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Research Article

Creation of Geo-database with System Model for Peri Urban Areas in Southern Part of Chennai Metropolitan Area

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Abstract: The main objective of this study is to develop a GIS based database for peri urban areas and developing a system model for a reasonable density value. Southern part of the Chennai Metropolitan Area has been selected as the study area. This has been divided into five zones with respect to population and growth. This geo-database consists of land use and population data, collected from Chennai Metropolitan Development Authority. This study has been done under the do minimum condition of taking 275 persons/ha as density value, zone 4, namely Perumbakkam, the excess of floor area (maximum value) observed in the horizon year 334.96 ha. In a desirable condition, taking the density value as 333 persons/ha in zone 2, namely, Okkiyam thuraipakkam, the excess floor area (maximum value) observed in the horizon year was 795.77 ha, whereas in an extreme condition, taking density value as 500 persons/ha in zone 2, namely, Okkiyam thuraipakkam, the excess floor area (maximum value) observed in the horizon year as 1754.07 ha. We have created the geo database for all the five zones with vital attribute data and system model developed for a density value of 275/ha with growth rate of 6% for every year which shows good result in land area availability in all the five zones. Hence, it is recommended that for the development of peri urban areas in southern part of Chennai Metropolitan Area (CMA), this density value may be considered.

Keywords: GIS based database, peri urban, sub urban, sustainability

INTRODUCTION

Urbanization is inevitable, when pressure on land is high, agriculture incomes are low and population increase is excessive this is the case in most of the developing countries of the world. Urbanization has become not only the principal manifestation but also an engine of change, in the 21st century, which has become the centre of urban transition for human society. In the transition from rural to urban, Peri Urban is the third category of area that comes after urban and sub urban area classification.

The Peri Urban areas refer to the settlements beyond, about or around cities. These areas accommodate the spillover developments of the core cities. They often form an immediate urban-rural interface and may eventually evolve into urban areas. Peri Urban characteristizes some activities that occur near the city limits, in the areas that we usually call urban fringes. A majority of them are in the fringe of established areas. However, they may also be clusters of residential development within rural landscapes. They have significant ecological, bio-diversity, land and cultural heritage values. These areas may be within the planning areas but outside the administrative boundaries of the cities. The Peri Urban settlements and the core cities have very strong interactions, inter-dependence and inter-relationships.

Robert and Reinhard (2006) have compared the development of cities between India and Western countries (Western Europe and US). They have found a distinction in the socio-economic groups, which generates Peri urban development. Whereas in the US and Europe, suburbanization is clearly a phenomenon related to the affluent middle class, Peri urban development in India is due to the migration of the economically under privilege.

Motivation for this study: For certain reasons, urbanization is desirable for human development. However, uncontrolled urbanization has been responsible for many of the problems that our cities experience today, resulting in substandard living environment, acute problems of drinking water, noise and air pollution, disposal of waste, traffic congestion etc.

Chennai is one of the major cities in India, which covers an area of 172 km^2 and recorded a population of 43.44 lakhs in 2001 (46.81 lakhs in 2011) and the Chennai Metropolitan Area (CMA), which extends over an area of 1189 km^2 (and keep an extending) has the population of 70.41 lakhs. Due to increase in population, the density of population in CMA has increased from 672 persons/km^2 in 1901 to 5922 persons/km^2 in 2001 and Chennai city has registered an increase from 7800 to 24681 persons/km^2

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Table 1: Number of household in Chennai city and CMA

	No. of households (in lakhs)				Growth rate in percentage			
Households/year	1971	1981	1991	2001	1971	1981	1991	2001
Households in city	4.44	6.29	7.96	9.62	-	41.7	26.55	20.85
Households in CMA	6.89	9.04	11.82	16.19	-	31.2	30.95	36.97

The database been collected from Government of India (2001)

(26903 persons/km^2 in 2011) (CMDA (Chennai Metropolitan Development Authority), 2011; Government of India, 2001).

The urban problems occur due to the concentration of too many activities in a very small space and inefficient relationships of work places and residences. For the past three decades, the increase in number of residential housing units is more in Chennai city compared to CMA. Nevertheless, the percentage increase in the city is on the decline, since persons who migrate to Chennai also have the tendency to settle within CMA but outside the city, due to congestion, lack of infrastructural facilities, high cost of land value and other problems seen within the city. Table 1 shows that households' growth rate keep on decrease in city region rather compared to CMA region.

The objective of this study is to study and appreciate Peri Urban development in CMA and to develop GIS based database and perform color-coding for a spatial extent of the study area. In order to establish the adequacy level with regard to population density for Peri Urban areas and land use, we have developed a System Dynamics model that recommends the best scenario and policy guidelines towards sustainability of Peri Urban planning. The scope of this study is to build the population and corresponding landuse model with present growth condition to the future requirement and test at with various scenarios for future population into developable residential land and out of this scenario, to choose the appropriate one for recommendation it, for a better livable peri urban in future.

PERI-URBAN DEVELOPMENT

Melbourne's peri-urban region: According to Researchers from the School of Global Studies, Social Science and Planning, RMIT University (Buxton *et al.*, 2008) Melbourne's peri-urban area development is influenced by the capacity of the residents to support a commuting population, who travel long distances to work in regional or metropolitan centers.

Key regional forces driving changes are suburbanization, counter-urbanization, population retention and centripetal migration. Factors affecting regions and communities include demographic changes, power relationships, institutional arrangements, regional cultures and government policies. Contiguous metropolitan areas exert strong regional impacts on peri-urban areas by acting as sources of demand for peri-urban amenities and values and by attracting peri-urban residents to employment, recreational and cultural opportunities.

Role of peri urban areas development: Praveenkumar *et al*. (2011) have built a micro level system dynamic simulation model for south Chennai‘s periurban area population and calculated the required residential area to accommodate the predicted population. They have taken up Chennai Southern corridor as the study area. In this corridor, they have identified 33 Peri Urban areas, which indicate a high potential for future development. Then these areas have been grouped into five zones with a core village in each zone. The core villages have been identified based on population and growth. The development of core village leads to development of other villages associated with it automatically.

As part of this study, a Household Survey was conducted in a few Peri Urban areas, by taking 100 samples at random. This survey had collected information about water quality and quantity, electricity, road facility, transportation accessibility, solid waste collection by interrogating households with formatted questionnaire and raplics have been noted. The results were inferred in terms of pie charts for all categories separately.

Finally, some of recommendations from this study say that FSI could increase to two or three in order to accommodate more number of people in future (current FSI is 1.5). Development of Peri Urban areas will become highly significant to counteract climate change and environmental degradation in future. Development of Peri Urban areas should be sustainable in order to face water shortage and inadequacy in the entire basic and essential infrastructure.

DENSITY DEFINITION

Measuring urban density: An Overview of Urban Density (2012) was provided and it is a very specific measurement of the population of an urbanized area, excluding non-urban land-uses. Non-urban uses include regional open space, agriculture and water-bodies. There are varieties of other ways for measuring the density of urban areas:

Determining development density: According to Oh *et al*. (2005) research aimed at developing an integrated framework for assessing urban carrying capacity, can determine development density based on current infrastructures and land use.

GIS APPLICATION ON URBAN DEVELOPMENT

GIS Modeling Technology is meant to support complex environmental and planning issues. In a real regional planning, intensive spatial data processing is usually required, using geo-processing tools to produce output datasets. During a customary GIS work for regional planning, GIS analysts use specific geo-processing tools to perform a logical sequence of tasks (a geo-processing workflow). They should keep track of the work steps performed and make out a good documentation of all input/output data; if something changes (e.g., a land use changes), most of the work has to be repeated. A GIS spatial model makes this easier-it automates the workflows by connecting tasks and processes together (Schaller and Mattos, 2009).

Monitoring land-use changes by GIS and remote sensing techniques: Selçuk *et al*. (2003) have examined land-use changes in Trabzon over the year 1960-2000 and exposed changes in residential areas and shoreline changes in order to detect and control on urban encroachment using Remote Sensing and GIS. In this study, they have acquired data for a 31 k^2 area in order to determine Trabzon's land-use changes in the last 40 years.

In this respect, Standard Topographic Maps, produced in 1960 in scale of 1/25,000, digitized and required vector data overlaid on it. Besides, four aerial photographs-1974, Landsat 5 TM image-1986 and Landsat 7 TM+ image-2000 has been provided. This data can be processed using GIS and Remote Sensing techniques. When the improvement of the Trabzon city was observed from historical time to the present, there was a physical growth from the city-centre to outer places. Due to this inclination, surrounding green fields of the city has become exposed to the adverse effect of constant urban growth.

The city Trabzon had a stable development stage until 1920. Between 1920 and1960, an outer spread of urban residential growth started gradually. Between 1960 and 1985, with a considerable population growth, spreading of residential growth gained considerable speed. Especially between 1985 and 2000 years period, this spreading continued at an enhanced speed. In the event, this urban development regime will continue increasingly until required precautions do not take off.

In monitoring the city that has a rapid changing characteristic, the analysis of broad areas with satellite images is far easier and faster than the classical surveying methods, especially for the administrators and provide a high-level approach chance to the urban improvement in total. Urban growing areas should be channeled under the control of local authorities, using GIS and Remote Sensing techniques especially in planning stages and monitoring urban areas.

A method for planning mandatory green: Ziyu and Wowo (2011) has aimed at developing a model for generating the mandatory green plan and implementing it in GIS, to further develop a feasible model by reviewing the relevant laws and regulations and summarize generating rules of the mandatory green, in addition and applying the developed model in a test case. Yuhua District in Nanjing, China was taken as study area. Based on the regulatory plans of this area, a GIS data layer was first assembled. A model was built to generate the final plan of mandatory green for the study area. Compared with the modeled mandatory green plan, the regulatory green plan was arbitrary and failed to comply with legal requirements.

All the legal parameters concerning mandatory green aim to protect people from different kinds of hazards and nuisances, including noise, dust, pollution and fire. Sources of these hazards were centralized at roads, power lines, railways, water bodies and industrial lands. The mandatory green is in the form of a buffer area with different widths. The difference in buffer widths is determined by the kinds and levels of hazards to be prevented or mitigated and takes into account the land use of the neighborhood. Despite these differences, it is easy to determine the mandatory green by GIS buffer analysis.

The GIS model includes three steps such as processing input data, assigning buffer widths and applying spatial analysis. The spatial analysis tools that are mostly used include buffer analysis, union analysis and intersect analysis. These tools are applied to calculate the location and area of mandatory green. In order to simplify the operation and improve efficiency, they used the Model Builder tool to integrate all the operations of spatial analysis into a comprehensive autonomous generating model of mandatory green.

Generating mandatory green in GIS directly connects the requirements of laws and regulations to real situations reality with the help of the model, the quantitative parameters are converted to a plan automatically. Both the location and area of mandatory green is guaranteed and land resources will not be a waste. The calculation result of the model could be used directly as a reference for planners, as well as assessing criteria for the government.

The results have been compared with either regulatory plans or reality; the difference could be visualized intuitively. Since all parameters of the model have been extracted from both national and local regulations, the generating model could be applied to different zones of China with appropriate adjustments in accordance with local regulations. The measurement of some hazards such as a concentration of carbon dioxide or a heat island effect may vary continuously and be subject to dominant wind direction. The buffering algorithm used in the current model could not be applied to such cases.

Formulating a sustainable development land use scenario using GIS: Christopher (2002) has formulated the sustainable land use scenario using ArcGIS 8. The shire (township) of Hervey Bay was selected as study area which is situated along the east coast of Australia and includes North Fraser Island, on the principle of sustainable development by working closely with the Hervey Bay City Council's Integrated Planning Unit (IPU).

Driving the model: A number of socio-economic, physical and environmental data inputs have been collexted from a wide range of national, state and local government agencies and used to formulate the strategic planning scenario. Core physical and environmental data inputs include cadastral land parcels, building footprints, road, sewer, water, land use, remnant vegetation, national parks, state forests, riparian vegetated areas, coastal wetlands, areas of prime agricultural land, areas of indigenous significance and existing open space.

ArcGIS was used to manage the various data sets and enter them into What if? 1.1, allowing the Hervey Bay City Council IPU to quickly begin running and testing various planning scenarios. The process was iterative in that a number of draft scenarios were formulated and compared before the final scenario was derived. The formulation of each of the draft planning scenarios requires the council planners to specify the suitability factors that would affect the future allocation of specific land uses. What if? presented the planners with an intuitive.

The final scenario generated for Hervey Bay focused on the principle of sustainable development, incorporating areas of both environmental and economic significance and allowing trade-offs to occur between these sometimes conflicting concerns. The Hervey Bay City Council IPU developed the final set of suitability factor weightings and ratings to generate the digitally developed future land use strategy. By overlaying the existing city boundary, the existing land capacity of the city was analyzed with respect to the projected land use location-allocations for 2021. The results show that the existing city boundary needs to be extended to accommodate the projected increase in low-density residential and park-residential land use categories.

In rural and coastal local government areas in Australia, strategic plans are updated and gazette (published) approximately, every 5 or 6 years. Traditionally these plans have been maticulasively formulated through the use of expert knowledge and visual interpretation of paper map outputs and tabular information. Tools such as ArcGIS and What if? 1.1 allow alternative scenarios to be generated easily, tested and regenerated and presented to council members and the community for feedback, improving the decision making process.

GIS model applications: Schaller and Mattos (2009) aimed at the development of GIS processing tools and models to support regional environmental planning and management in a 5-year cooperation between the Universities of Munich (Germany) and Redlands (USA). Large spatial databases were structured and modern geo-processing technologies such as ESRI’s ModelBuilder have been used to develop frameworks of GIS models and decision support tools.

Planners with no GIS expertise are able to run ModelBuilder models as their use is based on intuition. The models also make the sharing of planning process with other planners, decision makers and the public easier. The models may be stored and used as a template for different applications or for planning other regions with similar planning requirements.

The results include a Decision Support System in the form of a complete database, models that can be easily adjusted to different planning goals or regions and allow identification of land use conflicts, sensitivity analysis, assessment of development scenarios and their impacts, besides a graphical representation of the processing workflows and high quality output maps. Actual planning projects were the bases for application examples in the Munich Region: the Landscape Development Concept and the urban growth model framework.

METHODOLOGY AND DATA COLLECTION

Planning of a project has to be done before its implementations carrying. Methodology flow chart is defined by incorporating ideas and the steps involved for the project implementation. Identification of goal and defining objective will always be the first step followed by review of literature and selection of study area.

Methodology framework: Problem identification is the first and foremost step for any study. The present study deals with phenomenon of increasing urban population along the study area. The objectives have been formulated after thorough review of literature to frame the methodology for the study.

Data collection: The study area chosen consists of Peri urban areas of the southern part of CMA. The data has been collected as Secondary data. Following are the data collected from Chennai Metropolitan Development Authority and Government of India.

The following Table 2 shows the each panchayat union’s population (over the past decades) as well as residential area in 2006.

Table 2: Population and residential area data for study area

Village name	Population for the corresponding year 1971	1981	1991	2001	Residential area in ha (2006)
Agaramthen	818	1042	1199	1222	47.75
Arasankalani	118	163	284	527	11.36
Injambakkam	1684	2387	5151	10117	169.48
Jaladampettai	812	983	5062	7240	93.02
Karapakkam	312	1416	2587	3795	44.17
Kasapapuram	200	261	452	603	28.04
Kottivakkam	2138	3650	11856	13884	156.12
Kovilambakkam	985	1273	5673	9277	64.58
Kovilancheri	422	532	714	572	10.93
Kulapakkam	953	1167	1980	2825	47.25
Kulathur	523	666	-	2098	80.14
Madipakkam	2692	3431	11437	15548	246.71
Maduraipakkam	286	327	416	727	11.63
Medavakkam	2789	3939	6432	9725	162.24
Meppedu	-	-	-	-	-
Mulacheri	76	96	149	770	16.71
Muvarasampattu	949	3046	5819	6162	59.09
Nanmangalam	887	1240	2101	3323	115.40
Nedunkundram	2635	1710	4935	6870	65.48
Neelangarai	1151	2451	7134	15637	234.76
Okkiyam thuraipakkam	2192	3088	9679	25952	315.29
Ottiyambakkam	528	689	902	811	30.44
Palavakkam	1047	3433	10969	14361	149.06
Perumbakkam	1385	2229	3673	8081	200.08
Perundavakkam	94	120	-	-	19.80
Puthur	668	3223	947	1243	14.91
Semmancheri	713	928	1582	3744	67.94
Sittilapakkam	984	1218	2279	4989	90.45
Thirusulam	2395	4802	5572	5973	53.36
Thiruvancheri	529	771	1355	638	29.72
Uthandi	999	1434	2178	2497	67.10
Vengaivasal	1352	1791	3298	8892	112.70
Vengambakkam	573	705	861	1142	33.28

Compiled from Government of India (2001) and CMDA (2011)

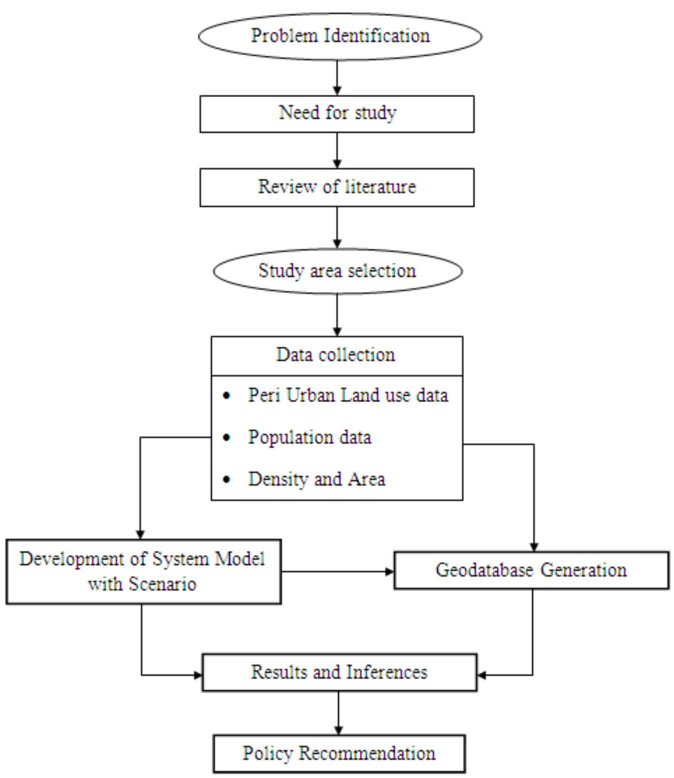

Fig. 1: Study methodology

Steps followed in the analysis:

- Creation of thematic maps using GIS techniques for Study area.
- Areas required for urbanization have been determined based on population projection using system dynamics model.
- Do minimum develop partial effect and Desirable scenarios and analyze for suitable adaptation. Here a flow chart indicating the various steps involved been shown in Fig. 1.

STUDY AREA

CMA (Chennai Metropolitan Area) consists of many peri urban areas around the city. Among these area, peri urban areas coming under southern corridor indicate high potential growth in future. Major educational institutions located in the southern corridor enhance the possibility of development in future. It shows that migration is comparatively more in southern region and this increases the scope for study. Therefore, the southern corridor has been taken as study area. The selected Punchayat Unions in Southern part of Chennai Metropolitan Area (CMA), is bounded by NH 45 (west), city boundary (north), shoreline (east) and the CMA boundary limit (south). Graphical representation of Study area shown in Fig. 2.

The villages are grouped into five zones. Each zone is provided with a core village and every other village depends on the corresponding core village. The Core village is chosen based on its high population and growth rate. The following are the zones:

Zone 1: Madipakkam: Zone 1 consists of the following four village: Madipakkam, Perundavakkam, Thirusulam, Muvarasampattu and core village among them is Madipakkam.

Zone 2: Okkiyam thuraipakkam: The core village in zone 2 is Okkiyam Thuraipakkam and it consists of the following six villages, Okkiyam, Thuraipakkam Karapakkam, Injambakkam, Neelangarai, Palavakkam, Kottivakkam.

Zone 3: Medavakkam: The core village is Medavakkam. The following six villages comes under this zone: Medavakkam, Vengaivasal, Jaladampettai, Kulathur, Kovilambakkam Nanmangalam.

Zone 4: Perumbakkam: The core village is Perumbakkam and it consists of the following nine villages: Perumbakkam, Sittalapakkam, Arasankalani, Ottiyambakkam Kovilancheri, Maduraipakkam, Mulacheri, Semmancheri, Uthandi.

Zone 5: Nedunkundram: This zone consists of the following eight villages and the core village as Nedunkundram: Nedunkundram, Kulapakkam, Puthur, Meppadu, Thiruvanjeri, Kaspapuram, Vengambakkam, Agaramthen.

Model development and analysis: Generally, all data have three major components-position (spatial), attributes (thematic) and time (temporal). In the Geographical Information System (GIS), attribute data (often termed as thematic data or non-spatial data) are linked with spatial data or geometric data. An attribute has defined characteristics of entity in the real world.

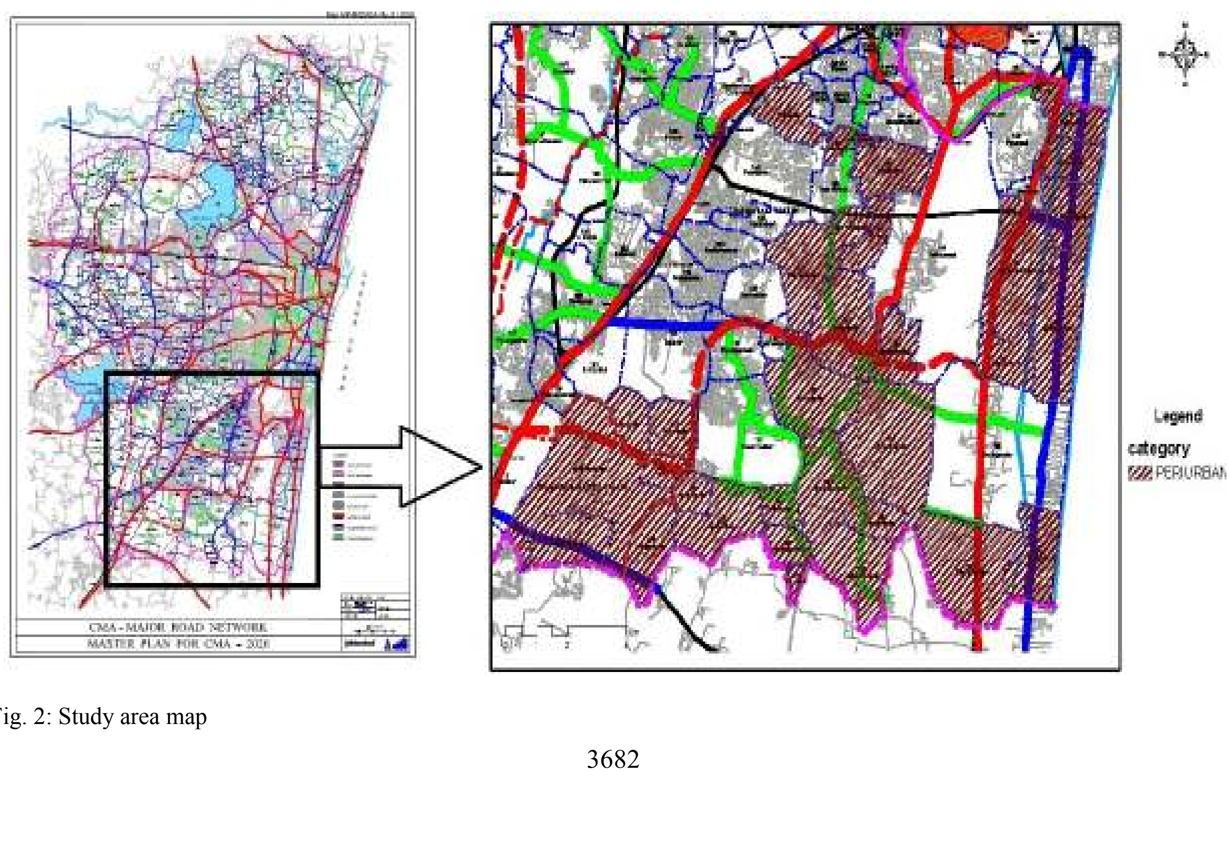

Fig. 2: Study area map

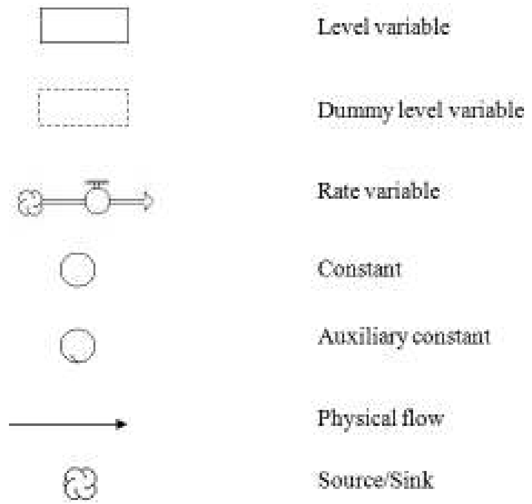

Fig. 3: System dynamics flow diagramming symbols

Attributes can be categorized as normal, ordinal, numerical, conditional and other characteristics. Attribute values are often listed in attribute tables, which establishes relationships between the attributes and spatial data (such as point, line and area objects) and among the attributes as well. Conventionally, databases store non-spatial data. However, in GIS, all entities are spatial entities linked with attributes. As a result, the conventional concept of database has been adapted to GIS in various ways.

Data models in GIS: The GIS uses several models to store geographic data. Relational data model (often called geo-relational data model) is one of the popular data models, which uses a split data system by storing spatial data and attribute data in separate files. Linked by the key field, the two data files are synchronized so that both types of data can be queried, analyzed and displayed in a common denominator.

Object-oriented data model is the most widely used data model in GIS and distinguishes spatial data from attribute data but stores both in a single database (often called geo-database). The Object-Oriented (OO) GIS data model offers common storage of spatial data inside Relational Database Management Systems (RDBMS). The OO GIS data model can exist inside a standard corporate relational database, the concept that combines the features of OO data model and relational data model, is often called object-relational data model.

Some experts believe that the development of the OO GIS data model is the most significant advancement in GIS technology in the last 10 years. Unlike the traditional GIS data models, which involve a myriad of linkages between data tables and between spatial and attribute data stored in different files, the OO GIS data model can accommodate vector and raster data, data tables and other GIS objects in a single, central repository.

Concept of system dynamics: System Dynamics (SD) is a methodology and computer simulation modeling technique for framing, understanding and discussing complex issues and problems. In addition, it is widely used to gain an understanding of a system with complex, dynamic and nonlinearly interacting variables. It allows a system to be represented as a feedback system.

System dynamics model development: For ease of presentation, the symbols used for flow diagramming of SD have been presented in Fig. 3.

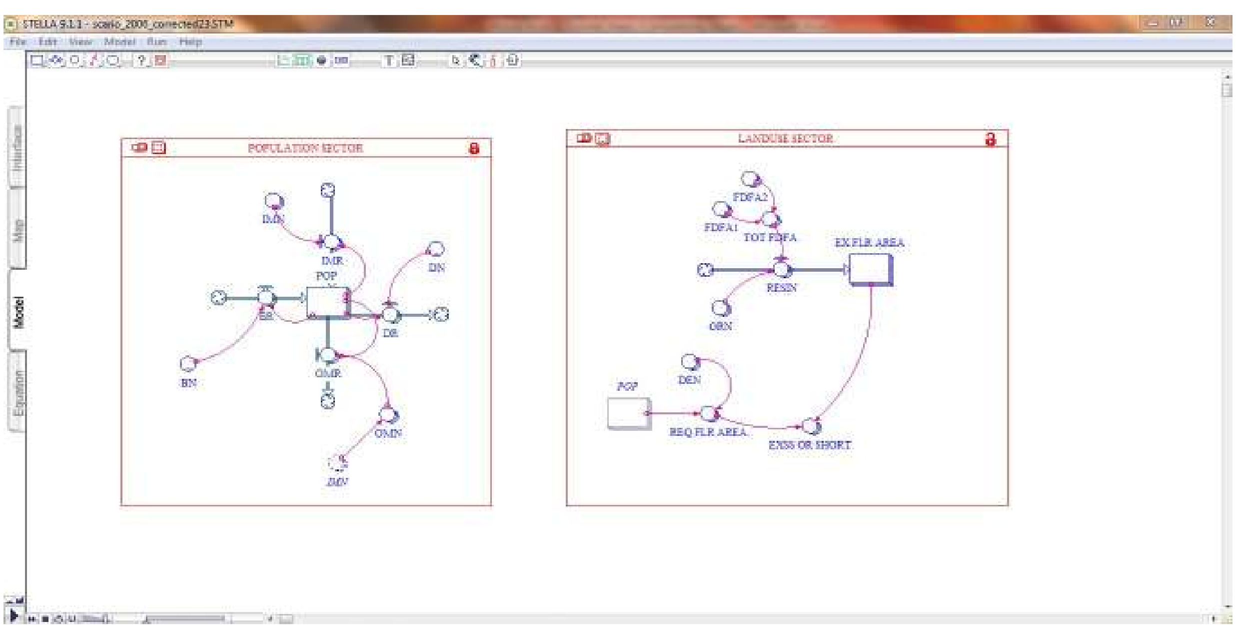

Fig. 4: Simulation model for all five zones

The system dynamics model has four basic building as listed below:

- **Stocks:** Stocks or levels are used to represent anything that accumulates. An example of stock would be population level at one point of time.
- **Flows:** Flows or rates represent activities that increase and decrease stocks. An example of flow includes birth rate or death rate.
- **Connectors:** Connectors are used to establish the relationship among variables in the model. They are represented graphically by the structure as arrows and the direction of the arrow indicates the dependency relationships. They carry information that can be a quantity, a constant, an algebraic relationship or a graphical relationship.
- **Converters:** Converters transform input into output. Converters can accept input in the form of algebraic relationships, graphs and tables.

The model of population projection is presented in this study. The modeling tool, which operates in an object-oriented simulation environment, allows the development of population projection models with significantly less effort than using traditional programming languages. It has a user-friendly graphical interface and supports modular program development. Building on these strengths the general architecture of a population projection model is described.

Model development using STELLA: The system dynamics model for the Study area is shown in Fig. 4 This can be developed in two sectors as population sector and land-use sector.

This model has been run for all five zones with various scenarios using the built-in function of Array editor.

Introduction to arrays: In many cases, copy and paste is the most straightforward way to represent the multiple parallel model structures involved. Unfortunately, the associated visual complexity of the resulting model diagram can become difficult to manage, for both the builder and the user of the model Arrays provide a simple, yet a powerful mechanism for managing this visual complexity. By "encapsulating" parallel model structures, arrays can help developer to present the essence of a situation in a simple diagram. Beneath the scenes, of course, arrays retain the richness of the disaggregated structure.

Introducing arrays into a model is conceptually straightforward. The process consists of three simple steps:

- **Use the array editor to define one or more dimensions:** A dimension is simply a category. Each dimension contains a set of elements. Select The Array Editor button on the Interface menu, the Model menu, or the Equations menu. In addition, it also get from within the define dialog of any arrayed variable.
- **Transform model variables into arrayed variables:** After defining one or more dimensions, transform non-arrayed variables into arrayed variables. To make the transformation, simply check the Array check box within the define dialog of any stock or converter. Whenever a stock is transform into an arrayed stock, any attached flows are automatically transformed into arrayed entities as well.
- **Define the equation logic for arrayed variables:** Within each arrayed variable, define the equation logic for each element within the array. It is possible to apply a single, generic equation to all elements within the array. Alternately, by "page through" the individual elements are arrayed in a variable in order to apply unique numerical values or equation definitions for each element.

Population sector: Population for each zone is a level variable for the southern corridor region. Factors like Birth Rate, Death Rate, In-Migration Rate and Out-Migration Rate influence the level. Birth and In-migration lead to positive population growth. Therefore, these two are input flows into the Population level. On the other hand, death and Out-migration are output flow from the Population level, leading to negative population growth. The following Fig. 5 shows the population sector and the abbreviation used in simulation software for all variables:

BN : Birth Normal
BR : Birth Rate
DN : Death Normal
DR : Death Rate
IMN : In-Migration Normal
IMR : In-Migration Rate
OMN : Out-Migration Normal
OMR : Out-Migration Rate
POP : Population

Therefore, this population model gives the output of population per year as per following formula:

Population = Population (initial) + Birth rate [Population (initial) *Birth normal] + In-migration rate [Population (initial) *In-migration normal]-Death rate [Population (initial) *Death normal]-Out-migration rate [Population (initial) *Out-migration normal]

The initial populations for zone 1, 2, 3, 4 and 5 are 40555, 83540, 27803, 22718 and 14543 respectively. The condition for Birth normal varies from 25/1000

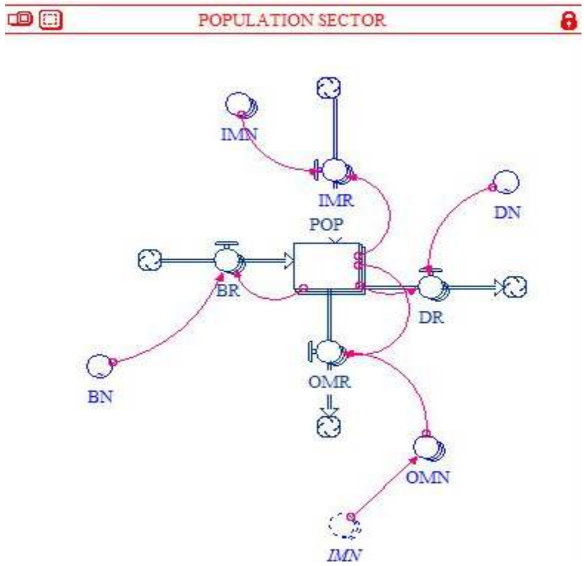

Fig. 5: Population sector for all five zones

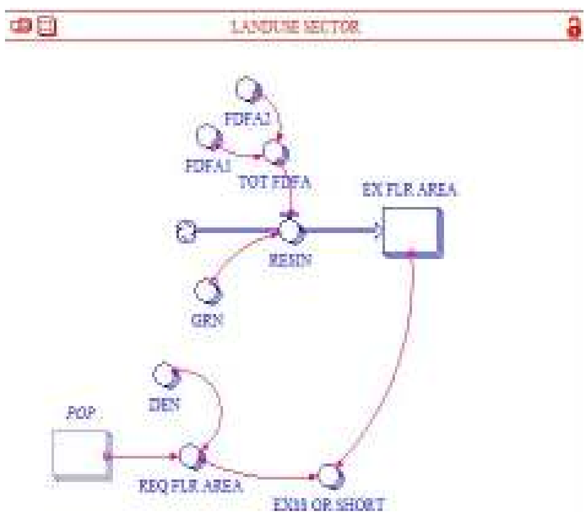

Fig. 6: Land-use sector model

Table 3: Available residential area in each zone

Zone	Residential area in ha	Total area in ha
1	378.96	674.7
2	1068.88	2221
3	628.08	2115
4	506.64	3352
5	266.43	2858

CMDA (2008 www.cmdachennai.gov.in)

persons to 10/1000 persons, Death normal varies from 10/1000 to 7/1000, In-Migration taken as 5%, Out-Migration taken from 10% of the In-Migration while projecting from the year 2001 to 2026, based on the trend and health policies of Central Government.

Land use sector: Like the population model, the existing residential floor area for every year can be developed with respect to the growth rate of residential intensity and available residential area of the each zone. Residential intensity is inflow into level because of positive polarization. Table 3 shows the Available residential area (plot area) for each zone and total area of each zone, which has collected from the CMDA.

The following are abbreviation used in this sector and in Fig. 6:

EX FLR AREA	: Existing Floor Area
RESIN	: Residential Intensity
FDFA1	: Future Developable Floor Area 1
FDFA2	: Future Developable Floor Area 2
TOT FDFA	: Total Future Developable Floor Area
GRN	: Growth Rate Normal
DEN	: Density
REQ FLR AREA	: Required Floor Area
EXSS OR SHORT	: Excess or Shortage

Initial formula as follows:

Future Developable Floor Area1 = existing residential area (remaining percentage from already developed) * plot coverage for constructing house * undeveloped remaining FSI.

Future Developable Floor Area2 = existing residential area (percentage from yet to be developed) * plot coverage for constructing house * undeveloped FSI.

Total Future Developable Floor Area = Future Developable Floor Area1 + Future Developable Floor Area 2.

Existing Floor Area = existing residential area (percentage from already developed) * plot coverage for constructing house (65% of plot area) * developed FSI:

Required Floor Area = Population/Density

Excess or shortage = Existing Floor Area - Required Floor Area

This sector has been built to test the model with scenarios for do minimum, desirable and extreme cases. First, the required residential floor area is calculated by dividing projected population (from population sector) with the desired density. Secondly, the difference between the existing residential floor area and the required floor area indicates excess or shortage in residential floor area. Initial condition for this sector of, Density for do minimum, desirable and extreme conditions are respectively 275/ha, 333/ha, 500/ha. Its positive (excess of floor area) or negative (shortage of residential floor area) signs can judge the output from excess or shortage.

RESULTS AND INFERENCES

The zone data has been built with the birth rate, death rate, in-migration rate and out-migration rate.

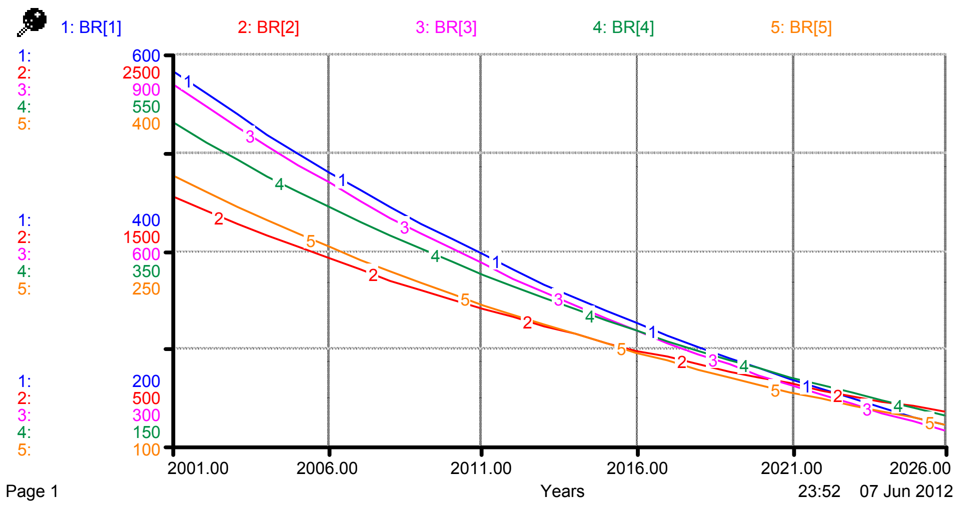

Fig. 7: Population sector-birth rate growth

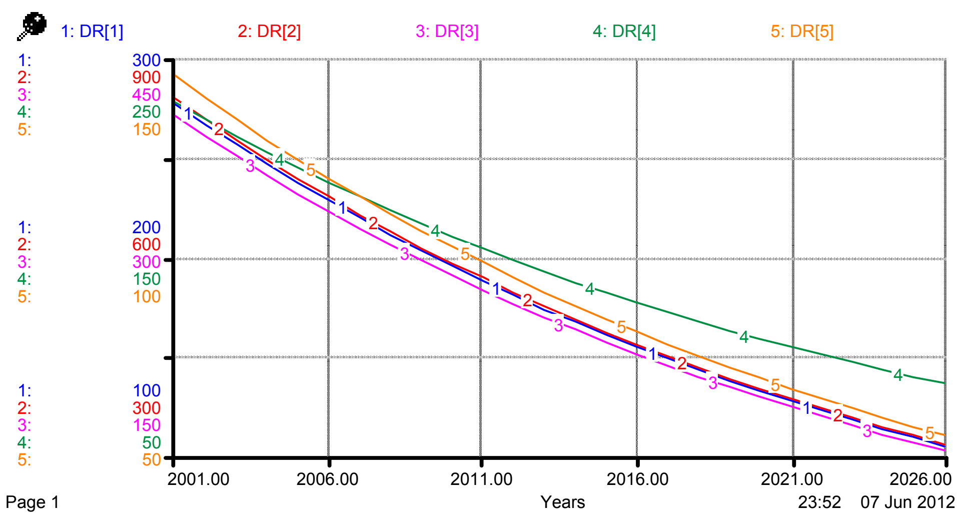

Fig. 8: Population sector-death rate growth

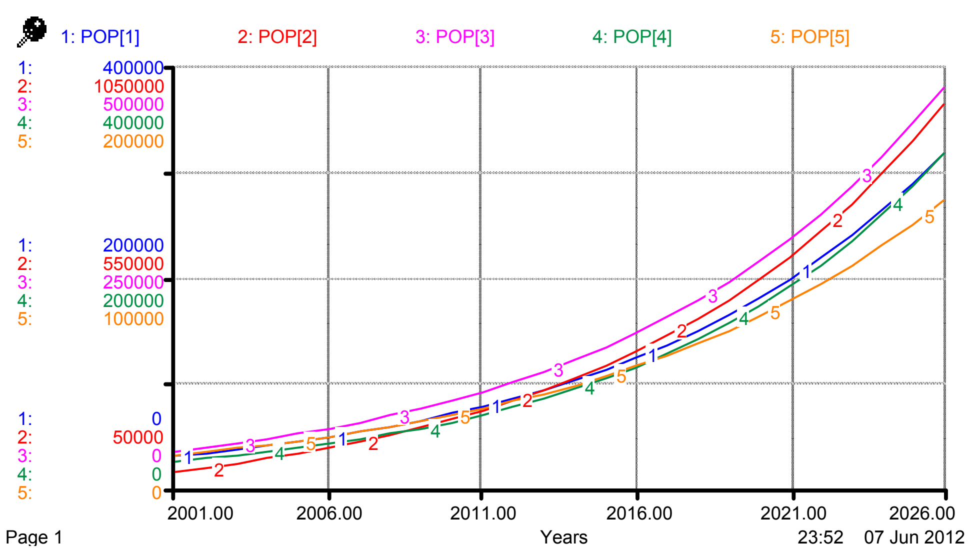

Fig. 9: Population sector-population growth

Birth rate growth for each zone shown in Fig. 7. This growth shows the exponential and smooth decrease in birth rate in each zone. The abbreviation used in the figure BR [] represents Birth Rate of Zone 1, 2, 3, 4 and 5 respectively.

Death rate growth for each zone shown in Fig. 8 shows the exponential and smooth decrease in birth rate in each zone. The abbreviation used in the figure DR [] represents Death Rate of Zone 1, 2, 3, 4 and 5, respectively.

Any change occurring in any of these rates, will cause corresponding changes in population. This sector has been projected from base year 2001 to horizon year 2026. The abbreviation used in the Fig. 9 POP [] represent the population of Zone 1, 2, 3, 4 and 5, respectively.

Results of land use sector simulation:

Simulation I (do minimum condition): Residential growth normal has been taken as 6% for zone 1. The results of simulation Do minimum Condition (Density is 275), Excess or shortage in Residential floor area for zone1 as 71.76 ha in the base year 2001 and 150.9 ha. In the horizon year 2026. This output is shown in Table 4.

Table 4: Do minimum condition output for zone 1

Years	Density	Population	Required floor area	Exist floor area	Excess or shortage
2001	275	27,683	100.67	172.43	71.76
2002	275	30,728	111.74	217.50	105.77
2003	275	34,063	123.87	262.58	138.72
2004	275	37,717	137.15	307.66	170.51
2005	275	41,721	151.71	352.74	201.02
2006	275	46,112	167.68	397.81	230.13
2007	275	50,928	185.19	442.89	257.70
2008	275	56,210	204.40	487.97	283.57
2009	275	62,006	225.48	533.05	307.57
2010	275	68,367	248.61	578.12	329.51
2011	275	75,350	274.00	623.20	349.20
2012	275	83,015	301.87	668.28	366.40
2013	275	91,431	332.48	713.35	380.88
2014	275	1,00,673	366.08	758.43	392.35
2015	275	1,10,823	402.99	803.51	400.52
2016	275	1,21,970	443.53	848.59	405.06
2017	275	1,34,214	488.05	893.66	405.61
2018	275	1,47,664	536.96	938.74	401.78
2019	275	1,62,439	590.69	983.82	393.13
2020	275	1,78,671	649.71	1,028.90	379.18
2021	275	1,96,504	714.56	1,073.97	359.41
2022	275	2,16,097	785.81	1,119.05	333.24
2023	275	2,37,624	864.09	1,164.13	300.04
2024	275	2,61,277	950.10	1,209.20	259.11
2025	275	2,87,267	1,044.61	1,254.28	209.67
Final	275	3,15,826	1,148.46	1,299.36	150.90

Table 5: Do minimum condition output for zone 2

Years	Density	Population	Required floor area	Exist floor area	Excess or shortage
2001	275	83,746	304.53	486.34	181.81
2002	275	92,958	338.03	613.48	275.45
2003	275	1,03,047	374.72	740.63	365.91
2004	275	1,14,100	414.91	867.77	452.86
2005	275	1,26,215	458.96	994.91	535.95
2006	275	1,39,498	507.26	1,122.06	614.79
2007	275	1,54,065	560.24	1,249.20	688.96
2008	275	1,70,046	618.35	1,376.34	758.00
2009	275	1,87,580	682.11	1,503.49	821.38
2010	275	2,06,824	752.09	1,630.63	878.54
2011	275	2,27,946	828.90	1,757.77	928.88
2012	275	2,51,135	913.22	1,884.92	971.70
2013	275	2,76,596	1,005.80	2,012.06	1,006.26
2014	275	3,04,555	1,107.47	2,139.20	1,031.73
2015	275	3,35,259	1,219.12	2,266.35	1,047.22
2016	275	3,68,981	1,341.75	2,393.49	1,051.74
2017	275	4,06,022	1,476.44	2,520.63	1,044.19
2018	275	4,46,710	1,624.40	2,647.78	1,023.38
2019	275	4,91,407	1,786.94	2,774.92	987.98
2020	275	5,40,511	1,965.50	2,902.06	936.57
2021	275	5,94,459	2,161.67	3,029.21	867.54
2022	275	6,53,731	2,377.20	3,156.35	779.15
2023	275	7,18,855	2,614.02	3,283.49	669.48
2024	275	7,90,410	2,874.22	3,410.64	536.42
2025	275	8,69,034	3,160.13	3,537.78	377.65
Final	275	9,55,428	3,474.28	3,664.92	190.64

Table 6: Do minimum condition output for zone 3

Years	Density	Population	Required floor area	Exist floor area	Excess or shortage
2001	275	40,555	147.47	285.78	138.30
2002	275	45,061	163.86	348.03	184.18
2003	275	50,000	181.82	410.29	228.47
2004	275	55,418	201.52	472.55	271.03
2005	275	61,362	223.13	534.81	311.68
2006	275	67,885	246.86	597.07	350.21
2007	275	75,047	272.90	659.33	386.43
2008	275	82,912	301.50	721.59	420.09
2009	275	91,550	332.91	783.84	450.93
2010	275	1,01,041	367.42	846.10	478.68
2011	275	1,11,468	405.34	908.36	503.02
2012	275	1,22,928	447.01	970.62	523.61
2013	275	1,35,522	492.81	1,032.88	540.07
2014	275	1,49,367	543.15	1,095.14	551.98
2015	275	1,64,586	598.50	1,157.39	558.90
2016	275	1,81,319	659.34	1,219.65	560.31
2017	275	1,99,717	726.24	1,281.91	555.67
2018	275	2,19,947	799.81	1,344.17	544.36
2019	275	2,42,192	880.70	1,406.43	525.73
2020	275	2,66,656	969.66	1,468.69	499.03
2021	275	2,93,560	1,067.49	1,530.95	463.45
2022	275	3,23,149	1,175.09	1,593.20	418.12
2023	275	3,55,692	1,293.42	1,655.46	362.04
2024	275	3,91,485	1,423.58	1,717.72	294.14
2025	275	4,30,853	1,566.74	1,779.98	213.24
Final	275	4,74,156	1,724.20	1,842.24	118.03

Table 7: Do minimum condition output for zone 4

Years	Density	Population	Required floor area	Exist floor area	Excess or shortage
2001	275	22,718	82.61	230.52	147.91
2002	275	25,421	92.44	280.74	188.30
2003	275	28,407	103.30	330.96	227.66
2004	275	31,706	115.30	381.18	265.89
2005	275	35,353	128.56	431.40	302.85
2006	275	39,384	143.22	481.62	338.41
2007	275	43,843	159.43	531.85	372.42
2008	275	48,776	177.37	582.07	404.70
2009	275	54,234	197.21	632.29	435.07
2010	275	60,273	219.18	682.51	463.33
2011	275	66,959	243.49	732.73	489.24
2012	275	74,359	270.40	782.95	512.55
2013	275	82,552	300.19	833.17	532.98
2014	275	91,624	333.18	883.39	550.21
2015	275	1,01,669	369.71	933.61	563.90
2016	275	1,12,794	410.16	983.83	573.67
2017	275	1,25,114	454.96	1,034.05	579.09
2018	275	1,38,760	504.58	1,084.27	579.69
2019	275	1,53,874	559.54	1,134.49	574.95
2020	275	1,70,616	620.42	1,184.71	564.29
2021	275	1,89,161	687.86	1,234.94	547.08
2022	275	2,09,705	762.56	1,285.16	522.59
2023	275	2,32,463	845.32	1,335.38	490.06
2024	275	2,57,674	937.00	1,385.60	448.60
2025	275	2,85,604	1,038.56	1,435.82	397.26
Final	275	3,16,547	1,151.08	1,486.04	334.96

Residential growth normal has been taken as 6% for zone 2. This output is shown in Table 5. Excess or shortage in Residential floor area for zone 2 is 181.81 ha. In the base year 2001 and 190.64 ha in the horizon year 2026.

Residential growth normal has been taken as 5% for zone 3. Excess or shortage in Residential floor area for zone 3 is 138.3 ha in the base year 2001 and 118.03 ha in the horizon year 2026. This output is shown in Table 6.

Residential growth normal has been taken as 5% for zone 4. Excess or shortage in Residential floor area for zone 4 is 147.91 ha in the base year 2001. It has been projected to the horizon year 2026 as 334.96 ha and shown in Table 7.

Residential growth normal has been taken as 5% for zone 5. Excess or shortage in Residential floor area for zone 5 is 68.34 ha in the base year 2001 and 288.11 ha in the horizon year 2026. This output is shown in Table 8.

In short, for the horizon year 2026, all the zones will have excess floor area ranging from 100 to 300 ha.

Simulation II (desirable condition on density value): The results of simulation Desirable condition by taking Density as 333, can be seen from Table 9 which shows

Table 8: Do minimum condition output for zone 5

Years	Density	Population	Required floor area	Exist floor area	Excess or shortage
2001	275	14,543	52.88	121.23	68.34
2002	275	16,012	58.22	147.64	89.41
2003	275	17,607	64.02	174.05	110.02
2004	275	19,339	70.32	200.46	130.13
2005	275	21,222	77.17	226.87	149.70
2006	275	23,269	84.61	253.28	168.66
2007	275	25,494	92.71	279.69	186.98
2008	275	27,915	101.51	306.10	204.59
2009	275	30,549	111.09	332.51	221.42
2010	275	33,416	121.51	358.92	237.41
2011	275	36,535	132.86	385.33	252.47
2012	275	39,932	145.21	411.74	266.53
2013	275	43,629	158.65	438.15	279.49
2014	275	47,656	173.29	464.56	291.26
2015	275	52,041	189.24	490.97	301.73
2016	275	56,817	206.61	517.38	310.77
2017	275	62,020	225.53	543.79	318.26
2018	275	67,687	246.13	570.20	324.06
2019	275	73,861	268.58	596.61	328.02
2020	275	80,587	293.04	623.02	329.97
2021	275	87,916	319.69	649.43	329.73
2022	275	95,901	348.73	675.84	327.11
2023	275	1,04,603	380.37	702.25	321.87
2024	275	1,14,084	414.85	728.66	313.81
2025	275	1,24,417	452.43	755.07	302.64
Final	275	1,35,677	493.37	781.48	288.11

Table 9: Desirable condition output for zone 1

Years	Density	Population	Required floor area	Exist floor area	Excess or shortage
2001	333	27,683	83.13	172.43	89.29
2006	333	46,112	138.48	397.81	259.34
2011	333	75,350	226.28	623.20	396.92
2016	333	1,21,970	366.28	848.59	482.31
2021	333	1,96,504	590.10	1,073.97	483.87
Final	333	3,15,826	948.43	1,299.36	350.93

Table 10: Desirable condition output for zone 2

Years	Density	Population	Required floor area	Exist floor area	Excess or shortage
2001	333	83,746	251.49	486.34	234.85
2006	333	1,39,498	418.91	1,122.06	703.15
2011	333	2,27,946	684.52	1,757.77	1,073.25
2016	333	3,68,981	1,108.05	2,393.49	1,285.44
2021	333	5,94,459	1,785.16	3,029.21	1,244.04
Final	333	9,55,428	2,869.15	3,664.92	795.77

For other zones output are tabulated in Annexure II

Table 11: Extreme condition output for zone 5

Years	Density	Population	Required floor area	Exist floor area	Excess or shortage
2001	500	14,543	29.09	121.23	92.14
2006	500	23,269	46.54	253.28	206.74
2011	500	36,535	73.07	385.33	312.26
2016	500	56,817	113.63	517.38	403.74
2021	500	87,916	175.83	649.43	473.60
Final	500	1,35,677	271.35	781.48	510.12

Table 12: Extreme condition output for zone 2

Years	Density	Population	Required floor area	Exist floor area	Excess or shortage
2001	500	83,746	167.49	486.34	318.85
2006	500	1,39,498	279.00	1,122.06	843.06
2011	500	2,27,946	455.89	1,757.77	1,301.88
2016	500	3,68,981	737.96	2,393.49	1,655.53
2021	500	5,94,459	1,188.92	3,029.21	1,840.29
Final	500	9,55,428	1,910.86	3,664.92	1,754.07

the minimum value of Excess or Shortage in Residential area for zone 1. That is, zone 1 as 350.93 ha in the horizon year 2026. This explains that the increase in density directly influence the floor space area.

Zone 2 has the maximum value in the horizon year 2026. In Table 10 shows the variation in 5 year time period.

Simulation III (extreme condition on density value): The results of simulation Desirable condition by taking Density as 500, can be seen from Table 11 which shows the minimum value of Excess or Shortage in Residential area for zone1. Zone 5 as 510.12 ha in the horizon year 2026. This explains that the increase in density directly influence the floor space area.

Zone 2 has the maximum value in the horizon year 2026. In Table 12 shows the variation in 5-year period.

This simulation model's Tables and equations are presented in Annexure II and III.

The study has found that consideration of the density value as 275/ha it shows that, the excess land area with good quality of life is observed in all the study zones. Hence it is recommended that this density may be adopted.

By accounting a density of 333/ha and 500/ha, in zone 2, it is found that the excess of floor area in the horizon year is increasing in both the cases 795.77 and 1754.07 ha, respectively.

CONCLUSION

The following are the outcome of the present study: The Geo-database created for the study area by using ArcGIS software consist of each of the five zones boundary polygon and the attribute data such as id, zone, catesgory, Population for various years (1971, 1981, 1991, 2001), Village name and Residential area (ha) in 2006. For all the five zones system dynamics models have been developed with an FSI of 1.5 and with varying density values. Under the minimum scenario of taking 275 persons/ha as density value in zone 3 namely Medavakkam, the excess floor area (minimum value) observed in the horizon year is 118.03 ha similarly, in zone 4 namely Perumbakkam with the same density value, the excess floor area (maximum value) observed in the horizon year is 334.96 ha. Under desirable scenario of taking density value as 333 persons/ha in zone 1 namely Madipakkam, the excess floor area (minimum value) observed in the horizon year is 350.93 ha Similarly, in zone 2, namely Okkiyam thuraipakkam with the same density value, the excess floor area (maximum value) observed in the horizon year as 795.77 ha. Under extreme scenario of taking density value as 500 persons/ha in zone 5 namely Nedunkundram, the excess floor area (minimum value) observed as 510.12 ha. Similarly, in zone 2 namely Okkiyam thuraipakkam with the same density value, the excess floor area (maximum value) observed in the horizon year as 1754.07 ha:

- It is very crucial to develop a Geo-database for the area like peri urban in Chennai so as get first hand information on not only spatial information but also attribute information to enable further judicial decision making in peri.
- Since the land area adapting of 275 persons/ha as density value with the growth rate of 6% for every year itself showing good result in all five zones, it is recommended that peri urban areas development in southern part of Chennai Metropolitan Area (CMA), this density value may be considered.

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