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Evaluating the Dynamic Functions for Sustainable Development of Chennai Metropolitan City, India: A System Dynamics Approach

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Abstract

Urbanization is a continuing process, which takes place in a vibrant manner in the developing countries, whereas the intensity of urbanization is lesser in developed countries and it is further lesser in under developed countries. Urbanization is influenced by different factors, which includes geographical location, the natural growth of population, rural-urban migration, cross-country migration, availability of infrastructure, national policies, conducive atmosphere in connection with socio, economic, political and environmental development, corporate strategies, people's aspiration, attitudes, culture, etc. Urbanization has both spread and backwash effects in the system. Therefore, cities are engines of economic growth in any country, and it can be considered as spread effect, and simultaneously it has backwash effects too. No doubt that the cities are the engines of economic growth, but not all the cities are engines of economic growth, since, the features of the cities, economic functions of the cities, availability of infrastructure facilities in the cities and even physical terrain of the cities, which are responsible for economic growth differ from one to another. Cities, which are more conducive for economic growth with required infrastructure facilities are really the engines of economic growth, otherwise, instead of functioning as a catalyst for the development, it aggravates the existing problems, in a multitude manner. When the city turned into engines of economic growth, it has more dynamic functions, and all the subsystems of the system, are functioning vibrant manner compared to the other cities. As a consequence, energy consumption is increasing in more dynamic functional cities on the one hand, and these particular cities release more quantity of carbon (CO_2) emission, which is highly responsible for greenhouse gases in the system, on the other. Having the aforesaid knowledge Chennai Metropolitan City, India, has been chosen to evaluate functional dynamism and conceptualize the integrated model for sustainability along with its constraints by employing system dynamics. This is an attempt to develop the integrated model for sustainability and an understanding of the implications of three major constraints viz., (i) the property constraints, (ii) the resource constraints, and (iii) development constrain arising between economic growth, environmental protection, and social equity, in the system. Finally, the study concludes that it is essential to understand and evaluate the dynamic functions that shape the growing megacities, which will pave the way for sustainable urban development in the system.

Keywords: Urbanization, Urban system, Integrated Planning Approach, System dynamics, Sustainable development

I. INTRODUCTION

The on-going rapid urbanization has already led to tremendous increase in energy consumption and associated emissions. In India, for example, the use of diesel in the transport sector has increased from 73 per cent of the total in 1991 to 81 per cent in 2000 (Zhou and McNeil, 2009). If the current trend is to continue, motorized traffic volume in India would reach 130,000 billion passenger kilometers. Compared to the year 2000, this would result in a five-fold increase in energy demand and carbon emissions in transport by 2020 (Singh, 2006). The trend is quite similar in many developing countries and emerging economies. In Malaysia, from 6.8 million vehicles in 1995, the motor vehicle ownership increased to 18 million, in 2008. With an annual growth rate of 7.78 per cent, it almost tripled in a little more than a decade. The transport sector alone accounts for 35.50 per cent of the total energy consumption in Malaysia (Ong et al., 2011). Under business as usual (BAU) scenario, direct energy demand and GHG emissions from the road transport alone is expected to reach 734 million tons of oil equivalent and 2384 million tons carbon dioxide equivalent by 2050 in China. The projected increase is 5.6 times more than the 2007 level (Ou, Zhang, et al., 2010).

In reality, the increase in emissions could be much higher than the one projected by BAU scenario. BAU scenarios often do not take into consideration social and cultural changes that are actually happening in many developing countries. In India, for instance, because of the social status attached to vehicle ownership, households have started owning more than one private vehicle. In future, they may be in a position to afford a vehicle for each and every member of the household. If that were to happen, GHG emissions would be much higher than projected under BAU scenario. It is not only the transport sector, where the demand for energy is growing. There has been a tremendous growth in energy consumption and emissions in the industrial sector as well. Approximately 188.32 million tons of CO_2 was emitted from the city of Shanghai alone in 2008 (Liu, Geng, & Xue, 2011). The situation is quite similar in other big Chinese cities. Carbon emission in the city of Nanjing has increased by about 50 per cent in the last decade. Industrial energy consumption, industrial processes, and transportation accounted for 37-44 per cent, 35-40 per cent and 6-10 per cent of urban emissions respectively (Bi, Zhang, Wang, and Liu, 2011). Most cities are quite aware of the fact that the existing carbon intensive path is unsustainable. But given the increase in public desire to own vehicles and technologies that require energy, increase in urban industrialization and increase in consumption of carbon intensive processed foods, emissions are growing not only in mega cities in developing countries, but also in second-tier cities. Cities in developing countries are quite aware of the fact that urgent measures are needed to move away from high emissions pathway, but given the host of local priorities, lack of capacity, resources, and understanding of policy tools that can help them achieve both local priorities as well as emissions reduction, they are finding it increasingly difficult to contain rising emissions (Hari Bansha Dulal, et al., 2012).

Global warming is an indisputable fact, which has seriously affected people's living environment and the development of human society. In addition to natural factors, human activities play a great role in climate warming, especially anthropogenic energy related CO_2 emissions (Ehrlich PR, et al., 1971). With the intensification of global warming and the continued growth in energy consumption, China is facing greater pressure to cut its CO_2 emissions down. Recently, there is an increasing concern about the influence mechanism and impact factors of energy-related CO_2 emissions. Many literatures on these issues have achieved valuable results. Dietz and Rosa estimated the effect of population, affluence and technology on CO_2 emissions. They predicted that population and economic growth would exacerbate the problem with GHG (Greenhouse gas) emission which in fact had been the case (Holdren JP, et al., 1974). Ying Fan et al. analyzed the same issue from a view of different income levels. They found that economic growth has the greatest impact on CO_2 emissions at the global level and different behavior fashions can greatly influence environmental change. The impact of GDP per capita on total CO_2 emissions is very great for low income countries, while the impact of energy intensity is very great in upper middle income countries (Waggoner PE, et al., 2002).A framework for assessing the effects of human activities on the environment was firstly proposed by Ehrlich and Holdren in the early 70s to describe the impact of growing population on the environment, named as IPAT model (Dietz T, et al., 1994; Forrester, J. W., 1969. Using IPAT model as a starting point for assessing potential action and policy levers to alter impacts, Waggoner and Ausubel redefined the IPAT identity, renaming it ImPACT, by disaggregating T into consumption per unit of GDP (C) and impact per unit of consumption (T), thus I = P x A x C x T (Forrester, J. W., 1961). To overcome this serious limitation, Dietz and Rosa reformulated IPAT into a stochastic model, named as STIRPAT model, which can statistically model non-proportionate impacts of variables on the environment (Forrester, J. W., 1968), known as: $\mathbf{CEt = aP_t^b A_t^c T_t^d e_t}$ **,** where CE indicates the environment impact, population (P), affluence (A) and technology (T) are taken as the deciding factors of CE, t denotes the year, et denotes the error term, a is the constant, b, c and d are the coefficients of P, A, and T respectively, which can be obtained by regression. The authors were analyzed CO_2 emissions by a STIRPAT model concluded that different regions should take differentiated measures to decrease CO_2 emissions according to local conditions. In all emission regions, government should regulate the price of energy products when increase residents' income for the bigger impact of A on CO_2 emissions. In high emission region, population size should be vigorously controlled and the scale of energy-intensive heavy industry should be strictly limited. Currently, improving T is still a primary way for CO_2 reduction in China. Thus, technological innovation should be encouraged to play a positive role on CO_2 reduction continuously. In all emission regions, low-carbon city should be built to avoid sharp increase in CO_2 emissions caused by rapid urbanization. Local government should actively develop its tertiary industry and high-tech industry to gradually reduce the proportion of heavy industry in all emissions regions especially in middle emission region. Although CO_2 emissions will remain increasing in China in the long term, targeted policies and measures on CO_2 reduction will have far-reaching and positive impact. (Huanan Li, et al., 2012).

In the last two decades substantial advances have been made in the understanding of the scientific basis of urban climates. These are reviewed here with attention to sustainability of cities, applications that use climate information, and scientific understanding in relation to measurements and modeling. The data needs, predictions and process understanding range from the protection of the inhabitants from short-term meteorological events such as intense rainfall through extremes of weather such as caused by heat stress enhanced by the urban heat island, and on to the long-term impacts of building design and urban planning and the role of transportation network design on air quality and health. Thus there are important social, economic and health benefits of an enhanced understanding of urban meteorological processes from the timescale of seconds to 100 years to 1000 years i.e., city-scale planning. Awareness of current scientific capabilities and understanding based on observations and modeling is essential. Here these are reviewed and the main areas where improvements in our capabilities are needed for the design of more sustainable cities are identified as areas where improvements in our capabilities are needed to ensure that in the next 10 years we actively move towards developing more sustainable cities. Each is given a high (H), medium (M) or low (L) ranking. The observation for the "need to measure fluxes of CO_2 using eddy covariance approach combined with isotopic analysis to determine not only the sizes of these fluxes but also to identify emission sources (for example, background concentration, gasoline combustion, natural gas combustion and respiration) to evaluate the role of cities on the earth–atmosphere carbon exchange". (H) (C.S.B. Grimmond, et al., 2010).

The sustaianble development concept was brought to popular global attention by the report "Our Common Future", prepared by the World Commission on Environment and Development(WCED) following its first meeting in 1984 (WCED, 1987). It was then defined as "development that meets the needs of the present without compromising the ability of the future generations to meet their own needs".The Rio Summit focused on environment and development (Rio de Janerio, 1992) responsible for Agenda 21, which marked a key milesstone as a comprehensive plan of action to be adopted globally, nationally and locally by organizations of the United Nations system, governments and major groups in every area concerned with the human impact on the environment (India Energy Hand Book, 2011; IPCC,2007). Also to be noted that some of the Millennium Development Goals (MDG) have urged for ensuring environmental sustainability and reduction of the percentage of the population under extreme poverty. Similarly, explaining implications of climate change for sustainable development the Intergovernmental Panel on Climate Change notes (IPCC) the importance of social and environmental equity in development. Thus, all the major world conferences and initiatives taken so far on environment and development have stressed on economically viable development, socially equitable development and protection of the environment for attaining sustainable development.

The share of world urban population 50.5 per cent or 3.5 billion of the people lived in cities in 2010. By 2050, this will increase to 6.4 billion or 70 per cent of the global population (NGM, 2011).Thus, the present and future levels of urbanization, particularly the rapid urbanization of developing countries has clear linkages to the global greenhouse gas (GHG) emissions. The unprecedented population concentration in the urban system, consumes huge quantities of primary energy (Fossil fuels) such as, coal, oil and gas by various sectors namely, residential, commercial, industrial and transportation. Combustion of fossil fuels is chiefly responsible for urban air pollution, regional acidification and the risk of human-induced climate change. In twentieth century, it has been observed that rapid increase in the use of fossil fuels adversely affects the climate and urban environment by the emission of carbon dioxide (CO_2) into the atmosphere. The over consumption of urban energy is highly responsible for the climate change impacts and environment damage. While planning for sustainable urban development the factor of climate change along with urban heat island effect need to be studied for understanding adverse impacts on urban environment. Among the most significant environmental challenges of our time are global climate change, excessive fossil fuel dependency and the growing demand for urban energy, are being the major challenges of 21st century and one of the greatest problems facing humanity. Cities denote instantaneously a challenge and an opportunity for climate change policy. Cities are the place where most energy services are needed because urbanization is closely linked to high population densities and concentration of economic activities i.e., production and consumption. Consequently, it is critical to explain about the role of cities within the world's energy systems and its correlation with the climate change issue. With more than half of the world's population already living in urban areas, and that percentage expected to rise to 75 per cent by 2050, it is clear that the path to sustainable development must pass through cities. Cities expanding in size and population pose increased challenges to the environment, of which energy is part as a natural resource, and to the quality of life. Adequate and affordable energy supplies have key for economic development and the transition from subsistence agricultural economies to modern industrial and service-oriented societies. Energy is central to improved social and economic well-being, and is indispensable to most industrial and commercial wealth generation. It is the key for relieving poverty, improving human welfare and raising living standards. But however essential it may be for development, energy is only a means to an end. The end is good health, high living standards, a sustainable economy and a clean environment. No form of energy - coal, solar, nuclear, wind or any other is good or bad in itself, and each is only valuable in as far as it can deliver this end.

Much of the current energy supply and use, based, as it is, on limited resources of fossil fuels, is deemed to be environmentally unsustainable. There is no energy production or conversion technology without risk or without waste. Somewhere along all energy chains - from resource extraction to the provision of energy services - pollutants are produced, emitted or disposed of, often with severe health and environmental impacts. Even if a technology does not emit harmful substances at the point of use, emissions and wastes may be associated with its manufacture or other parts of its life cycle. Achieving sustainable economic development on a global scale will require the judicious use of resources, technology, appropriate economic incentives and strategic policy planning at the local and national levels. It will also require regular monitoring of the impacts of selected policies and strategies to see if they are advancing sustainable development or if they should be adjusted. It is important to be able to measure a country's state of development and to monitor its progress or lack of progress towards sustainability. First, policymakers need to know their country's current status concerning energy and economic sustainability, what needs to be improved and how these improvements can be achieved. Second, it is important for policymakers to understand the implications of selected energy, environmental and economic programmes, policies and plans, and their impacts on the shaping of development and on the feasibility of making this development sustainable. Third, inevitably there will be trade-offs. In short, there is an imminent need for informed and balanced choices to be made on policy, investment and corrective action. When choosing energy fuels and associated technologies for the production, delivery and use of energy services, it is essential to take into account economic, social and environmental consequences. Policymakers need methods for measuring and assessing the current and future effects of energy use on human health, human society, air, soil and water. They need to determine whether current energy use is sustainable and, if not, how to change it so that it is. Therefore, the purpose of the energy indicators which address important issues within three of the major dimensions of sustainable development: economic, social and environmental.

Moreover, current trend of growing urban energy demand, the scarce non-renewable energy use could not be supplemented with renewable energy. The only possible solution is reduction of energy usage or efficient use of energy by minimizing CO_2 emission to safe guard the urban environment for present and future generations. Energy is central to socio-economic well-being and also to meet environmental demand. Therefore, integrated planning approach in energy production and consumption of an urban system in sustainable way is indispensable for achieving energy efficient urban development. Energy plays vital role for improving human, social, economic, environmental conditions on one hand and the other hand, it pollute the environment and increase greenhouse gas emissions. Hence, energy for sustainable development must be visualized in three major dimensions, such as social, economic and environmental dimensions, which is very much essential to achieve energy efficient sustainable development in the system. It is important to understand the forces that shaping the growing megacities of world in order to mitigate the climate change and its consequences, by the path way of energy efficient urban development through the guiding principles of sustainable development.

II. DYNAMICS OF URBANIZATION IN INDIA

According to United Nations, India has the highest rate of change of the urban population among the BRIC nations, which will remain above 2 per cent annually for the next three decades. At this rate, an estimated 854 million people will live in Indian cities by 2050, a figure which is the combined population of present day USA, Brazil, Russia, Japan and Germany. Even in the coming decade (2011-2020), India will add 95 million people to its already dense urban fabric, nearly one-fourth of its current urban population. India needs more cities, and it is a mere understatement to say that we might be misjudging the dimensions of the situation. With a land area of one third the size of USA, India harbors nearly four times the population i.e., present Indian has population of 1,210,193,422 (2011) as against the USA of 314,982,000 (2012). Unsurprisingly, Indian cities are not only the most populous but also among the densest urban agglomerations of the world, which poses unique challenges to the development of infrastructure and real estate. Creation of dense informal settlements within the city, impractical low cost housing at the exurbs or high-rising verticals are nothing but a manifestation of this inevitable immigration of people from rural to urban areas. Growth Scenario of urbanization of India between the year 1901 and 2011 are compiled and is presented in the Table 1.

India is one of the least urbanized countries in the world because between 1951 and 2001, the level of urbanization increased by 13 percentage points only. The urban population in India at the beginning of 20th century was only 25.85 million constituting 10.84 per cent of India's population in 1901, which increased to 285.35 million comprising 27.78 per cent of total population in 2001. Though urbanization in India is 27 per cent its urban population exceeds the total population of USA and Brazil. Today India has the second largest urban population in the world and more than two thirds of it lives in the 393 cities that have a population of more than a lakh. During the last 50 years, the rate of growth of urban population of India has been double that of the rate of growth of population. It took nearly 40 years between 1971 and 2008 for India's urban population to rise by 230 million and it could take only half that time to add the next 250 million. According to Mckinsey Report Indian cities are likely to house 40 per cent of the urban population by 2030.

Urbanization principally refers to dynamics of the proportion of total population living in urban areas. Urbanization is a continuing process, which takes place in a vibrant manner in the developing countries, whereas the intensity of urbanization is lesser in developed countries and it is further lesser in under developed countries. Urbanization is influenced by different factors, which includes geographical location, natural growth of population, rural-urban migration, cross country migration, availability of infrastructure, national policies, conducive atmosphere in connection with socio, economic, political and environmental development, corporate strategies, people's aspiration, attitudes, culture, etc. Urbanization has both *spread* and *backwash effects* in the system. As indicated in UN-Habitat's report 2008-09 (United Nations HABITAT, 2008) that the cities are engines of economic growth in any country, and it can be considered as spread effect, and simultaneously it has backwash effects too. The following activities emerged in the urban system, which can be considered as backwash effect of urbanization, including formation of slums, strengthening of the existing slums, squatter settlements, aggravating the problem of poverty, unemployment, under employment, disguised unemployment, and creation of all kinds of pollution, which lead to environmental degradation, damaging the cultural values that exists in the system, increase in heinous crimes, scarcity of infrastructure, and so on.

Urbanization and the phase of its acceleration is the foremost important aspect in deciding the level of the kinds of infrastructure requirement in the urban system, for its development. The features of urban population are changing not only as a result of its dynamism, but also the national development in which it belongs. Cities, towns, and urban agglomerations are expanding faster in most of the regions of the world, due to availability of infrastructure services in the particular system. Infrastructure is divided in to three types, which include physical, economic and social infrastructure. Energy is one of the vital components of Physical infrastructure in the system. These entire three infrastructures are very much essential for the development of the urban system. In India, the urban system which has more infrastructure services developed further, and continuously growing with higher intensity, whereas the urban system has less infrastructure services grows with less intensity. Provision of required amount of infrastructure services to Indian urban system becomes a mirage, due to the functions of population explosion in the urban system on one hand, and the Government of India and the respective State Governments attitudes on the other. Further, it has been also observed from various studies that whatever infrastructure is made available in the urban system by the Government of India and by the respective State Governments, turning into a drop in the ocean, due to unprecedented growth of population in the urban system. Various studies proved that there is strong nexus between infrastructure services and economic development in the urban systems. According to researcher's view, without required amount of infrastructure services in the urban system, the cities cannot be the engines of economic development. Provision of all kinds of infrastructure that can support the demand of current populism, which lead to vast transformation of natural resources into goods and services, eventually will consume enormous urban energy and end up with environmental chaos in the urban system.

Therefore, there is pressing need of vital urban planning solutions by way of integrating energy efficiency measures can lead the present and also upcoming generations to sustainable future of megacities in India

Table No.1: Urbanization Trend of India between 1901 and 2011

S.No.	Census Year	Number of Urban Agglomeration/Towns	Total Population	Urban Population	Percentage of Urban Population	Rural Population	Percentage of Rural Population
1	**1901**	**1827**	23,83,96,327	2,58,51,873	10.84%	21,25,44,454	89.16%
2	**1911**	**1825**	25,20,93,390	2,59,41,633	10.29%	22,61,51,757	89.71%
3	**1921**	**1949**	25,13,21,213	2,80,86,167	11.18%	22,32,35,046	88.82%
4	**1931**	**2072**	27,89,77,238	3,34,55,989	11.99%	24,55,21,249	88.01%
5	**1941**	**2250**	31,86,60,580	4,41,53,297	13.86%	27,45,07,283	86.14%
6	**1951**	**2843**	36,10,88,090	6,24,43,709	17.29%	29,86,44,381	82.71%
7	**1961**	**2363**	43,92,34,771	7,89,36,603	17.97%	36,02,98,168	82.03%
8	**1971**	**2590**	59,81,59,652	10,91,13,977	18.24%	48,90,45,675	81.76%
9	**1981**	**3378**	68,33,29,097	15,94,62,547	23.34%	52,38,66,550	76.66%
10	**1991**	**3768**	84,43,24,222	21,71,77,625	25.72%	62,71,46,597	74.28%
11	**2001**	**5178**	1,02,70,15,247	28,53,54,954	27.78%	74,16,60,293	72.22%
12	**2011**	**7936**	**1,21,01,93,422**	**37,71,05,760**	**31.16%**	**83,30,87,662**	**68.84%**

Source: Compiled by the Author based on the report of Census of India, 2011

A. *Objectives*

The main objective of this research paper is to assess the dynamic functions, for identifying the control parameters which decides the functions and conceptualize the integrated model by employing System Dynamics technique by considering energy as catalyst for the development of the study area. For achieving this few objectives were formulated by the researcher and are presented in the sequel. (i). to assess the existing conditions (socio-economic, physical, infrastructural, and environmental conditions) of the study area (System), (ii) to identify the control parameters, which decide the functions of the system, and assess their functions, and (iii) to conceptualize the integrated System Dynamics model for sustainable development of the system.

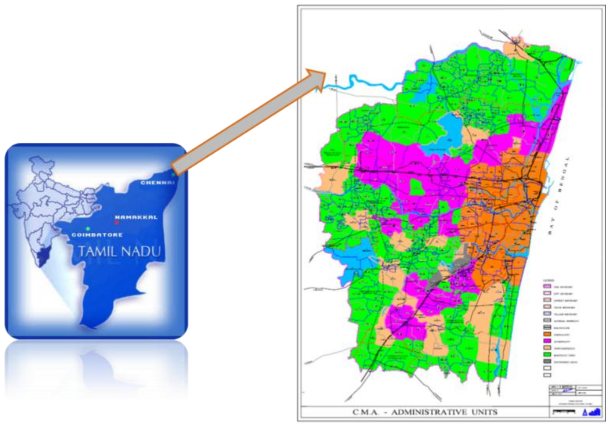

Fig.1: Location Map of Chennai Metropolitan City, India

III. STUDY AREA AT A GLANCE

Chennai' formerly known as 'Madras' is the capital city of Tamil Nadu, India located on the Coromandel Coast of the Bay of Bengal, and its latitude and longitude are 13.04º N 80.17º E, respectively. Chennai holds position of fourth most populous metropolitan area and the fifth most populous city in India.

Chennai city is blessed with good amount of industries, which include automobiles, computer technology, hardware manufacturing, and healthcare industries. It is the second largest exporter of software, information technology and information-technology-enabled services in India. A major chunk of India's automobile manufacturing industry is confined in and around the city, and it contributes 60 per cent of the automotive exports of India. Chennai Zone contributes 39 per cent of the State's GDP. It has Chennai Metropolitan Area (CMA) of 1189 Sq.km and has a population of 89.17 lacks as per Census of India, 2011. The extent of the Chennai District alone is 176 Sq.km, which has total population of 46, 46,732 holds highest population density of 29,526 persons per Sq.km. CMA covering of Chennai City and its Urban Agglomeration are considered for this present investigation. The geographical location and administrative units of the study area has been presented in Figure 1.The study area comprising of Chennai city, 16 Municipalities, 20 Town Panchayats and 214 Village Panchayats and 10 Panchayat Unions. Recently the Government of Tamil Nadu have announced their decision and extended the Chennai Corporation limits from176 sq.km to 426 Sq.km through the G.O.Ms.No.256, dated 26/12/2009.

The study area has been facing multidimensional problems in almost all aspects, which include physical, socio-economic, infrastructure, and environment. The exponential population growth has wreaked havoc on human life in the city environment. The doubling and tripling of urban population creating strain on the existing systems, which has manifested in environmental chaos. Chennai city faces the proliferated typical planning problems of urban expansion, inadequate housing, poor transportation, poor sewerage, erratic electric supply, and insufficient water supplies. An increasing number of trucks, buses, cars, three-wheelers and motorcycles all spewing uncontrolled fumes, all competing for space on city streets already jammed with jaywalking pedestrians, auto-rickshaws and cattle. The phenomena of rapid urban economic growth and urbanization are the main perpetrators, which besides bringing higher standards of living, has also brought problems related to the growth of dense and unplanned residential areas, environmental pollution, lack of services and amenities, solid waste generation, and growth of slums. Population growth and in-migration of poor people, industrial growth, inefficient and inadequate traffic corridors, and poor environmental infrastructure are the main factors that have deteriorated the overall quality of the city's environment. Chennai Metropolitan city is experiencing the planning issues in all the ways, from the view point of sustainable urban development. Having the aforesaid knowledge of Chennai Metropolitan City, India has been chosen for the present investigation.

IV. CONCEPT

Urban System concept has been employed in this present investigation. A system functions as a whole with the interaction of several subsystems. All the subsystems of the urban system, such as, physical, social, economy, ecology, environment, infrastructure and institutions are functioning together in the urban system, as a whole. All these subsystems of the urban system are interconnected, and interdependent to each other, i.e., a subsystem's output is one or more other subsystem's input in the system. In an urban system, if one of the subsystems defunct, or partially function or takes lead role in its function over a period of time, its effects would be reflected in the whole system.

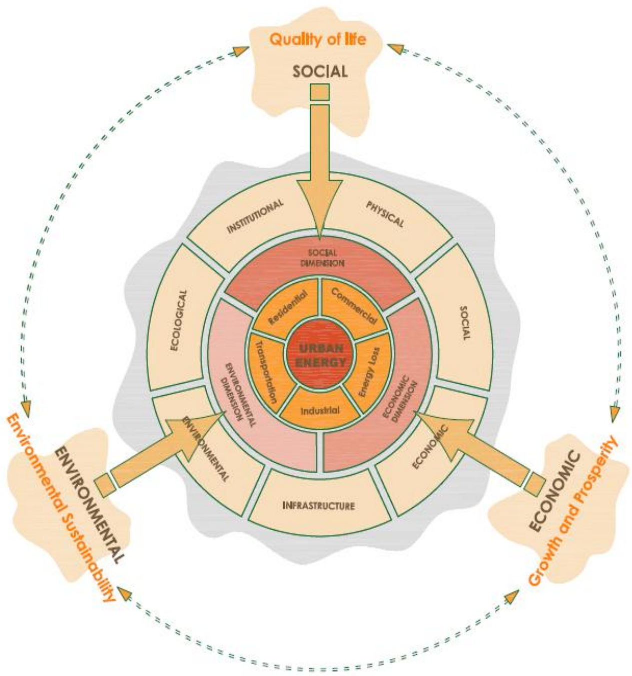

Fig.2: Energy: A central basic unit of an Urban System

Source: compiled by the author

In this present investigation, the study area is considered as a 'system'. Researcher has made an attempt to develop the integrated model based on the system's concept, by considering urban energy as a central basic unit of an urban system and presented in Figure 2. The figure reveals the integration among the all the subsystems of system, energy end use sectors and three major dimensions of sustainable development i.e., social, economic and environment, where energy is the central core for achieving energy efficient sustainable development in the system. Over the last three decades, several changes occurred in the study area particularly with respect to its structure, and all the sectors of the economy. It has been transformed from the educational city to Automobile city, and now to the information Technology city through massive industrial and information technology growth. It is imperative to have a close look at the functions of the system, and the factors, which decide the functions of the system, and further it requires integrated planning approach towards sustainable urban development to improve the quality of life by exploiting the available resources, and infrastructure services in the system. Therefore, system concept is employed to analyze the functions of the city and for evolving a set of plausible policy planning guideline for energy efficient sustainable development of the City.

V. DYNAMIC FUNCTIONS OF THE SYSTEM

Analysis of present status of development and understanding the functions of the system is indispensable for evolving plausible policies for development of the urban system. Survey research method has been employed to understand the present physical, socio-economic and environmental conditions, availability and level of infrastructure services; and institutional functions of the system at the grassroots level. A detailed investigation has been done to understand the functions of the system by considering a number of major variables. They are: plot size, type of dwelling unit, number of rooms, habitable condition of houses etc.; to understand the physical condition; income, household size, population, religion, primary and secondary occupation, education, male and female members in the households, expenditures, savings, indebtedness, etc., to understand the socio-economic conditions; land, water, and air quality, etc., to understand the environmental quality; to understand the availability of infrastructure services, the variables, such as, water supply, power supply, waste management, education, transportation, recreation, health, distance to various social infrastructure, quality of various social infrastructure etc., performance of government departments etc., to understand the quality of governance.

A survey was conducted in selected 315 households by employing the pre-tested schedules at the grassroots level to understand the functions of the system. Data collection was followed by data vetting, all the schedules were crosschecked for consistency, 14 schedules were discarded, and finally 301 schedules were considered for analysis. Subsequently the data were transferred into the code sheets to avoid errors. Household income has been considered as the dependent variable, and remaining other major variables are considered as independent variables for analysis and the results are presented in the sequel.

A. Socio-Economic Characteristics of the System

The socio-economic characteristics of the study area are analyzed based on the survey results. Income is the most important parameter, which decides the functions of the system, and sets the wheel of an economy in motion. It affects the expenditure choices, consumption pattern, savings, indebtedness, access to infrastructure services and housing affordability of the people, and revenue of the government. The increase in income leads to increase in standard of living, increase in using infrastructure services, increase in investment, which further leads to increase in production, trade and commercial activities, employment opportunities, increase in income, saving, etc. Consequent upon this increase in saving, there is increase in capital formation, and subsequently, increase in reinvestment in the system, thus the wheel of the economy is set into motion, which is very much essential for the development of any system. The analysis is done by considering the household income as the dependent variable, and, and the crux of the results are presented in the sequel.

Table 2: Income-Wise Distribution of Households

S. No.	Income-Group (Rs.)	No. of Households	Per cent
1	**< 40,000**	117	**38.87**
2	**40,000 - 80,000**	106	**35.22**
3	**80,000 - 120,000**	38	**12.62**
4	**120,000 - 160,000**	17	**5.65**
5	**160,000 - 200000**	14	**4.65**
6	**> 200000**	9	**2.99**
Total		**301**	**100.00**

Source: Compiled by the Author based on the Primary Household Survey 2013

The table 2 illustrates that more than one-third (38.87per cent) of the households are confined to lowest income category, i.e., monthly income less than Rs.40,000, and more than one-third (35.22 per cent) of the households are having income range between Rs.40,000-80,000. Subsequently, followed by 12.62 per cent, 5.65 per cent, 4.65 per cent, 2.99 per cent households are having income range between Rs.80, 000-120,000, Rs.120, 000-160,000, Rs.160,000-200,000 and above 200,000 respectively. It is observed that about two-third (38.87 per cent) of the households are confined in the lowest income groups, such as, less than Rs.40,000, and the remaining households follow a mainly decreasing trend along with their increase in income. The number of households in the highest income range above Rs.200, 000 is the lowest contributor, comprising only 2.99 per cent of the total households.

B. Correlation Coefficient Method

The Correlation coefficient method is used to analyze the parameters of the various subsystems that highly influence the system. The household data collected for this investigation are utilized for the said purpose and correlation coefficient between the dependent variable and independent variables have been established. The parameters, which have higher correlation with the dependent variable, are chosen as the controlling parameters for further analysis as phase-I. These parameters are very closely analyzed further by employing integrated System Dynamics Model, to identify the control parameters which are having more bearing in the system. A close examination of the data points of the household survey revealed that the monthly income from various occupations in some households is mutually exclusive, and others have more than one occupation. Therefore, monthly income of the households is considered as the dependent variable and all other parameters are considered as independent variables for analysis.

C. Control Parameters

The various control parameters of different subsystems of the system are decided on the above-discussed correlation coefficient method were analyzed by employing SPSS and the results are summarized in the Table 3. This table demonstrates the association between monthly income and other variables considered for the analysis for identifying the control parameters, which decides the functions of the system.

D. Regression Analysis

In this present research, multiple regressions is attempted by employing Statistical Package for Social Sciences (SPSS-20 version) to find out the tangible relationships of dependent variable, i.e., monthly income with multiple independent variables, such as, economic parameters, demographic parameters, expenditure parameters, etc., based on the above control parameters. Multiple regression equations are attempted separately for the parameters, and it is observed that except expenditure parameters, other parameters do not provide tangible relationships in the system, thus a multiple regression analysis is done and is presented in the sequel.

E. Multiple Regression Analysis

Multiple regressions is attempted on basic parameters by considering monthly income as the dependent variable (y) and other basic parameters, such as expenditure, number of bed rooms, occupation, preference among the fringe area, water quality, spending on energy, gender, and motive of buying house are considered as independent variables. The multiple regressions are employed, and are presented as below:

Table No. 3: Association between monthly income and other variables

S.No.	VARIABLE	INTERPRETATION
1.00	**Size of correlation:0.90 to 1.00**	**Very high positive correlation**
1.10	None	
2.00	**Size of correlation:0.70 to 0.90**	**High positive correlation**
2.10	Monthly income and Actual Savings Amount.	.877(**)
2.20	Monthly income and Actual Expenditure Amount	.813(**)
3.00	**Size of correlation:0.50 to 0.70**	**Moderate positive correlation**
3.10	Monthly income and Actual Spending on Energy	.579(**)
4.00	**Size of correlation: Less than 0.50**	**Low positive correlation**
4.10	Monthly income and Number of Four-Wheelers Owned	.356(**)
4.20	Monthly income and Number of Bed Rooms	.350(**)
4.30	Monthly income and Number of Vehicle Owned	.276(**)
4.40	Monthly income and Private job (Primary)	.246(**)
4.50	Monthly income and Professional (Primary)	.228(**)
4.60	Monthly income and Quality of Living	.228(**)
4.70	Monthly income and Business + Salary	.220(**)
4.80	Monthly income and Water Quality	.215(**)
4.90	Monthly income and Salary	.214(**)
4.10	Monthly income and Type of House : Semi-detached	.205(**)
4.11	Monthly income and Physical condition of House : Good	.203(**)
4.12	Monthly income and Physical condition of House : Livable	.199(**)
4.13	Monthly income and Number of persons Married	.197(**)
4.14	Monthly income and Land Quality	.188(**)
4.15	Monthly income and Private Mode of Transportation to Railway station	.185(**)
4.16	Monthly income and Air Quality	.178(**)
4.17	Monthly income and Private Mode of Transportation to Recreation place	.175(**)
4.18	Monthly income and Public Mode of Transportation to Railway station	.173(**)
4.19	Number of Females	.170(**)
4.20	Monthly income and Number of Persons in a Household	.167(**)
4.21	Monthly income and Public Mode of Transportation to Recreation place	.167(**)
4.22	Monthly income and Private Mode of Transportation to Work place	.162(**)
4.23	Monthly income and Private Mode of Transportation to Shopping/Market	.161(**)
4.24	Monthly income and Public Mode of Transportation to Shopping/Market	.160(**)

S.No.	VARIABLE	INTERPRETATION
4.25	Monthly income and Public Mode of Transportation to Work place	.156(**)
4.26	Monthly income and Travel Distance to School/College	.151(**)
4.27	Monthly income and Time duration of Water Supply	.151(**)
4.28	Monthly income and Type of House : Flat	.139(*)
4.29	Monthly income and Travel Distance to Recreation place	.133(*)
4.30	Monthly income and Travel Distance to Railway station	.133(*)
4.31	Monthly income and Noise Pollution	.133(*)
4.32	Monthly income and Private Mode of Transportation to School/College	.131(*)
4.33	Monthly income and Business	.130(*)
4.34	Monthly income and Business (Primary)	.117(*)
4.35	Monthly income and Travel Distance to Public Transport	0.113
4.36	Monthly income and Preference among the Fringe Area : Thiruninravur	0.109
4.37	Monthly income and SC	0.104
4.38	Monthly income and Public Mode of Transportation to School/College	0.104
4.39	Monthly income and Other Jobs (Primary)	0.103
4.40	Monthly income and Frequency in a week to Public Transport	0.102
4.41	Monthly income and Number of persons Unmarried	0.098
4.42	Monthly income and Post-Graduation	0.096
4.43	Monthly income and Retired (Primary)	0.083
4.44	Monthly income and Other Source of Income	0.080
4.45	Monthly income and Motive of Buying House : Investment	0.079
4.46	Monthly income and Business + Agriculture	0.076
4.47	Monthly income and None (Secondary Occupation)	0.071
4.48	Monthly income and Agriculture	0.069
4.49	Monthly income and Other Religion	0.068
4.50	Monthly income and OC	0.068
4.51	Monthly income and Preference among the Fringe Area : Tambaram	0.067
4.52	Monthly income and Water Supply System : Public and Own Source	0.065
4.53	Monthly income and Number of Males	0.064
4.54	Monthly income and Private job (Secondary)	0.062
4.55	Monthly income and Motive of Buying House : Requirement	0.062
4.56	Monthly income and Any Other Occupation (Secondary)	0.061
4.57	Frequency in a week to Railway station	0.057
4.58	Monthly income and Self-employed (Secondary)	0.055
4.59	Monthly income and Travel Distance to Shopping/Market	0.054
4.60	Monthly income and Travel Distance to Work place	0.054
4.61	Monthly income and Graduation	0.053
4.62	Monthly income and Business (Secondary)	0.053
4.63	Monthly income and No. of Two-Wheelers Owned	0.052
4.64	Monthly income and Frequency in a week to Recreation place	0.052
4.65	Monthly income and Type of House : Detached	0.051
4.66	Monthly income and Motive of Buying House : To Rent Out	0.051
4.67	Monthly income and Muslim	0.050
4.68	Monthly income and Christian	0.046
4.69	Monthly income and Frequency in a week to Work place	0.046
4.70	Monthly income and Water Supply System : Own Source	0.045
4.71	Monthly income and up to Higher Secondary School	0.041

S.No.	VARIABLE	INTERPRETATION
4.72	Monthly income and Age of House	0.040
4.73	Monthly income and Government job (Primary)	0.038
4.74	Monthly income and Condition of the Road : Kutcha	0.038
4.75	Monthly income and Condition of the Road : Pucca	0.038
4.76	Monthly income and Preference among the Fringe Area : Red hills	0.038
4.77	Monthly income and up to Matric	0.037
4.78	Monthly income and Number of Cycles Owned	0.037
4.79	Monthly income and Preference to Move to Fringe Areas	0.032
4.80	Monthly income and Agriculture (Primary)	0.031
4.81	Monthly income and Property Rent	0.027
4.82	Monthly income and ST	0.025
4.83	Monthly income and Type of House : Row	0.025
4.84	Monthly income and Hindu	0.024
4.85	Monthly income and Preference among the Fringe Area : Poonamallee	0.023
4.86	Monthly income and Type of House : Apartment	0.022
4.87	Monthly income and OBC	0.013
4.88	Monthly income and Illiterate	0.013
4.89	Monthly income and Salary + Agriculture	0.013
4.90	Monthly income and Water Supply System : Public	0.012
4.91	Monthly income and Self-employed (Primary)	0.011
4.92	Monthly income and Agriculture (Secondary)	0.008
4.93	Monthly income and Preference among the Fringe Area : Aavadi	0.005
4.94	Monthly income and Frequency in a week to Shopping/Market	0.003
4.95	Monthly income and Frequency in a week to School/College	0.003

Note: ** Correlation is significant at the 0.01 level.

* Correlation is significant at the 0.05 level.

y = f (x1, x2, x3,…………….xn)

The multiple regressions obtained by employing the above function is

Y = 29749.450 + 1.307x1 + 5796.307x2 + 22181.779x3 + 33891.569x4+5770.004x5+1.223x6- 5630.175x7+13087.114 x8

R = 0.842

R2 = 0.710

F Value = 89.227

P Value = < 0.001**

y = monthly income

x1= actual expenditure

x2=number of bed rooms

x3= occupation (business + salary)

x4= preference among the fringe area

x5= water quality

x6= actual spending on energy

x7= number of males

x8= motive of buying house

Correlation coefficient method has been used to finalize the control parameters in the system.

VI. ASSESSING SUSTAINABLE DEVELOPMENT SCENARIO OF THE SYSTEM

Researcher have made an attempt to understand the sustainability and environmental conditions which exists in the study area i.e., Chennai Metropolitan Area, Tamil Nadu, India. To realize the tangible functions of the study area at the public official level, survey research techniques have been employed to conduct the investigation. A detailed investigation has been conducted to understand the dynamic functions of the system by considering the following major variables. The Authors have conducted the detailed professional survey by using the pre tested schedule among 101 senior officials of various Government Departments/Agencies located in Tamil Nadu, India, which involved in planning and development activities to understand the dynamic functions of the system.

Table No.4: Abstract of survey respondents

S.No.	Specialization /Occupation	Frequency	Per cent
1	Urban Planners	38	37.60
2	Municipal Administrators / Policy makers	21	20.80
3	Civil Engineers	12	11.90
4	Scientists	11	10.90
5	Academicians	10	9.90
6	Environmental Engineers	9	8.90
Total		**101**	**100.00**

Source: Compiled by the Author based on the Professional Survey 2013

The abstract of the survey respondents participated in the survey are furnished in Table 4. This table reveals that respondents are grouped in six categories. They are: (i) Urban Planners (37.60 per cent) (ii) Municipal Administrators/Policy makers (20.80 per cent) (iii) Civil Engineers (11.90 per cent) (iv) Scientists (10.90 per cent) (v) Academicians (9.90per cent), and (vi) Environmental Engineers (8.90 per cent) respectively. It is on the basis of this information and discussion that the present inquiry is proposed, namely, an evaluation of the extent to which the adoption by communities of sustainable development policies can be explained by the local government of Chennai Metropolitan City, India. It is proposed that this study still has relevance is the extent to which the studied communities can be characterized as displaying a necessary foundation for the emergence of appropriate or sustainable behaviour. Secondly, it will provide some sense of dynamics behind the adoption of sustainable development policies among the people of study area.

VII. PLANNING AND DEVELOPMENT OBJECTIVES OF THE STUDY REGION

In this present investigation, professional survey conducted in May-June, 2013 interviewed by the researcher and opinion obtained randomly from selected local government officials from 18 departments /agencies involved in planning and development activities in the study area. The results of the survey have been carefully analyzed using statistical techniques like, Chi-square test and Friedman test were carried out, by employing SPSS-20 software version, to understand the association among various occupational groups about the planning and development objectives in the study area and core results are presented in the Table No. 5 and Table No.6 respectively. The purpose of this study is to identify the initiation of sustainability policies for Chennai which is one of the largest cities in India. The city tends to be more inflicted with the types of dysfunctions which affect the sustainability (i.e., pollution, congestion, sprawl, etc.), in the system. Respondents were asked to indicate the best reflection of their opinion about the following sustainable planning and development issues of the study region. The most important results of the professional survey 2013 are presented in the sequel.

The table 5 demonstrates the opinion about the objective of removal of restrictions on FSI in the urban core for achieving energy efficient urban development in the system. More than two-third of occupational group agreed and less than one-third are disagree for the removal of FSI in the study area. Further the table reveals that the within occupational group Environmental Engineers, Scientists, and Policy makers believes 100 per cent, 90.90 per cent and 85.70 per cent respectively.

The table 6 depicts the priority among the twelve identified most influential parameters for energy efficient urban development using Friedman test by employing SPSS. The table demonstrates that the least mean rank value of 3.78 in respect of ‘Limiting the FSI restriction within the Carrying Capacity’ is ranked as number ‘1’ as top most priority, followed by the rank value of 4.02 for ‘Transportation demand and transportation capacity ‘and highest mean rank value of 9.99 conveys the lowest priority as ‘Choice of Individual preference - too high or too low density ranked as ‘12’.

Table No.5: Removal of restrictions on FSI in the inner urban core for achieving energy efficient urban development

S.No.	Specialization/ Occupation	Yes	No	Total	Chi-Square value	P Value
1	Urban Planners	**20**	**18**	**38**	21.054	0.001**
		(52.60%)	(47.40%)	(100.00%)		
		[29.00%]	[56.30%]	[37.60%]		
2	Municipal Administrators/Policy makers	**18**	**3**	**21**		
		(85.70%)	(14.30%)	(100.00%)		
		[26.10%]	[9.40%]	[20.80%]		
3	Civil Engineers	**9**	**3**	**12**		
		(75.00%)	(25.00%)	(100.00%)		
		[13.00%]	[9.40%]	[11.90%]		
4	Scientists	**10**	**1**	**11**		
		(90.90%)	(9.10%)	(100.00%)		
		[14.50%]	[3.10%]	[10.90%]		
5	Academicians	**3**	**7**	**10**		
		(30.00%)	(70.00%)	(100.00%)		
		[4.30%]	[21.90%]	[9.90%]		
6	Environmental Engineers	**9**	**0**	**9**		
		(100.00%)	(0.00%)	(100.00%)		
		[13.00%]	[0.00%]	[8.90%]		
Total		**69**	**32**	**101**		

Source: Compiled by the Author based on the Professional Survey 2013

Note: 1.The Value within ( ) refers to Row percentage, and 2. The Value within [ ] refers to Column percentage

Table No.6: Most influential parameters for energy efficient sustainable development

No.	Influential Parameters	Mean Rank	Chi-Square value	P Value
1	Distance from the CBD area and the housing area	6.11	215.204	0.001**
2	Limiting the FSI restriction within the Carrying Capacity	3.78		
3	Transportation demand and transportation capacity	4.02		
4	Providing adequate Physical and Social infrastructures in the system	4.78		
5	Resulting loss of facilities of existing residents is considered	8.20		
6	Choice of Individual preference - too high or too low density	9.99		
7	Transport lines (regular bus/rail routes) alter the directions of city growth	6.98		
8	Encouraging mixed land use development	4.71		
9	Distance from the work area to the housing area	6.10		
10	Discouraging private transport by introducing congestion charges	8.25		
11	Increase the share of residents Who Walk, Cycle or take Public Transportation to Work w.r.to minimum standards (time)	7.61		
12	Relationship with FSI and Road width for limitation of FSI	7.49		

Source: Compiled by the Author based on the Professional Survey 2013

Note: ** Correlation is significant at the 0.01 level.

VIII. APPLICATION OF THEORY AND SYSTEM DYNAMICS APPROACH

System theory (Forester W.J., 1994) has been employed in this investigation. The study area has been considered as a system and achieving energy efficient sustainable development in the system is considered as the major objective. A conceptual model is developed to establish the functions of the system, based on System Dynamics technique, in which energy has been considered as the catalyst for energy efficient sustainable development of the system. Industrialization has brought labor opportunities and thus the opportunity for a better life. By improving the conditions and the rights of workers and city individuals more people have found it attractive to move to the city. When there are more opportunities in the city more people are attracted to stay there by immigrating or simply just by not moving away. Along with the population growth and increased opportunities comes the higher demand of goods and services, and increasing pressure on the already existing built environment. This in turn encourage technology to improve, density to increase, and more efficient systems to take place. While creating more densely populated areas, more goods and services are demanded, technology evolves, and the city offers a wider range of opportunities compared to less urban areas. This way the loop is mutually dependent and dynamically evolves over time as shown in Figure.3 and demonstrates in a closed loop of typical urban development.

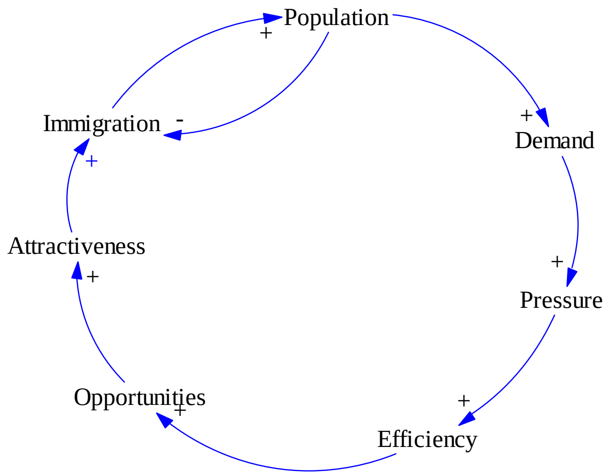

Fig.3: Cause and Loop Diagram over a typical Urban Development

Source: Compiled by the Author

System dynamics implies the dynamic behavior of a system and is interested in conceiving, studying the dynamics of functions, and understanding the behavior of models representing a real world system. Due to the concern of improving and hopefully control system behavior, sustainability oriented planners apply this approach. Observing and identifying problematic behavior of systems over time is the essence of system dynamics. System dynamics are known for its holistic view which demands a multidisciplinary and general approach in order to render the real world system. In this research, sustainable urban development itself is an interdisciplinary area which makes it essential to accommodate this criterion. In the real world, planning processes and their actors make interaction with physical and institutional structures in the society. These interactions lead to feedback loops, stocks and flows, and nonlinearities in the system structure which in turn result in system behavior. By understanding feedback loops we gain better knowledge of the complexity of the system and realize how to control or influence the system components in order for desired behavior and outcomes to occur. In linking resources and information stocks and flows in feedback loops it demonstrates how the system components are woven together in a higher level of details.

A. *Feedback Loops*

By nature, people tend to see the world as a linear *cause and effect* system. The world is however more complex than that, when implementing feedback loops the core of the system dynamic concept is captured. The mental models we obtain and created by feedbacks which determine the dynamics of real world systems. Then we address how the processes of information influence other parts of the system and in turn influence itself our mental models alter and our understanding of the system complexity increase in value. Over time, the complex interplay between all the subsystems of the system will increase. Feedback loops will thus evolve and may consist of additional variables and changing patterns.

Feedback loops are causal loops that demonstrate the influence dynamics of components in the system. By linking resources and information feedback loops are designed and presented in Figure 4.

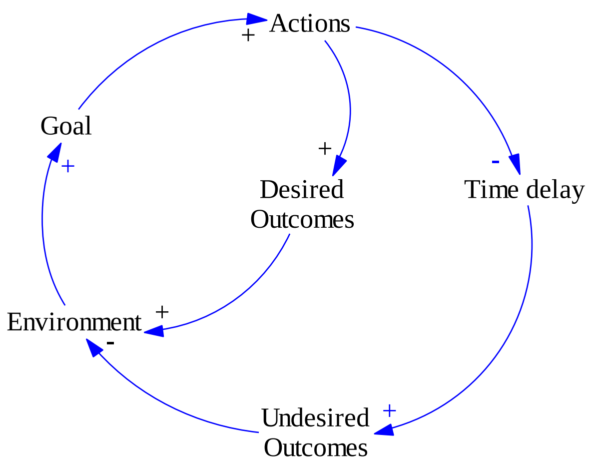

Fig.4: Feedback Loop for decision-making in System Dynamics

Source: Compiled by the Author

Figure 4 demonstrates the inter-dependency between goals, actions, outcomes and the environment in the general term. In

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the context of sustainable urban development the city's total environment is desired to be improved. On behalf of the city better environmental quality, increased economic growth, and improved social justice in the urban society are set as goals. The level of the goals is up to the person behind the evaluation, and can be concrete and sharpened for economic interests, or bigger and more diffuse for an overall sustainability concern. The goals further lead to certain actions which in turn result in outcomes. The outcomes may improve our environment as desired or cause undesired changes to it. Undesired outcomes may occur in longer time frames compared to desired outcomes due to a delay in time. Both undesired outcomes and time delays are often not taken into account when planning and actions are implemented as it is impossible to know all action effects and consequences. Even though a similar action has been implemented in other cities before, a city may experience other consequences and thus different outcomes than originally desired. This demonstrates that the more well through the system dynamic approach is, the better the knowledge of what might be the outcomes of the actions is, but that one never knows the total impact of actions until they are set to life and observed over time.

There are three constrains arising between economic growth, environmental protection, and social equity is defined as the *property constrains*, the *resource constrains*, and the *development constrain* in the system. Property constrain is addressing the tension between economy's need for growth in outcome and the society's need for justice leading to a question of owning and distributing land our buildings. The resource constrains rises from the tension between economy's interest of production and growth, and the natural environment's interest of preserving resources for the quality of the nature and future exploitation. The resource constrain is thus representing the question of how to distribute, utilize and regulate the availability of resources. The last constrain rises between social demand for space and equity, and the environmental demand for green space and a healthy environment, called the development constrain.

B. Conceptualizing the Integrated Model for Sustainability

As desired outcomes influence the environment beneficially and undesired outcomes may lead to negative change in the environment the goal will adjust to the environmental change and hence change the actions involves if necessary. Due to this synergy the loop will continue to develop the city by the goals, actions and outcomes it brings. The goal changes and the whole process in the feedback loop start its dynamic process all over again. When understanding the interrelated and interdependent pieces of the puzzle a better picture on the world is given and we may be better equipped to make good decisions for the future. In terms of sustainable development it is especially important to be able to include the long-term perspective and time-delays, and thus understand what affects and outcomes actions may lead to and realize that in order to do the best thing for the future we must see the world as a system infinitely generating desired and undesired outcomes. Sustainability issues are experiencing the difficult task of managing all three perspectives at the same time, and as there exist many different goals and perspectives in all the three areas, the system complexity needs qualified planners in order to be resolved for a better sustainable future.

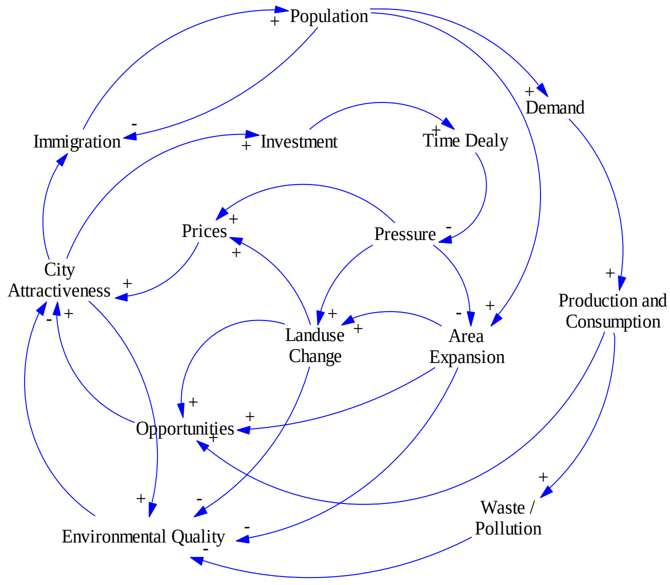

Fig.5: Integrated Model for Sustainability and its Constrains of an Urban System Source: Compiled by the Author

It is interesting to note how these three constrains are functionally interconnected and interdependent to each other. The general integrated model for sustainability and its constraints has been conceptualized and is presented in Figure 5. This figure depicts overall integration and casual linkages in the system. Their constraints are parts of a larger system, and in order to understand the situation and model of sustainable urban development we must consider these strong relations. Yet, it also demonstrates that in order to see the whole we must also see all the subsystems. If decisions are to be made it is beneficial to take a closer look at the conflicts and divide the overall model parts which are easier to relate to planning and decision making. It will ease the understanding of where to intervene in the system. In other words, by understanding the whole we understand the system and by taking a closer look at its parts we understand where our leverage points are in terms of better planning of sustainable development. We need to understand the whole in order to understand all the subsystems, their interactions, interdependencies, casual linkages and vice versa.

C. Modeling

System Dynamic Models would be developed for various subsystems to understand thier functional dynamism. For example, the Population sub-system model has been developed by the authors and presented in Figure 6. This model is employed to understand the population dynamics and associated real functions of the system, and likewise all the subsystem models would be developed based conceptulized integrated model for sustainabilty and combined together to develop the integrated system dynamics model. STELLA 9.1.4. Software is employed to develop the System Dynamics model. The evolved System Dynamics model is validated by employing simulation technique, to understand the reliability of the model for further investigation. The Validated System Dynamics model is employed to project the control parameters, which decide the functions of the system for the year 2041 A.D., with the present trend and thereby the projected year model for the year 2041 A.D. is developed for evolving plausible policy planning guide lines.

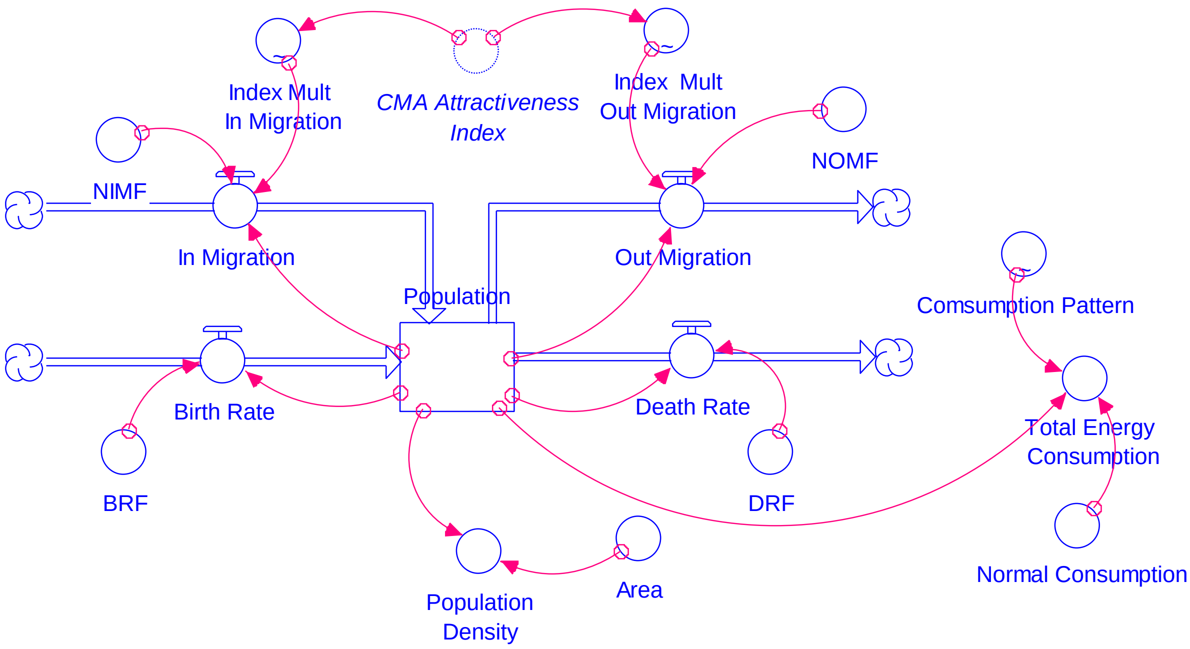

Fig. 6: Population Sub-system Model

Source: Compiled by the Author

IX. CONCLUSION

In this present article, a detailed analysis was done pertaining to socio-economic conditions, analysis of infrastructure facilities, energy consumption, energy conservation and status of sustainability in the system. Analysis of the data provided an insight about this system, its dynamic functions, and also paved the way for identifying the most important control parameters, which decides the functions of the system (Study area). In 21st Century urbanizing world, sustainable development planning invites the new paradigm of systematic evaluation, which is inevitable requirement to have a close look to understand their functional integrity and its dynamism of a particular system.

In conclusion, Energy is central to socio-economic well-being and also to meet environmental demand. Integrated planning approach in energy production and consumption of an urban system in sustainable way is indispensable for achieving energy efficient urban development. Energy plays vital role for improving human, social, economic, environmental conditions on one hand and degrade the environment by the generation of huge waste and excessive greenhouse gas emissions in the system on the other. Even though urban planners /policy makers are making continuous attempt to encounter these modern day challenges, but could not succeed to desired level, due to unprecedented population explosion and increase in urban energy demand, especially in the developing and least developed countries. Further, it exerts greater stress and daunting task which prevails in the system. Therefore, energy for sustainable development must be visualized in social, economic and environmental dimensions, which is very much essential to achieve energy efficient sustainable development. It is important to understand the forces that shape the growing mega cities of the world, by considering energy as the catalyst in the development process will pave the way for energy efficient sustainable development in the system.

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