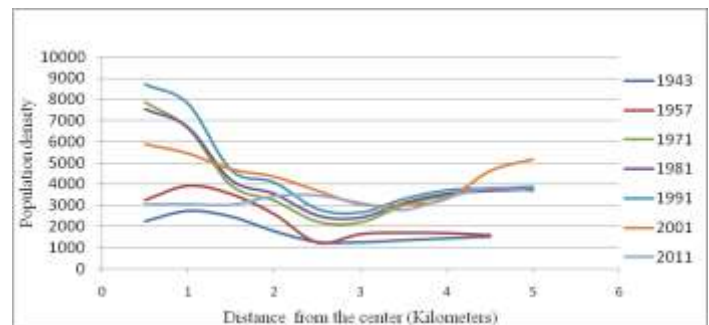

Figure 4. Population Density Change in Kandy City from City Center, 1943- 2011

In view of measuring density change in the city through time by using negative exponential model it is obvious that gradient values have increased from 1943 up to 1991which was the period that city growth associated with the British and local administration(Table 1). Density gradient was peak in the year 1957 and had a little drop in 1971 but has over again increased up to 1991.
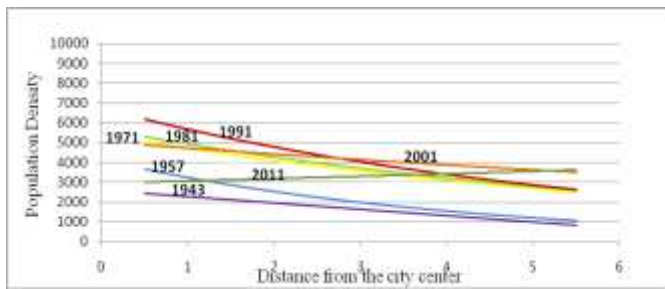
44

Figure 5. Change of Density Gradients in Kandy City from 1943- 2011

TABLE 1. CHANGE OF CENTRAL DENSITY AND DENSITY GRADIENT VALUES IN KANDY CITY -1943-2011

Year	Central Density (D_0) (Persons per sq/ km)	Density Gradient (b)
1943	2598	-0.16
1957	4137	-0.24
1971	5430	-0.13
1981	5681	-0.14
1991	6744	-0.17
2001	5020	-0.06
2011	2946	0.36

Starting point of change of this highly compacted nature is clearly obvious in the year 2001 and further in 2011. Central density has dropped from 6744 persons per sq km in 1991 to 5020 persons per sq km and 2946 persons per sq km further in 2011. Density gradient has declined from -0.17 in 1991 to -0.06 having a more gentle slope. The tendency in this regard in 2011is that the negative exponential curve changed into positive exponential cure is an indication the density increase with the distance. Density gradient is 0.36 for the year 2011 and indicates that the density is much low at the center and is high at the periphery.

IV. Conclusion

This paper mainly focused residential density in evolution of urban structure of world heritage city of Kandy which is one of the oldest historic city in Sri Lanka grown under the influence of foreign and the local administration. As shown by the data over the last 140 years of period city growth has undergone progressively showing the characteristic of 'S-shaped curve' of the population growth. Period before 1891 is evident as 'lag phase of growth' while 80 years of period from 1891 to 1971 confirms the 'exponential growth phase' of the population. After 1971 growth of the city is being experiencing with a slow rate of growth adding less amount of population indicating the city is in the 'stationary phase' exhibiting the 'maturity' of growth.

Population density analysis confirms the general nature of city expansion in the world as postulated by the empirical studies. In the phase of exponential growth in between 1943 to

1991 population density is highest at the city centre from which it exponentially falls with increasing distance from the city centre. The continuous increase of central density in the phase of exponential growth was aggravated by British administration and local political factors after the independence in the country.

During the last 60 year period from 1943 to 2001 Kandy city was highly compacted with the continuous increase of population in its core. This compacted nature has initially changed after 2001 and further 2011 shifting the residential population into its periphery.

After 2001 the city is being experiencing the stationary phase and it exhibits the 'maturity' of urban growth. Density analysis clearly confirms the two hypotheses of world city expansion exhibiting the density declining with increasing distance from the city centre and its flattening nature through time. This spatio-temporal change of residential population of the Kandy city is a sign of decentralization of population which lead the suburbanization trend of the city by the year 2001.

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