CELLULAR AUTOMATA MODELLING IN BANGALORE – A CASE STUDY OF PEENYA – A GEOINFORMATICS APPROACH

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Abstract
Indian cities growth cannot be determined easily because it is complex systems, research scholars and scientists have been able to simulate some of this complexity. One of the simplest but yet successful techniques for doing this is cellular automata(CA).Cellular Automata Model stores the data and information in cells. City like a Bangalore it is very important to do the analysis to study the growth and development. Bangalore is having world's fastest development in term of economic. Rapid changes have been taking place in Bangalore City because of increasing the Land Values every day. Earlier Bangalore City had the name as Garden City but now the view has been changed and it is considered as the IT hub. I am taking Peenya as a case study, because getting result and evaluate it for the small portion of area is easy. Some criteria's have been used to understand the CA Model of Peenya. Maximum use of GIS software and small portion of Image processing have been used. The major objective of my research topic is to identifying the future development will taking place in Study area using cellular based automata modeling.

Keywords: *Cellular Automata, GIS, Image Processing.*

Introduction

The rapid growth of urban areas raises important issues to modern societies in general and to the planning processes in particular. Sustainable development is now the key driver of urban growth imposing detailed scrutiny of trends, strategies, and public policies that are aimed to shape desirable futures. The complexity of these problems is such that there are no direct ways to achieve a solution nor these solutions are based on a single approach. On the one hand the consideration of different inputs – physical, sociological, economic, and historical, among several others – gives the comprehensive planning process, the necessary tools to tackle complexity. On the other hand, this high level of complexity can be a potential weakness, because the problems become increasingly more complex as the natural evolution of societies takes place, demanding from planners new levels of commitment and accuracy in their research and practice. This knowledge can be used to develop models that aim to explain urban phenomena, retain knowledge from urban systems, and forecast planning scenarios. The study presented focus on the application of a cellular automata (CA) model to simulate urban change in the Metropolitan Area of Bangalore. Cellular automata (CA) are becoming increasingly used as urban modelling tools mostly because they are simple to build, flexible to formulate, and capable of generating complex patterns that can emerge from historical evolution trends through the diffusion process.
Cellular automata were initially used to investigate emergent, complex and adaptive behaviour, especially self-organizing systems (Wolfram, 1984). Applied in urban dynamics studies, the CA framework is continuously amended and relaxed to generate realistic patterns. In the original CA, transition rules are universal and applied synchronically to all cells. In real urban processes and forms, however, no single rule governs the behaviour of

the entire system. To solve the rigid transitional rules, urban dynamics CA transition rules are formulated using Boolean statements, and probabilistic expressions such as IF, THEN and ELSE. The flexibility thus gained in these expressions, simplifies the representation of more complex systems (Batty, 1996).

Study Area

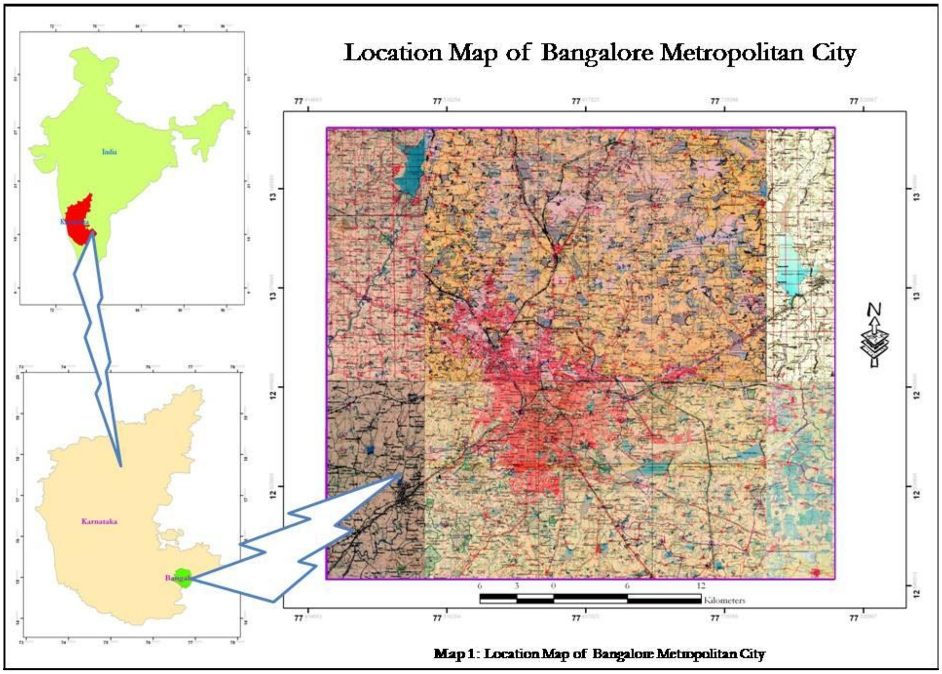

Figure 1. Location Map.

Bangalore city has a colorful past and begin life as the "village of the half-baked gram". At the beginning of 20^{th} century, Bangalore city had many sobriquets like "Pensioner's paradise", since retired army officers preferred to settle in Bangalore in big sprawling houses; the "Garden City" with the green and beautiful maintained Lalbagh and Cubbon Parks in the heart of the city, and the "air-conditioned city" because of its pleasant climate. However today, it is known as the "Fastest growing city in Asia", the city of 21^{st} century" for the potential investors from abroad and the "Silicon Valley of India" for the global electronic and computer giants. The study area forms a major part of the Bangalore Urban and Rural district, which was carved out as a separate district from the original Bangalore district in 1986, to differentiate its urban and rural components. The study area covers the areas of Bangalore Urban districts, 4 taluks namely Bangalore North, Bangalore South, Bangalore East and Anekal. Bangalore rural districts, Part of Hoskote, Devanahalli and Nelamangala. Within these districts study area covers 198 BBMP Wards. The absolute location of the study area is Top left corner **$77^{0}25^{'}49.399^{''}$E** and **$13^{0}11^{'}24.17^{''}$N,** Bottom right corner **$77^{0}47^{'}49.534^{''}$E** and **$12^{0}51^{'}13.526^{''}$N,** the absolute location of the seed point in Bangalore city is **$77^{0}34^{'}34.307^{''}$E** and **$12^{0}58^{'}21.103^{''}$N.** The total geographical study area is **1500** sq km.

Creating Cellular Automata model for Metropolitan city like Bangalore is difficult task. To understand the growth and development of the city CA Model will help us and gives the good result.

Objectives

The major objective of the research papers is to understand the importance of Cellular Automata Model. Only small parcel of area have been taken to evaluate the result. Peenya has been selected for the case study. Criteria for Bangalore and Criteria for Peenya is totally different because I have chosen the criteria based on the geographical area. For Peenya some important criteria have been taken which are having importance in daily life. The study show the CA model of Peenya based on those criteria.

Data Sources

I have used spatial data and non-spatial data for my research. GPS data have been used for the good accuracy. Secondary data like Information form reputed websites that is BMTC, DEPOS, Road Network, Lake Development Authority, Traffic Data have used. Survey of India Toposheets and Satellite Imagery of NRSC also been used.

Methodology

Majority of my work is based on ARC GIS Software, Creating Cellular Automata Models and analysis part done. Minor part of my work done using GPS and Remote Sensing Technology. Field collection data have been processed in SPSS Packages.

Creating CA Model

A cellular automation consists of a grid of cells distributed normally in a matrix form that has the following basic features

Working principle: The CA model in general works by Simulating the present by extrapolating from the past using the image time-series, Validating the simulations via the remotely sensed time-series of past conditions and through the available collection of field observations, Allowing the model to iterate to the year of choice in future and Comparing model outputs to an autoregressive time-series approach for annual conditions

Urban Modeling: The formalism described in the first section adapted to meet the needs of urban researchers in several ways: **Cell space:** of course, the idea of an infinite spatial plain is unrealistic in an urban context. Cellular automata are therefore constrained in their cell space to finite dimensions. **Cell states:** In the traditional cellular automation, cell states are discrete (and quite often binary): alive or dead, one or zero. There is little in the city, however, that is discrete. Most conditions--land use, land value, land coverage, demographic mix, density, etc.--are continuous, and of course urban spaces are multi-faceted. **Neighborhoods:** The idea of the neighborhood in the formal cellular automation is rather restrictive. Urban neighborhoods come in many shapes, configurations, and sizes. **Transition rules**: Perhaps the greatest tinkering with cellular automata models comes in the formulation of the transition rules. It is here that cellular models of urban systems are generated with adherence to what we know in theory about cities. Recently, urban studies using cellular models have introduced an innovative range of parameters into transition rules in a bid to enhance their realism. These parameters have included probabilistic functions, utility-maximization, accessibility calculations, exogenous links and constraints (linking cellular models to other models), weights, hierarchies, inertia, and stochasticity.

Discrete Time: Discrete time is abstract in standard CA. It is corresponding to a certain time point of CA model running only. Therefore, how to match the abstract time to a material date is very important during the process of simulating geography phenomenon using VCA (Vector Cellular Automata).

When we work with satellite images, we consider each pixel of the image as a cell of the cellular automation and we normally take the 8 around pixels as neighborhood (Moore Neighborhood), although we can take the 4 around pixels (von Neumann Neighborhood) or even the 24 around pixels (Extended Moore Neighborhood). The changes in cells states occur in discrete time form. In each iteration the whole cells are checked and rules are applied trough the transition function to each cell taking into account the around neighborhood to change its state.

Fuzzy logic allows the continuous analysis between “false” and “true” and bridges the gap between qualitative and quantitative modeling.Fuzzy logic does not comply with the binary property of dichotomy; hence fuzzy variables may consist of partially overlapping fuzzy sets. When a fuzzy set is meant to manage quantitative (numerical) information, it is fully described by a membership function which returns a membership value (μ) within [0,1] for a given object in the fuzzy set. Otherwise we refer to them as fuzzy symbols.The knowledge base is represented as “IF…THEN” rules, connecting hypotheses to conclusions through a certainty factor.

Combinations of CA and FL have only recently appeared in geographic applications and spatial modeling. Most of them are used to simulate the expansion of spatial or spatially referenced phenomena such as forest firesimulation, electricity load forecasting and urban growth modeling. Regarding the field of urban modeling there are approaches that use FL to calculate some of the CA parameters and approaches that apply fuzzy systems to simulate growth such as the theoretical approach proposed by Dragicevic.

Table 1. To Create Cellular Automata modeling for Bangalore Metropolitan City some weighted criteria’s have been chosen those are listed below.

Sl No	Criteria	Types	Remarks
1	Roads	Important Major Roads, National and State Highways, Core and Ring Roads, Nice Roads and Other	2600 KM
2	Railways and Its Associated Features	Indian Railway, Namma Metro (BMRCL), Mon Railways and Commuters Rail	958 KM
3	Bus Stops	Important Bus Stops, Satellite and TTMC Private Bus Stops	43 Bus Stops
4	Lakes	Dry Lakes, Developed Lakes	236 Lakes
5	Dumping Yards	Working and Non-working	6 Dumping Yards

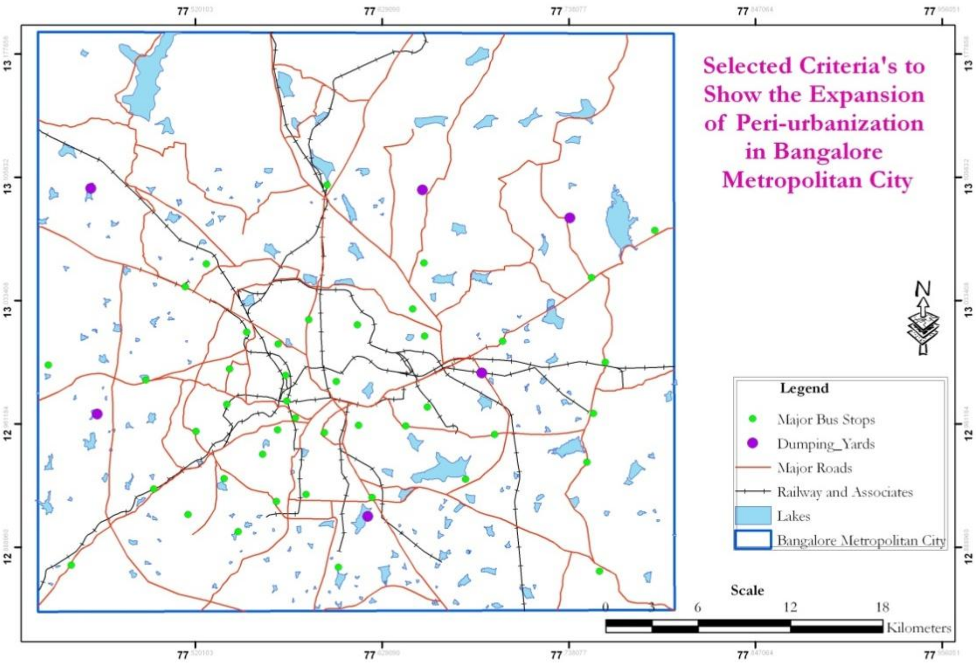

Figure 2. Selected Criteria's to create Cellular Automata Model

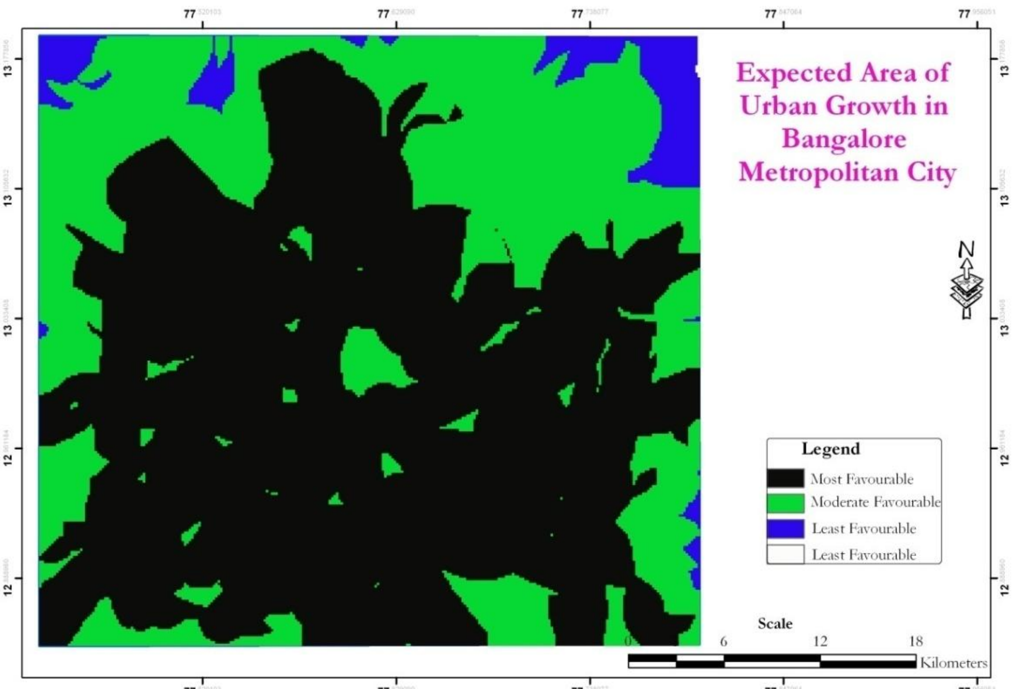

Figure 3. Expected Area of Urban Growth in Bangalore Metropolitan City

Role of GIS in CA based Modeling: In order to be useful and realistic, urban models depend on real-world data such existing urban land uses and growth patterns, existing road network, location of various facilities, availability of infrastructure facilities etc. that can be integrated and mapped in a modeling scenario. Geographic Information Systems have emergeda prime framework for the integration and management of a range of spatial real world data. However, to use GIS alone as a modeling tool have been received with skepticism as it has limited modeling functionalities and has constraints in handling temporal data sets. Nevertheless, GIS and CA in combination can be used as a strong couple to model the urban growth to take advantages of both the techniques. For example, although the capacity of CA to explore complex systems has been well established (Itami, 1994), its capacity to represent real patterns is yet to be proven. In case of GIS, its spatial data analysis capacities may be insufficient to handle complex urban dynamics. The integration of the dynamic strength of CA with the effective spatial representation found in GIS thus may be beneficial to achieve realistic representation of a phenomenon such as urban growth.
The above model is prepared based on the selected criteria's. the chosen major criteria's are Road Network only Major and Important, Railway network and its associated features. Important Bus stops in the city limit and outskirts. Lakes (which have water) and Dumping yards (used to dump city wastes). The map shows the lest to most favourable conditions to live in the city. Some places are located in the city but those places are shown in moderate favourable place. City like Bangalore it is difficult to get the places of least favourable.

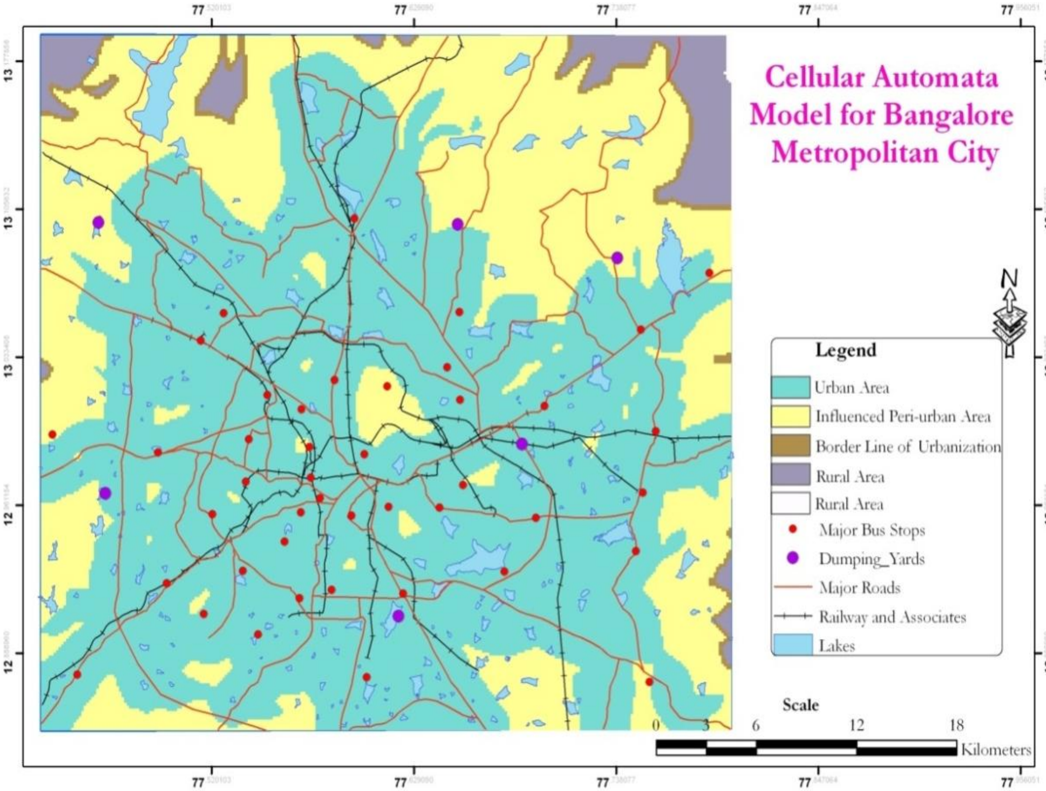

Figure 4. Cellular Automata Model for Bangalore Metropolitan City

Result and Discussion

Peenya is one of the important selected pocket to create Cellular Automata Model. It is well known industrial in Bangalore Metropolitan City.

Peenya – Geographical Setting

Peenya is the name of an industrial area of the Bangalore city in India. It is considered to be one of the largest industrial areas in Asia. Peenya lies on Bangalore-Mangalore. The co-ordinate location of Peenya is 13.033 N Latitude and 77.531 E Longitude. It houses small, medium, and large scale industries.

Peenya Industrial area is covered by 31 BBMP Wards, in that Yeshwanthapura, Jalahalli, HMT Layout, Goraguntepallya, Marappanapallya, Nandhini Layout, Laggere, Peenya Industrial Area, Nagasandra, T Dasarahalli, KalyanaNagara, Bagalkunte, Shettihalli, KuvempuNagara, Vidyaranyapura, RMV II Stage, Mattikere comes within the study area and Atturu, Yelahanka Satellite Town, AramaneNagara, SubramanyaNagara, Hegganahalli, DoodaBidarakallu wards partially covers the Peenya Industrial Area.

The Peenya Industrial area is having the population of 8, 12,243 Persons, average density of the Peenya Industrial area is 1343 person per sq km. From Bangalore city to Peenya the Distance is about 11km. The growth of the Bangalore Metropolitan Region can be seen in the East, Central, South East and South part of the Study area.

The Peenya Industries association, which was founded in 1978 with a handful of enthusiastic entrepreneurs with the objective of safeguarding the interest of industrial units in Peenya Complex, now has 3700 members. Over the years the Association has transformed itself from a welfare organization into a facilitator for the promotion and growth of small-scaleindustries. The Association has attained the status of being recognized by both the Central and State Governments in the formulation of industrial policies. The Association is a registered body under Karnataka Societies Registration Act, 1960.

There are many favourable factors available for selecting Peenya Industrial Area. Further these factors are used to create the Cellular Automata Model for the Peenya Industrial Area. It is difficult to take all the available favorable factors in to consideration, because of unavailability of the data and time scale. The important selected favorable factors are - **Road Network (Major Main Roads), The Major Industries**,**Major Bus Stops and Depot's**, **Transportation and Communication**, **Banking and Finance, Medium-Low Class Residential Area**.

Road network is one of the important favorable factors selected to create Cellular Automata Model for Peenya Industrial Area. The study area has 268 K M of Road network that includes 17 K M of National Highway, 14 K M of Ring Roads and remaining are the major roads connected to the major areas and create the road network for the Peenya Industrial Area.

Peenya Industrial Area includes the major Industrial Hubs like Peenya, Yeshwanthapura, Rajajinagar, Jalahalli East, Jalahalli Village, Jalahalli West, Hengnahalli, Dasarahalli, Laggere and Goraguntepallya. Some of the major Industires are Brindavan Alloys Limited, Karnataka Iron and Metal Industries Private Limited, Pooja Polymer Industries, Balambika Industries, Gokul Das Garments, Gokul Das Exports, Pavithra Engineering Works, Appro Lubes Pvt Ltd, Karnataka Chemical Industries Pvt Ltd, Peenya Industrial Gases Pvt Ltd

The study area has 53 Bus stops, but for the research purpose 19 have been taken and these are considered as important because of the availability of the buses and fulfillment of the passenger requirements. The major bus stops are Yeshwanthapura (TTMC), Jalahalli, Peenya, Goraguntepallya, HMT layout, Vidyaranyapura, Dasarahalli, IISc, ChikkaBanavara, Abbigere and Mattikere. The major Depot's are Yeshwanthapura, Peenya, Jalahalli and Vidyaranyapura.

Peenya Industrial area requires good transportation and communication network, it has been registered good transportation service providers for the raw and manufacturing goods, transportation, and they have Lorry Owner Associations and Other transportation vehicleassociations. Yeshwanthapura, Nandini Layout, Peenya, T Dasarahalli and Jalahalli are the important areas which provide the good transportation facilities. Industrial Area requires good finance and banking facilities. Maps represent the points those are representing the availability of National Banks and private finance. Points plotted only in those areas are having more than a 5 banks. Nine points have been taken for creating C A Model. Peenya Industrial has many low class Residential areas; those are Bagalkunte, Laggere, Heganahalli, Mallasandra, ChikkaBanavara, Shingapura, ChikkaBettahalli, Thindlu, Jalahalli Village, Yeshwanthapura and Peenya Industrial Area. Industrial workers salary and wages are very low compared to the IT Industries, so they are depending on the Low Class Residential areas.

Peenya Industrial Area has many Non-favorable factors but for the study purpose and for creating the Cellular Automata Model two factors has been taken into consideration, those are:**Traffic Jam Spots,Under developed Lakes**.

The study area is having NH, Ring Road and other major roads, so obviously traffic is very high, especially places like Goraguntepallya, Nandini Layout, Yeshwanthapura, Peenya Signal, T Dasarahalli, Metro to Rajkumar Road, Indian Institute of Science and Surrounding areas. Some of these places have flyovers but traffic is not controlled, because of the worst conditions of the roads and large number of vehicles. Nandini layout, IISc and T Dasarahalli area roads are upgrading shortly and many under passes and flyover projects have been taken places.

In Peenya Industrial Area many lakes are not yet taken for the Developmental purpose, so this is one of the Non-favorable factors. Some of the lakes included areChikkaBanavara lake, Abbigerelake, Kempapura lake, Lottegolahalli lake, Shivapur lake. Some industries discharges the industrial waste to these lakes, so government is not concentrating on these lakes.

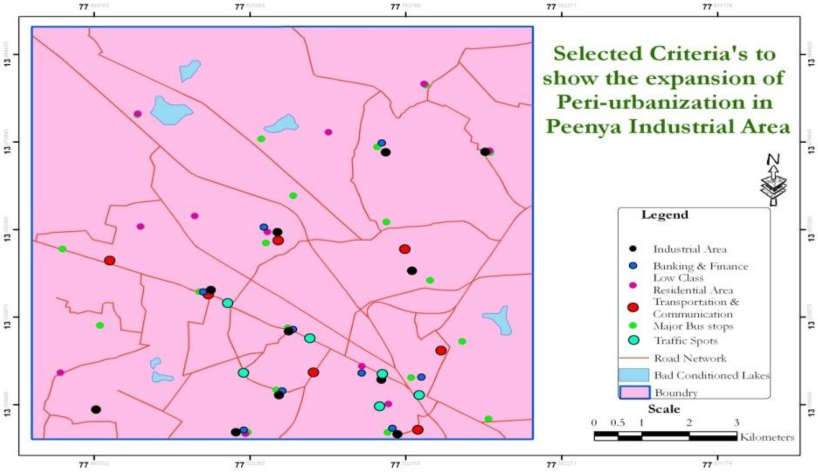

Figure 5. Peenya Map using selected criteri's

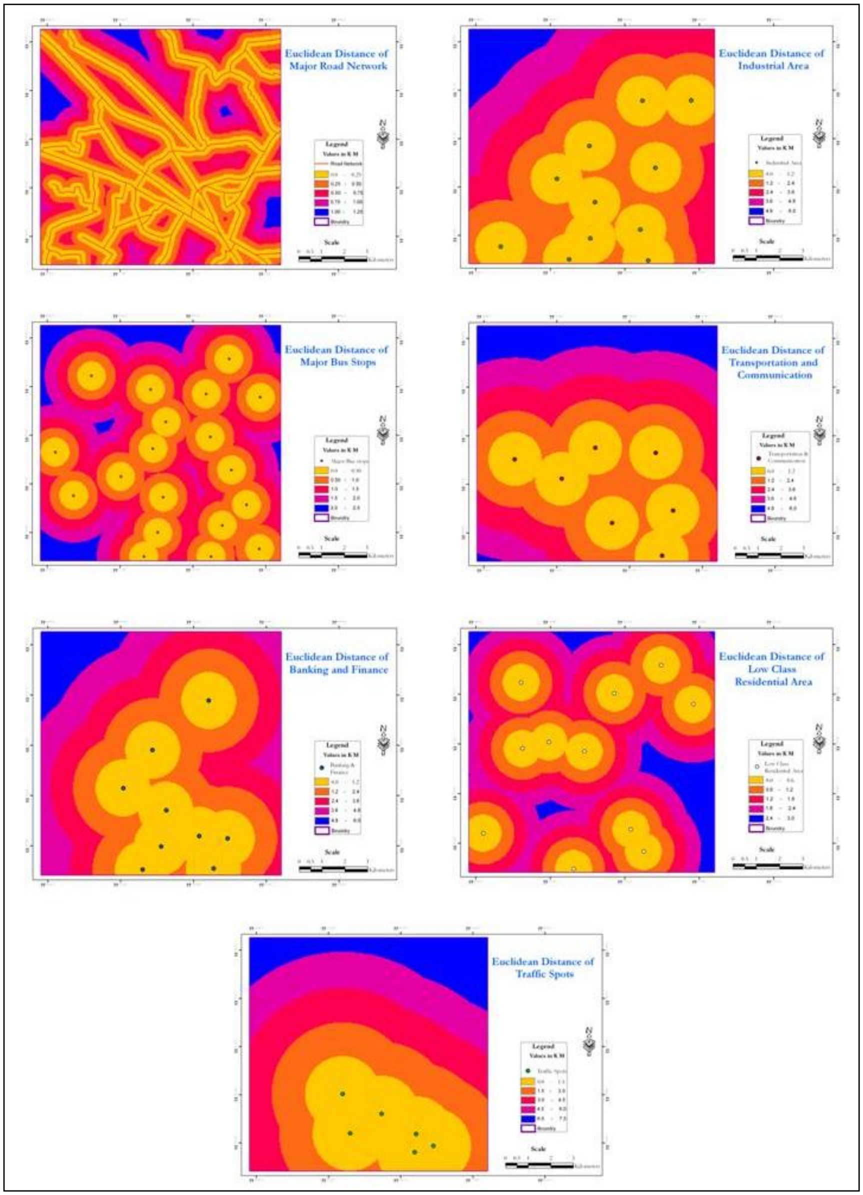

Figure 6. Euclidean Distance Map of Peenya

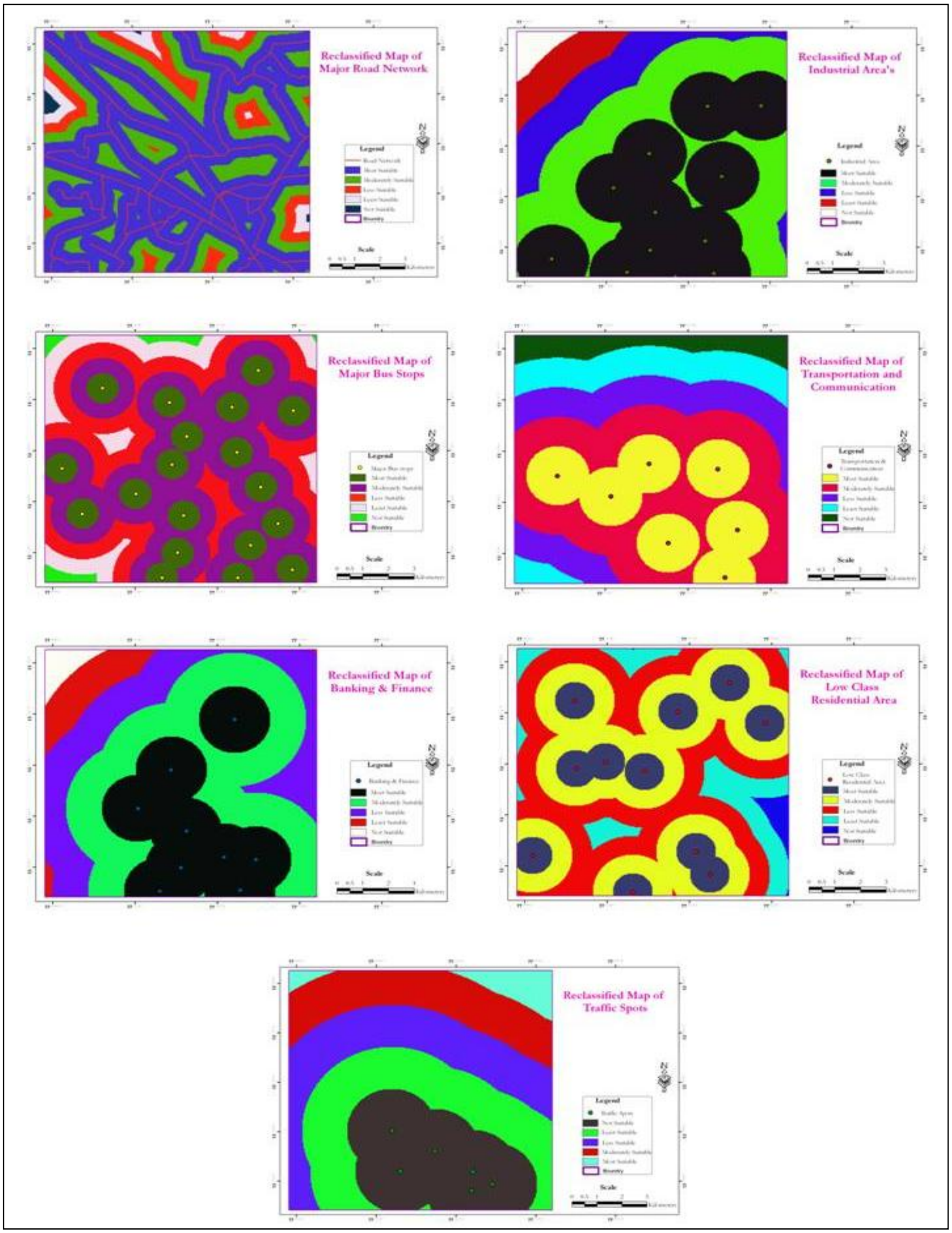

Figure 7. Reclassified Criteria's Map of Peenya

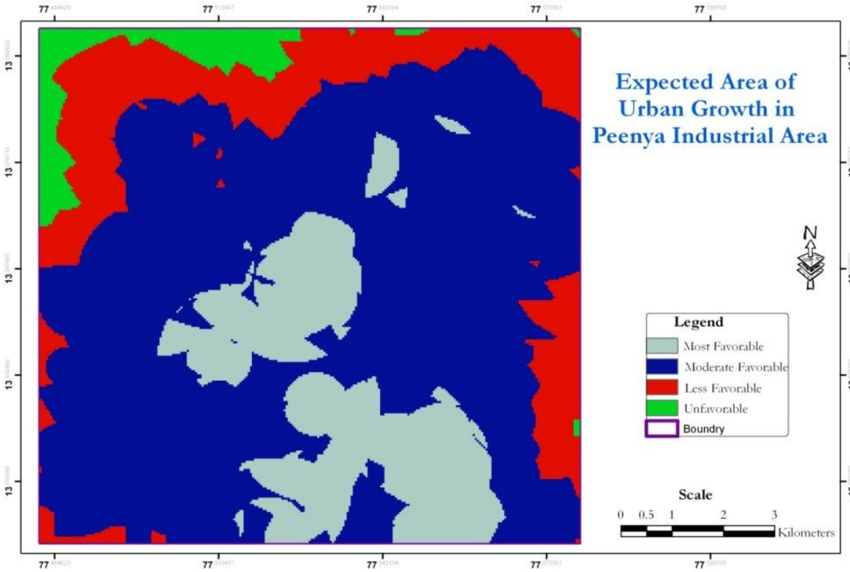

Figure 8. Expected area of Urban Growth in Peenya Industrial Area.

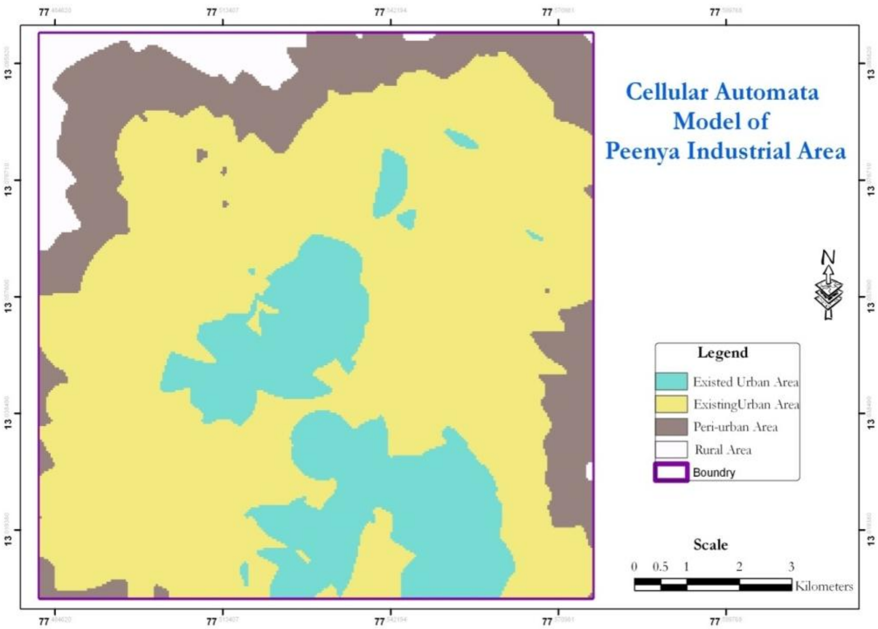

Figure 9. Cellular Automata Model of Peenya Industrial Area.

On the basis of Cellular Automata Model created using certain criteria, shows the result that the peri-urban region in Peenya Industrial Area is spread towards the North, North East and North West corners of the study area. Some of the rural patches were also available in the North West corner of the study area.

Conclusion

Peenya is one of the biggest industrial estates in Asia with an annual turnover of around Rs. 11,000 crores. It contributes over Rs. 1000 crores in terms of Central excise, customs duty, commercial tax and corporate tax. However, Peenya today is an industrial area with poor infrastructure, crying for a proper underground drainage system, roads, footpaths and streetlights. The industrialists in the area pay around Rs. 1 crores every year to the Dasarahalli City Municipal Council. Barring a few stretches of the 268 km road network in the 100 sq. km industrial area, the rest are in a shambles. Many roads resemble mud roads in villages and the carriageway and footpath can hardly be distinguished from each other. Even the main roads have deep potholes.Heavy vehicles carrying goods and machinery find it difficult to negotiate these roads. The estate has a 7.20-lakh-strong workforce, and those using the main thoroughfares in the area experience a nightmare during peak hours. For the women, who constitute 50 per cent of the workforce, using these roads at night can be a harrowing experience as the roads are not properly lit. The appeals and protests organized by industrialists and letters to the State Government and the municipal council have fallen on deaf ears.

Based on the created CA Model of Peenya we can understand the merits and demerits of the study area. Using this kind of models planning can be done for the backward regions.

References

Johan Lahti., Modelling urban growth using cellular automata: A case study of Sydney, Australia, 2008.

Al-Ahmadi, K., et al., Calibration of a fuzzy cellular automata model of urban dynamics in Saudi Arabia. Ecol. Complex. (2008), doi:10.1016/j.ecocom.2008.09.004

Barredo, J.I., Demicheli, L., Lavalle, C., Kasanko, M., McCormick, N., 2004. Modelling future urban scenarios in developing countries: an application case study in Lagos, Nigeria. Environment and Planning B: Planning and Design 32, 65–84.

White, R., Engelen, G., 1997. Cellular automata as the basis of integrated dynamic regional modelling. Environment and Planning B: Planning and Design 24, 235–246.

Clarke, K.C., Hoppen, S., Gaydos, L.J., 1997. A self-modifying cellular automaton model of historical urbanization in the San Francisco Bay area. Environment and Planning B: Planning and Design 24, 247–261.

Lau, K.H., Kam, B.H., 2005. A cellular automata model for urban land-use simulation. Environment and Planning B: Planning and Design 32, 247–263.

Barredo, J., Kasanko, M., Mccormick, N. &Lavalle, C. 2003., Modelling dynamic spatial processes: simulation of urban future scenarios through cellular automata. Landscape and Urban Planning, 64(3), 145-160