Current World Environment Vol. **10**(1), 121-142 (2015)

Environmentally Sustainable Development of Urban Settlements In India: A Framework For Development of Indicators

SHUVOJIT SARKAR[1]* and T.K. BHATTACHARYYA[2]

[1]Department of Architecture, School of Planning and Architecture, New Delhi, India.
[2]Department Of Architecture, Jadavpur University, Kolkata, West Bengal, India.

http://dx.doi.org/10.12944/CWE.10.1.15

(Received: December 10, 2014; Accepted: January 08, 2015)

ABSTRACT

There have been numerous efforts worldwide at various scales (global/national/regional/local) in the field of development of sustainable development indicators, focussing on either one or all of its various dimensions, following the Rio Summit in 1992. However, India has fallen behind in the area of development of Sustainable Development Indicators and none of the Indian cities figure in the review of the IISD Compendium, the most comprehensive database to date to keep track of Indicators efforts. A review of the initiatives by several international agencies and countries in formulation of the sustainability indicators though provide necessary guidance, the final framework needs to address the urban sustainability issues in the Indian context. The objective of this paper is to develop a set of indicators at macro and micro level for environmentally sustainable development of the urban settlements in India. It involves recommending an approach, a methodology and a structural framework for deriving the indicators set at various levels focussing on resource dynamics of urban settlements. Domain based classification has been followed wherein domains have been identified based on essential natural and built in resources. Further, for each domain environmental sustainability determinants have been recognised and based on them multilevel indicators have been identified with a goal of greater livibility and quality of life. A way forward has been given for the evaluation of indicators for formulation of policies at national level and action plan at local level with stakeholder's participation.

Key words: Environmental Sustainability, Urban Settlements, Frameworks, Indicators, Macro level, Micro level.

INTRODUCTION

Review of Sustainable Development Indicator Initiatives

Several International and National agencies across the World have been working towards formulating indicators of sustainable development at various levels since the concept of 'Sustainable Development' got a major impetus after the 'Brundtland Commissions' Report in 1987. A review of the indicator initiatives across the world gives an insight into their conceptual approach, structural framework, aspect of sustainability focussed and the outputs in terms of policy response or action plans.

The reviewed major indicator initiatives, which have provided a relevant direction and guidance for the present study, have been discussed here in brief. The United Nations Commission for Sustainable Development **(**UNCSD) indicator system (1996-2006) is based on monitoring and implementation of AGENDA 21 focussing on all the dimensions of sustainability at national level.

It is based on a flexible policy oriented framework of themes and sub-themes, emphasising on the multi-dimensional nature of sustainable development by integrating the four pillars of sustainability (social, economic, environmental and institutional). UNCSD indicators provide a good base for policy development process at the national level.

The Organisation for Economic Co-operation and Development (OECD) Indicators (1993) focus on environmental issues of sustainability at the national scale and are structured on Pressure-State-Response (PSR) framework and have emerged as the most widely used indicator framework for environmental reporting. The outcome is well-defined set of measurable and policy-relevant environmental indicators grouped in several categories corresponding to a specific purpose, a logical approach that recognises that there is no universal set of indicators; and a dynamic process where none of the indicator sets are final or exhaustive and need regular refinement.

The United Nations Commission on Human Settlements **(**UNCHS) indicators (1996) aim at attaining objectives of 'Habitat Agenda' following a policy based framework and an action oriented indicator system. They now focus on broader issue of sustainable development encompassing all the three dimensions apart from housing and shelter issues of urban settlements with specific focus on Millennium Development Goals (particularly on improvement of slum dwellers) .

The European Common Indicators (Ambiente Italia, 2003) are ready to use set of indicators based on thematic framework and bottom up approach which can help local authorities in monitoring their progress in environmental sustainability at the local level.

The UECIQES China (1989) is a very successful initiative structured on target based framework for environmental protection in urban areas at local level. It is a system of assessment of environmental performance of the cities through a reward based incentive mechanism and enhances the sense of responsibility of government authorities at all levels for urban environmental protection.

The Kitakyushu Initiative, Japan (2000) is focused on urban environmental sustainability and brings together practices and experiences of Kitakyushu and other cities in the Asia Pacific region to provide an effective guideline for this region. It uses a variation of PSR framework realising its limitations and focus on not isolating causes and effect and adopts the systems approach.

The Environmental Indicators Human Settlement (1998), Australia is based on systems approach which uses Extended Urban Metabolism Model (EUMM) in state of the environment reporting on human settlements at the national level. EUMM considers the quantity of materials in human settlements from raw input to waste outputs and the transformation of these through the dynamics of urban settlements processes into desirable livability outputs. This model is normative, having clear goals of reducing resource input, reducing waste output and improving livability for future generation. It follows a domain based approach where indicators have been developed under the ten identified domain areas of the human settlements.

Structural Frameworks

Structural Frameworks are the rational over which the indicators are outlined. Different indicator initiatives across the globe have developed various framework methods over the time which mainly differ in the way the different aspects of sustainable development are being focussed, the inter-connection between the various aspects, the way they highlight the major issues to be monitored and the criteria for selection of indicators for assessment of the state of sustainability and providing necessary inputs for decision making.

The few commonly used frameworks for developing sustainability indicators, as seen in the major indicator initiatives discussed above, have been examined here in brief to provide the necessary input in selection of the structural framework for the present study:

Policy Based Framework

A policy based framework is based on developing a comprehensive inventory of major social goals and devising indicators to measure progress towards these goals. Such indicators originate from a nation or a community concern in a particular area and aim at establishing urban strategies and policies. The UNCHS indicators programme and the subsequent Global Urban Observatory have been developed based on this framework.

Theme and Index Driven Framework

A thematic /index driven framework works by establishing broad themes and sub themes such as livability, sustainability, compact city, ecological city or good governance which are generally multidimensional, involving different aspects which have different indicators, or may be expressed as indexes such as Human Development Index, City Development Index or linear combinations of indicators. They do not target at specific policy goals and not necessarily associated with a strategy. Thematic framework has been in development of UNCSD and EU Common Indicators

Causal Framework (Pressure- State-Response Framework)

The Pressure-State-Response framework developed and popularised by OECD (2004) for State of Environment reporting has emerged as the most widely used indicator framework for environmental reporting. The PSR framework represented an advance in environmental indicators development by introducing the concept of cause and effect relationship amongst indicators covering human pressure on the environment, actual state of the environment, and the responses which may be undertaken to alleviate environmental damage. For example emission of CO_2 due to human activities is an Environmental pressure indicator, rise in global temperature is a State of Environment indicator and various actions like carbon tax, planting of trees etc. at global, national or local level are response indicators. One of the advantages of PSR framework is its attention to responses to environmental problems which are often neglected in the area in indicator studies (Australia, 1998).

Driving force-pressure-state-impact-response (DPSIR) framework is an extended version of PSR framework, adopted by the European Environmental Agency (EEA) and the European Statistical Office (Eurostat, 1997). Driving forces are the underline causes of pressure such as demography, urbanisation, lifestyle, economic situation, poverty etc**.**

There are two major limitations in the underlying foundation on which the PSR framework is based. Firstly, it is difficult to categorise an indicator as a pressure or a state or a response, because the focus of the observer may change depending on the underlying objective. The indicator, which is a pressure in one perspective, may be a state in another and a response in a third (Australia, 1998). For example, housing, which is a pressure indicator for land use, is a state indicator for construction domain and is a response for the homelessness.

Secondly, the pressure, state and response/ impact mechanisms are complex and cannot be isolated into single cause and effect. There can be relationships between causes themselves and the effects themselves.

The causal framework (DSR model) initially adopted for development of UNCSD indicators was later abandoned realising its above limitations and especially it was found to be inappropriate for economic and social indicators as it lacks focus on policy (UNCSD, 1996).

To overcome the above limitations, a modified version of PSR has been used in Environment Sustainability Index (ESI), developed by the World Economic Forum (WEF) where apart from PSR two additional components were added, human vulnerability and global stewardship (WEF, 2005). Kitakyushu initiative is another such example where the modified PSR framework does not isolate cause and effect relationship and include the vulnerability of the human system to cope with changes in the environment (Dhakal, 2002). .

Systems Framework- The Extended Urban Metabolism Model (EUMM)

The Extended Urban Metabolism Model (EUMM) developed by Newman et al. (1996) for State of the Environment reporting in Australia (Australian Environmental indicators human settlements,1998) interpret cities as dynamic urban system (population dynamics, economy, industry, infrastructure, transport, institution, linkages) which require inputs of key resources (Land, water, Energy, Population, Finance) which are drawn into the urban processes and transform them into desirable livability outputs or Services (Employment, Income, Health, Education, Housing, Accessibility to services, Community life) and waste (Solid waste, Sewage, Air pollutants, Noise). The desirable change for the system is improvement of livability and reduction of waste. EUMM is closely aligned with the paradigm of sustainable development where future orientation, sustainability goals and targets and linkages among different dimensions are made explicit (Australia, 1998; Newton, 2001).

Performance/Target Based Framework

This framework is based on outcome oriented indicators system capable of providing data for establishing and assessing public sector goals and targets in the context of agency management and accountability, strategic planning, economic development program evaluation, customer satisfaction and city competitiveness.

The UECIQES China (1989) is structured on target based framework for assessment of environmental performance of the cities through a reward based incentive mechanism and enhances the sense of responsibility of government authorities at all levels.

Aim of the study

The aim of this study is to develop a set of indicators at macro and micro level for environmentally sustainable development of the urban settlements in India.

Objectives of the study

- To recommend an approach for developing the multilevel indicators set focussing on resource dynamics of urban settlements
- To develop a set of core indicators for urban settlements in India for state of the environment reporting at the national/city level.
- To develop a set of additional indicators for assessing the urban ecosystem at micro level (neighbourhood level) and to overcome the challenge of data availability at local level.
- To ensure that the indicators adequately cover all the major urban environmental issues in the Indian context
- To identify relevant data sources for each indicator, wherever available
- To define the baseline information that is needed to properly interpret the results of the indicators in the form of policies at national level and action plans at local level.

Scope of the study

The study focusses on urban environmental sustainability and issues of economic and social sustainability per se remain beyond the scope. However, apart from the physical environment those areas where social and economic factors exert an environmental effect may be considered suitably wherever necessary.

Methodology

Conceptual Approach

Sustainable Development is a broad and multidimensional concept. The most popular definition of Sustainable Development as given by Brundtland Commission (WCSD, 1987) is “Sustainable development is the development that meets the needs of the present without comprising the ability of the future generations to meet their own needs”. A modified version of this definition to make it applicable to the urban context is “the path of urban environmental sustainability is the one in which urban development meets the environmental needs of the present urban dwellers without compromising the ability of non-urban dwellers and the future generations to meet their own needs which are affected by the environment” (MoE Japan,2002).

Thus for environmental sustainability of an urban settlement it requires monitoring of the internal environment of the settlement and its success in fulfilment of basic needs of its inhabitants while minimising undesirable effects; as well as the effect that the settlement has on the wider natural environment through resource use and waste outputs. Hence to achieve the aim of environmentally sustainable urban development following two major goals have been identified:

a) Ecological resilience of the Natural environment- To preserve balance of the natural resources and the restoration and renewal capacity of the natural ecosystem.

b) Sustainable development of the Built Environment- Energy efficient settlements with adequate and secure housing and efficient infrastructure.

To achieve the above goals, the study focuses on formulating an indicator system which performs the following tasks:

- To assess the state of the environment
- To provide necessary inputs to the policy makers
- To keep track of the changes in the environment and to do a performance review of the environmental policies
- To inform the general public about the state of the environment and raise awareness

The study focusses on formulating an indicator set which can satisfy the following characteristics to the extent feasible:

- Multilevel indicators

a) Core indicators-common set of indicators with available data at broader level and with opinion of experts; and

b) Additional indicators- specific set of indicators relevant to a local area and with public participation

- Simple and easy to understand by policy makers and the general public
- Bottom up approach and multi stakeholders participation
- Policy responsive and Action plan oriented
- Analytically sound
- Mix of quantitative and qualitative indicators
- Quantifiable with available reliable data

Selection of the Structural Framework

A review of the major structural frameworks in use in development of sustainability indicators brings to the notice that irrespective of systems framework advantage over the causal and thematic ones, especially in development of environmental indicators, it has not been much explored. Australian Environmental indicators human settlements is the sole literature in indicator research found using EUMM model (Australia, 1998).

The systems approach differs from the policy based approach in beginning with a simple but explicit physical model or systems diagram of the city or the environmental system, within which the various actors operate and in which linkages and causality between various sectors are delineated. The limitations of the PSR framework for urban indicator development have also been addressed via the Extended Urban Metabolism Model which makes explicit the notion of livability and reinforces the normative concept of improved environmental outcomes over time. EUMM is closely aligned with the paradigm of sustainable development where future orientation, sustainability goals and targets and linkages among different dimensions are made explicit (Australia, 1998; Newton, 2001).

Thus, for the present study, system framework based on *Extended Urban Metabolism Model* (EUMM) developed by Newman et al. (1996) has been adopted with modifications relevant to context of the study.

EUMM observes cities as systems which require raw inputs of resources which are transformed through the various forces at work in the urban process into livability outputs and waste outputs. The desirable change for the system is reduced resource use, enhanced livability and reduced waste. The components of the EUMM are discussed below and their relationship has been explained in the fig1 :

Resource Inputs

The raw inputs required for functioning of an urban settlement are generally derived from natural resources- Land, Air, Water and Energy (from both renewable and non-renewable sources). Food, drinking water, materials for building and industries, oil for transport etc. are derived from the said natural resources.

Dynamics of Urban Settlement

Population growth and spatial distribution are major determinants of urban activity, intensity of resource usage and environmental impact. The various economic and industrial activities, provision of infrastructure, transport facilities and linkages, institutional and cultural facilities are all various driving forces which are required to sustain a population in an urban settlement and hence consume resources and generate desired outputs and waste by-products.

Livability

It is a measure of quality of life of an urban settlement which is governed by the parameters such as clean and healthy natural environment (air quality, water quality, urban green) and sustainable physical built environment (access to proper housing and efficient infrastructure) along with various economic and social factors such as employment opportunities, affordability, better health and educational facilities and interactive and safe community life.

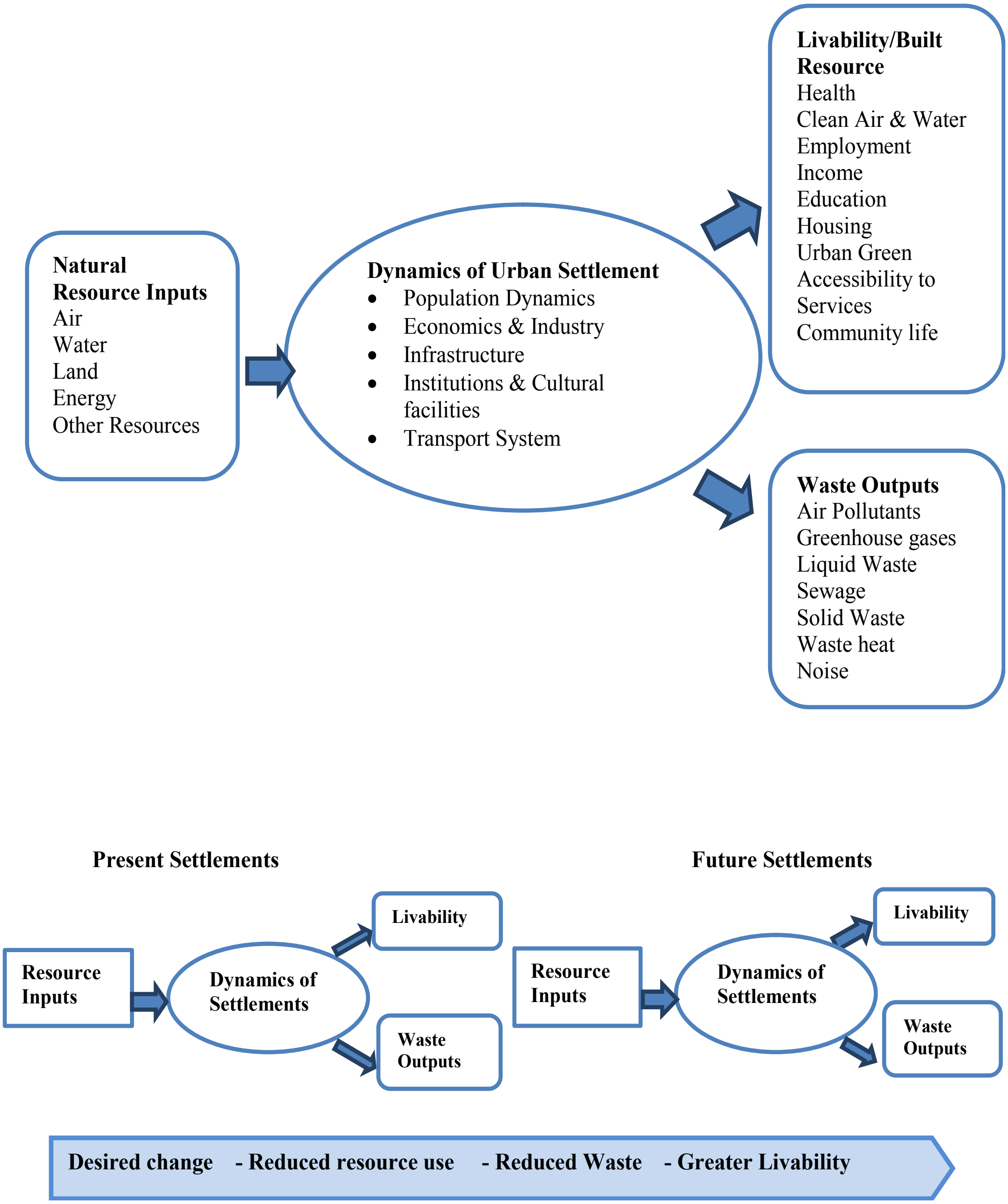

Fig. 1: Extended Urban Metabolism Model of Human Settlements
Source: Adapted from Newman *et al.*(1996)

Waste Outputs

The consumption of resources by various human activities lead to various undesirable by-products such as air pollutants, greenhouse gases, liquid waste, sewage, solid waste, toxins, heat and noise.

The relationship between the various components of EUMM has been explicated in Fig. 1 below. For sustainable living conditions it is required to have judicious use of input resources so that they can replenish over time and a reduction in waste production through various measures such as end-of-pipe technologies, systematic redesign etc. to minimise the environmental impacts and increase the quality of life.

Identification of Domains

The objective of the study is to develop set of indicators for greater livability in urban areas with focus on environmental dimension. For this, as seen in Australian Environmental indicators human settlements (1998), domain-based classification becomes appropriate as this ensures experts participation for the development of sound indicators with the required scientific or disciplinary backing.

For the present study, the five domains have been identified based on the essential natural and built in resources: air, water, land, energy, housing and infrastructure which are required for the sustenance of population and the urban system and quality of life. Since the population growth and density affects the natural and built environment by exerting consumption pressure and by generation of waste, population has been chosen as the sixth domain.

For greater livability of the settlements following urban environmental sustainability determinants have been elucidated for the above identified domains with the goal of achieving healthy and resilient natural environment and sustainable built environment.

1. Population- Sustainable population growth and density for reducing the consumption pressure on resources and generation of waste
2. Air- Maintaining air quality and reducing pressure on the atmosphere
3. Water- Maintaining water quality and reducing pressure on the water systems
4. Land- Balanced built land use and urban green and reducing demographic pressure for development
5. Housing- Access to proper and durable housing for satisfaction of basic need of Shelter
6. Infrastructure- Access to infrastructure for satisfaction of basic needs of clean and adequate water and sanitation
7. Energy- Efficient energy use by sensible use of resources and minimisation of waste

Formulation of Indicators

Formulation of indictors should reflect a thorough understanding of the systems they are going to monitor. A set of domain models have been developed for the above identified resource based six domains: air, water, land, energy, housing and infrastructure structured on EUMM model for providing the framework within which the core indicators at the macro level and additional indicators at micro level could be developed. The seventh domain population has been treated as one of the major underlying force determining the intensity of resources usage and environmental impact through various urban activities.

In developing the models for the identified domains the focus is on explicating the observable parameters i.e. the resource input, livability and waste output and the unobservable complex parameters i.e various forces at work in urban settlement for conversion of resources to the various outputs have not been enumerated. This approach satisfies the property of an indicator. For example health of a human body is tested through various indicators like temperature, blood sugar etc. without going in to the complexities of what happens inside the human body.

The selection of indicators under each identified domain has been made keeping in mind the sustainability determinants along with data availability at macro level and scope of collecting data for that parameter at micro level. Care has been taken to choose a set of concise, simple, easily understandable and interpretable indicators which are also analytically and scientifically sound.

Population

The world population has been estimated at 6.916 billion in 2010 by the population division of United Nations Department of Economic and Social Affairs. UN projections, 2012 envisage a continued increase in population and the global population is expected to reach around 10.9 billion by 2050. According to the State of the World's Cities Report 2008/09, nearly 60% of the world's population will live in urban areas within the next two decades, and it is in the developing countries that this growth will take place most rapidly. Cities consume 60% to 80% of the world's energy production and natural resources. With the urban population of the developing world projected to reach more than 5 billion people by 2050, ideas about how to combine urbanization and sustainability are of critical and immediate importance.

The tremendous growth in urban population that has been seen through the latter half of the twentieth century, in developing countries particularly, is a consequence of both demographic change and of substantial and continuing migration from rural to urban areas. Population growth is responsible for 80 percent of deforestation worldwide and about three quarter of arable land expansion (UNFPA, 1992). Population growth and environmental degradation are engaged in a complex, multi-factor relationship, where one serves to exacerbate the adverse impacts of the other (UNER,1995). The concentration of population in particular areas can have a particularly damaging effect on environments once critical pollution thresholds are exceeded. Unless properly planned and managed, this alarming growth is increasingly resulting in urban sprawl, mounting stress on infrastructure, creation of slums, a widening rich–poor divide, deteriorating quality of urban services and increased environmental pollution and energy use.

India is the second most populous country in the World after China and together they constitute 37% of the world's population. As per Census of India, out of the total population of 1210 million in 2011, about 377 million are in urban areas.

Selection of Indicators

Unprecedented population growth is the root cause of urban sustainability problems. From the environmental point of view stress is on reducing the demographic pressure on the resources and the environment.

Population in absolute numbers, population growth rate and population density of the built up area have been chosen as indicators at macro level as these define the carrying capacity of an area and the ability of the environment to regenerate and cope with human intrusion.

At the micro level apart from the above indicators depending upon the characteristics of the residential area/mixed land use floating population may also be one of the indicators to assess the pressure of the population coming for various jobs during the day time.

Air

The quality of air in an urban area depends upon the geography of the place, meteorological conditions and the various economic activities and type of energy use. Air pollution in India is quite a serious issue with the major sources being vehicle emissions, industries, generators, fuel wood and biomass burning (domestic combustion), fuel adulteration, road side dust, construction activities etc. An approach for improving the air quality in urban areas require identification of emission sources, an assessment of the extent of contribution by these sources to ambient air quality, prioritization of sources that needs to be addressed and accordingly formulation of an action plan. The various air pollutants generally found in urban areas are SPM, PM_{10}, PM_{25}, SO_2, NO_X, CO, O_3, Benzene etc. as per the various studies by government monitoring authorities. Amongst the above mentioned pollutants the major parameters for assessment of air pollution in the urban areas in India as being monitored under the National Ambient Air Monitoring Program (NAMP) conducted by CPCB are SO_2, NO_2 and RSPM (i.e., PM_{10}). Respirable Suspended Particulate Matter in particular pose a serious immediate health hazard for the urban dwellers. CO_2 and other greenhouse gases concentration is a global phenomenon and is responsible for global warming.

Selection of Indicators

Fig.2 illustrates the EUMM model applied to the Air domain. From the environmental perspective **stress is on reducing down the quantum of air pollutants and green house gases for clean air and health of urban dwellers.**

SO_2, NO_2 and PM_{10} concentrations have been chosen as indicators of air quality assessment at macro level as these as the air pollutants generally found in urban areas in India and their concentration within permissible limits indicate that there is manageable stress on the atmosphere due to various human activities. CO_2 concentration, a global phenomenon is considered in terms of its annual emissions for assessment of climate change impact on the environment.

At the micro level apart from assessing SO_2, NO_2 and PM_{10} concentrations data, a qualitative assessment is done specific to the characteristic of the local area through reconnaissance survey and stakeholders feedback to identify the major sources of emission and to prioritize and address the problem areas. Hence the chosen indicators are emissions from residential energy use, emissions from commercial energy use, emissions from industrial energy use, vehicular emissions and emissions from burning of soild waste/dry leaves. Since SPM/RSPM concentration pose a serious immediate health hazard for the urban dwellers, an assessment is done at the local level through the indicators- percentage of of paved(black topped) road length/total area under roads and percentage of road with roadside green/plantation.

Water

Water is one of the basic resources for sustenance of life on this earth. In an urban settlement water is required for carrying out essential activities of various sectors and even for various recreational purposes.

In the urban areas, water is tapped for domestic and industrial use from rivers, lakes, streams and wells. Around 80% of the water supplied for domestic use comes out as waste water. Waste water in the form of treated, partially treated and untreated sewage, effluents from industries, storm water runoff from improper solid waste dump areas, landfills, agricultural fields, roads etc. when discharged in water bodies or allowed to sink in the ground are the major causes of surface and ground water pollution in the urban areas. Water pollution

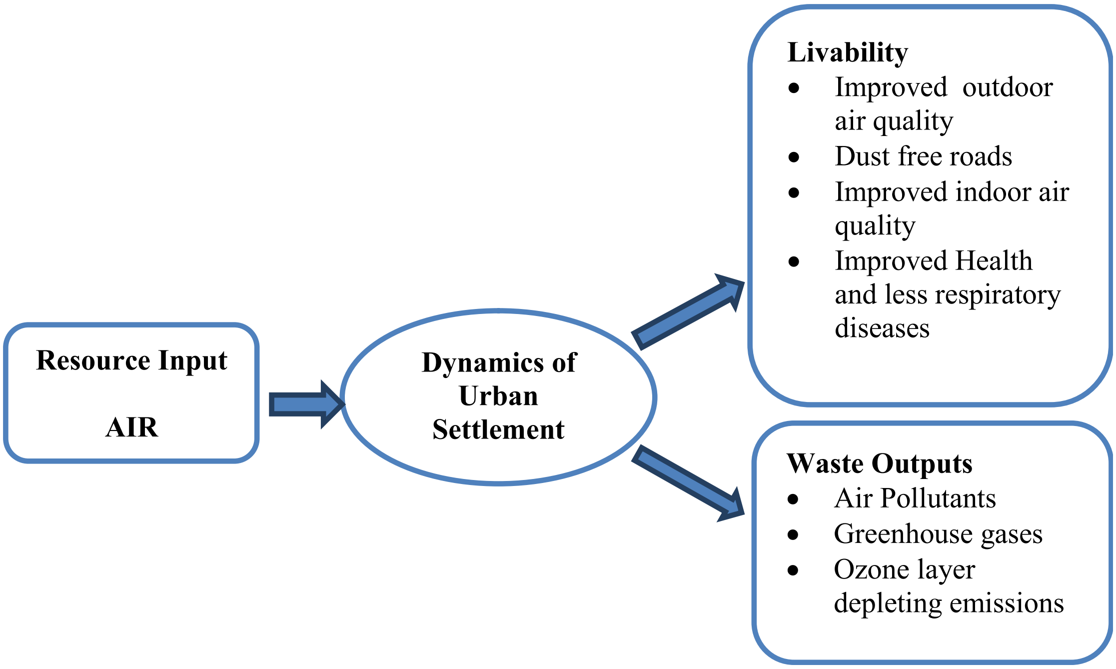

Fig. 2: Domain Model for Air (Source: Author)

is responsible for the various public health problems and the loss of aquatic/marine life.

Municipal Sewage is defined as "waste (mostly liquid) originating from a community, may be composed of domestic wastewaters and /or industrial discharges" (CPCB, 2009).As per the various monitoring studies conducted by CPCB, Municipal Sewage is the major source of water pollution in India, particularly in and around large urban centres. Drinking water increasingly fails to meet standards due to pollution, poor operation of sewage treatment facilities, lack of disinfection and the poor condition of supply systems and sewerage systems. Supplying safe drinking water is therefore an important environmental sustainability issue which requires explicit emphasis on quality.

Selection of Indicators

Fig.3 illustrates the EUMM model applied to the Water domain. From the environmental perspective **stress is on maintaining water quality by reducing down the quantum of water pollutants for availability of clean and safe drinking water for urban dwellers.**

For assessment of the health of the water sources at macro level average BOD (or DO) concentration of the major water bodies has been considered for water quality assessment. In the coastal urban areas average COD concentration of the coastal water may be considered for assessment of water pollution and hence the water quality.

At the micro level both surface and ground water pollution and quality of the drinking water supply are assessed by doing a reconnaissance survey of the local area and from stakeholder's/ community feedback. The chosen indicators are the mode of sewage disposal (municipal connection/ pit/ septic tanks/open defecation/storm water drains), solid waste disposal(open dumping /dumping in storm water drains) , contamination of storm water runoff (agricultural fields,/landfills/chemical working sites/others)and incidences of water borne diseases if any.

Land

Land, being a limited resource, needs to be utilized in a sustainable manner. There is a tremendous land pressure to satisfy the residential, commercial, industrial and public facilities requirements of the growing population. The various human activities driven land usage pattern in urban areas leads to various environmental problems.

The large scale urbanisation of land to satisfy the demands of the growing population

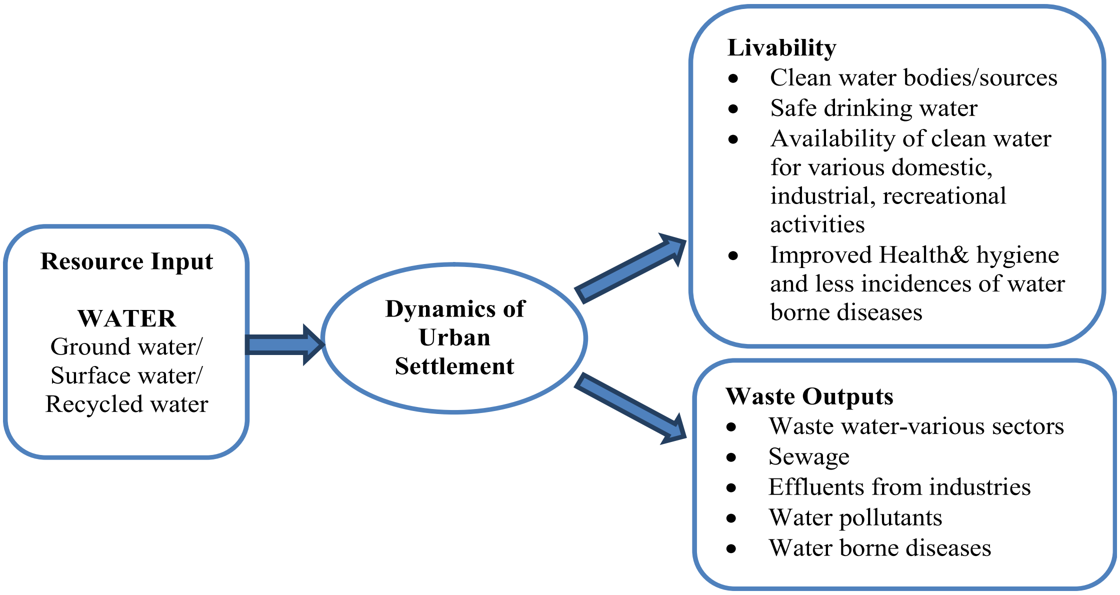

Fig. 3: Domain Model for Water (Source: Author)

encourages cutting of trees, destruction of green cover and a rise in hard paved areas/concrete surfaces. This leads to soil erosion, loss of nutrient rich top soil i.e. soil fertility and loss of biodiversity.

An increase in impervious surfaces alters the natural water cycle by less evapotranspiration, less percolation of storm water in the ground and an increase in surface runoff leading to declining ground water table and increased rain fed urban floods. There is also loss of dissipation spaces like wetlands and mangrove lands leading to increased events of urban floods. Moreover, the urban heat island effect due to the increase in built and paved surfaces leads to increased temperatures that are linked to global warming and climate change.

Also the use of chemicals in agricultural fields and the generation of hazardous waste from various industrial and building construction activities pose a serious threat to human health and natural environment. The dumping of these wastes on land leads to contamination of land and ground water and surface runoff from these areas leads to surface water pollution.

Selection of Indicators

Fig.4 illustrates the EUMM model applied to the Land domain. From the environmental perspective stress is on sustainable landuse with balance between the land under built use and urban green and reducing various environmental impacts due to the demographic pressure for development on the land.

Sustainable land utilisation to cater to various urban needs is an important component of livability. Therefore land use pattern at macro level is one of the indicators mainly focussing on percentage of land under residential use, green space and under roads.

Urban green spaces help in local habitat and biodiversity conservation, enhance micro climate by reducing albedo and solar radiation load, prevents soil erosion and aids in better air quality by trapping particulate pollutants. The role of green space in urban system is very crucial and thus for assessing the sufficiency of the green space at macro level the chosen indicators are the per capita availability of green space and area of green cover available per thousand population.

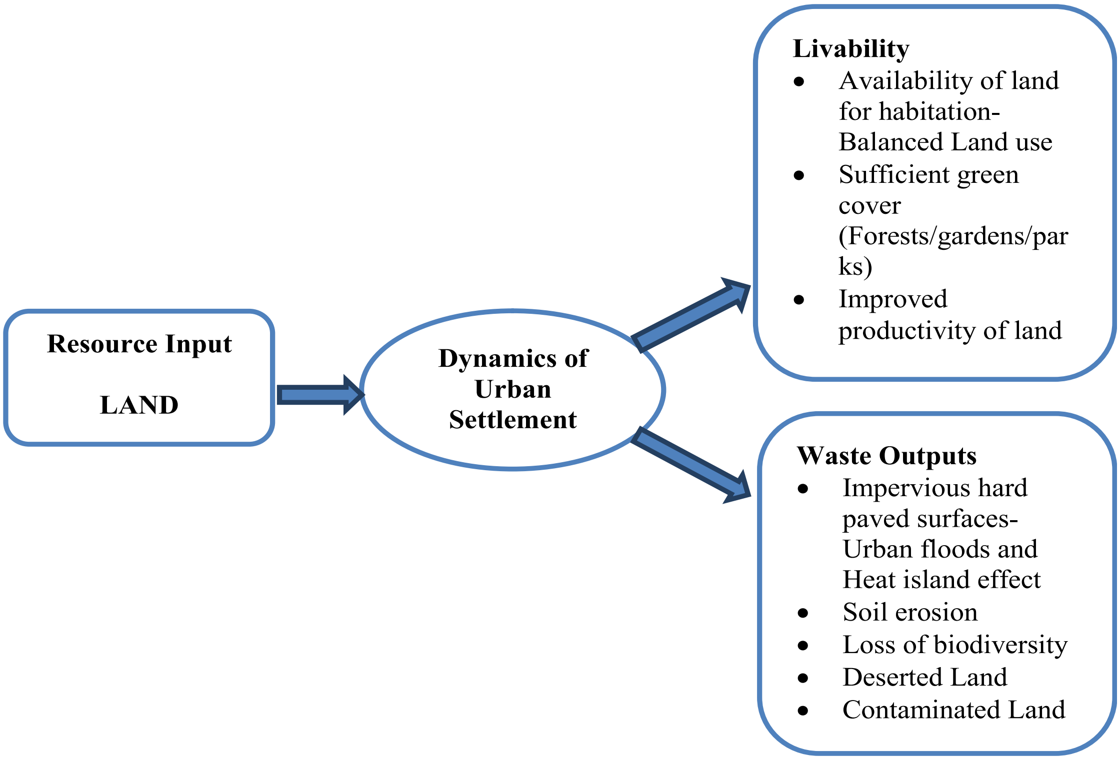

Fig. 4: Domain Model for Land (Source: Author)

To assess the unproductive land at the macro level the chosen indicator is the percentage of land under sanitary landfills/ hazardous dumping or percentage of deserted land if any.

At the micro level also the landuse pattern i.e. land under various uses- residential, mixed use, roads and green spaces is assessed for sustainable land utilisation and to understand the residential characteristic of the area. The measurement of green area ratio w.r.t to the total land area is an indicator for assessment of urban habitat and micro climate. The surface run off rates of different land cover types at a neighbourhood level will be another indicator to assess the risk of rain fed urban flooding and erosion.

Another indicator at the micro / neighbourhood level is the impervious surface ratio w.r.t to the total area of the land to assess the changes in evapotranspiration rates due to increase in built and paved areas. Evapotranspiration is a collective term for the transfer of water into the atmosphere from both vegetated and non-vegetated surfaces (Wang *et al.)*

For assessment of urban heat island effect due to impervious surfaces on the microclimate, measurement of albedo of different surfaces is required. Albedo is the ability of a surface to reflect incoming solar radiation. Surfaces with low albedo absorb most of the solar radiation whereas surfaces with high albedo reflect most of the solar radiation (Akbari et al., 1992).Impervious surfaces cause increased land surface temperature and results in an air temperature difference in the urban and the countryside which is called the urban heat island effect. Urban green spaces reduce surface temperature by releasing water vapour in the air through evapotranspiration, providing shade to the built forms and dark surfaces and reducing the energy use. Thus urban vegetation reduces the urban heat island effect and enhances the urban microclimate.

Another indicator is for assessment of contamination of land if any is taking place by dumping of hazardous waste/chemicals etc. which may be ascertained by a reconnaissance survey and stakeholders feedback.

Housing

Housing is one of the basic necessities of life. It is the major consumer of number of resources and is generally the place where the domestic sector engages in most of its activities interacting with different aspects of physical and human environment. Construction of houses involves a use of different materials such as concrete, clay, steel, timber etc. A large amount of energy is consumed in the building process, directly through transport of materials and indirectly through embodied energy in various energy intensive materials such as cement, steel, aluminium etc. Housing is also a major generator of waste both through the building construction process (demolition waste, construction debris) and also by the use of the occupants (solid waste, sewage etc.). Thus the various construction activities and domestic activities of the households are major contributors of atmospheric, water and noise pollution.

Adequate, appropriate and affordable housing is vital for a satisfactory quality of life. Appropriate housing means secured housing with basic physical and social infrastructure facilities and adequate open space. Housing is an important part of economy and a major component of capital investment. There is a housing shortage in most of the developing countries including India. The tremendous population growth mainly due to rural urban migration in most of the major cities in India results in unplanned growth of the cities with high housing density (overcrowding), overstressed infrastructure, unhealthy living conditions and related environmental problems. Housing crisis results in high property prices and mushrooming of slums with unhygienic living conditions.

Selection of Indicators

Fig.5 illustrates the EUMM model applied to the Housing domain. From the environmental perspective stress is on access to proper and durable housing with sustainable density for satisfaction of basic need of appropriate shelter and quality of life.

The high population growth and the resulting high density and overcrowding are one of the major causes of urban sustainability problems. Hence housing density i.e numbers of houses per thousand of population and the average household size have been considered as the indicators for accessing overcrowding and overstressed infrastructure issues at broader level.

To assess the availability, non-availability and shortage of proper, durable and secure housing the indicators chosen at macro level are the share of population living in pucca houses, the share of population living in slums and the share of population as pavement dwellers.

At the micro level/neighbourhood level the chosen indicators are housing density, the average household size and the durability and condition of housing stock

Infrastructure

Urban water supply and sanitation are basic human needs for better quality of life and enhanced productive efficiency of the people. India along with other developing countries is facing a serious challenge of providing basic services and resources to its growing urban population at an unmatched rate.

The domestic, commercial, industrial and other water requirements of urban areas is met by tapping water from natural sources i.e. rivers, streams, wells and lakes. As per the website of Ministry of Water Resources, Govt. of India, the water demand for various sectors is projected to increase from 813Km3 in 2010 to 1093Km3 in 2025. As per CPCB Report 2009, the National average for per capita water supply is 179 lpcd (litre per capita per day) for class-I cities and 120 lpcd for Class-II Towns and about 78% of the urban population has access to safe drinking water.

Almost 80% of the water supplied for domestic use comes out as wastewater. As per CPCB,2009 the estimated sewage generation from class-I cities and class-II towns together is 38,254 MLD, out of which only 35% is treated with a capacity gap of 30% of total generation, which needs immediate attention. Moreover only about 38% of urban population has access to proper sanitation services. This improper collection, treatment and disposal of waste water are a major source of ground water and surface water pollution in India, particularly in and around large urban centers. The contamination of locally available freshwater supplies has serious impacts on public health and ecosystem.

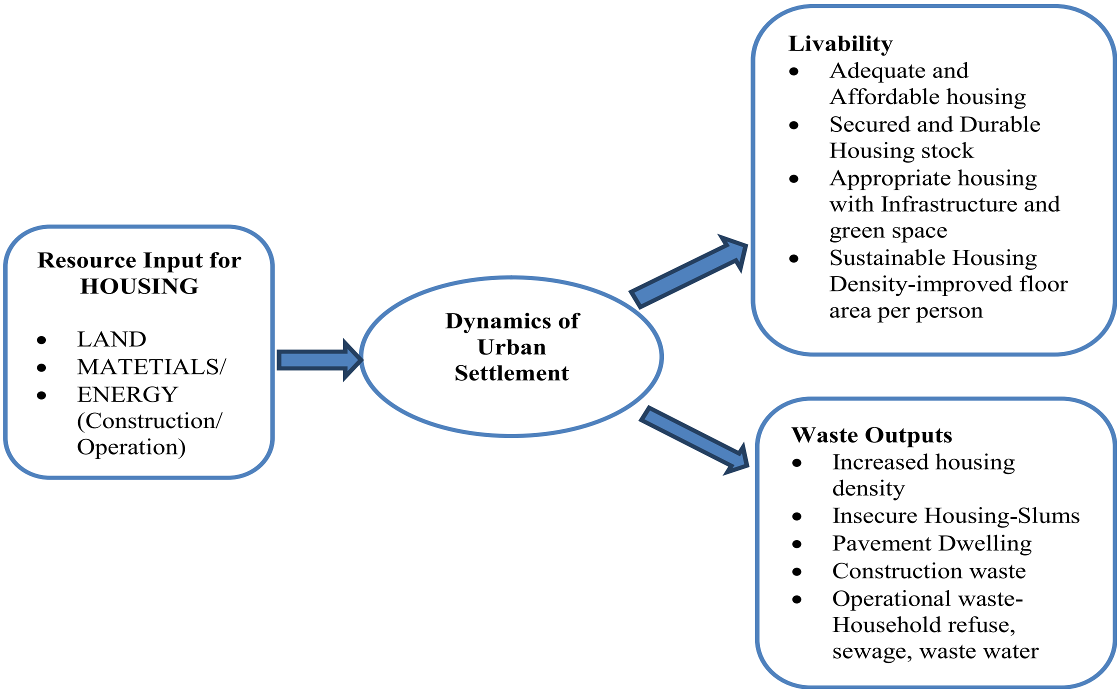

Fig. 5: Domain Model for Housing (Source: Author)

Improper collection, transportation, processing and disposal of Municipal Solid Waste is also another major environmental concern in the urban areas in India. Various studies conducted by CPCB reveals that per capita generation rate of MSW in India ranges from 0.2 to 0.5 Kg/day and about 90% of Municipal solid waste is disposed of unscientifically in open dumps and landfills causing serious health and environmental hazards. MSW generation rate is higher in metro cities compared to smaller towns due to the changing lifestyles and increased purchasing power of urban India.

Thus faced with rapid urbanization and the accompanying growing demand and growing pollution issues, Indian cities are not able to provide infrastructure services that are adequate, neither quantitatively nor qualitatively.

Selection of Indicators

Fig.6 illustrates the EUMM model applied to the Infrastructure domain. From the environmental perspective stress is on access to proper and sufficient infrastructure facilities for basic needs of clean and adequate water and sanitation

The main function of an urban water system is to deliver safe drinking water and to manage and treat wastewater. All households need to be connected with piped water supply without leakages and proper sewerage system. The storage of water in the household and round the clock availability of water through taps represents higher quality of life. Also, there is equity issue where a section of society does not get water for basic usage, where as another section make wasteful usage of water. Thus the chosen quantitative indicators for assessing the adequacy of water supply and sewage infrastructure at macro level are water supply per capita, percentage of population with potable water supply, percentage of water demand met with piped water supply, percentage of households with source of water within premises, wastewater generation per capita, percentage of households with sewage connection and percentage of households with access to proper toilet facilities within premises.

High per capita solid waste generation put pressure on waste collection, management and disposal and thus per capita solid waste generation and percentage of solid waste collected have been chosen as indicators for assessing the solid waste management facilities at macro level.

At the micro level a qualitative assessment of the water supply, sewerage and solid waste management infrastructural facilities has been done through the following indicators with a strong feedback from the community: source of water supply (municipal piped supply/hand pumps/ well/community taps/water tankers/others),piped water supply reliability(number of hours of supply per day), percentage of households with source of water within premises; mode of Sewage disposal(municipal connection/ pit/septic tanks/ open defecation),percentage of households with proper toilet facilities within the premises; type of solid waste generation(domestic/commercial/ industrial/hospital/hazardous), frequency of solid waste collection(regular/irregular), solid waste segregation, solid waste disposal(open dumping/ bins/dalaos), frequency of solid waste transportation from dalaos(regular/irregular)

Energy

Energy is essential for social and economic wellbeing and plays an important role in the prosperity of a Nation. Energy in the form of oil, gas, electricity is an inevitable necessity for functioning of domestic sector, commercial sector, delivery of goods and services like water supply, sewerage network, manufacturing in industries, building construction, transportation etc. and ensuring quality of life.

However there is a strong relation between energy use and severe impacts on the environment and health of the human beings. Energy is produced from a range of raw inputs and during the process there are inherent inefficiencies which results in waste by products such as emissions of particulates, noxious gases, greenhouse gases, residues, noise etc along with depletion of resources over time.

Also, there are large disparities in the level of energy consumption, not only among different regions (urban and rural), but also among various sections of the society in the same region due to economic disparity. Thus the need of the hour for sustainable development is provision of adequate energy services at affordable prices minimising environmental impacts and without affecting the long term availability of the resources to avoid future energy crisis. This can be achieved by appropriate fuel choice, replacing inefficient technologies for efficient ones and use of renewable energy in place of non-renewable resources.

As per U.S. Energy Information Administration, 2013, India is the fourth-largest energy consumer in the world, following the United States, China, and Russia. India has the world's fifth-largest coal reserves and it is India's primary source of energy; the power sector accounts for more than 70% of coal consumption. As per the same report

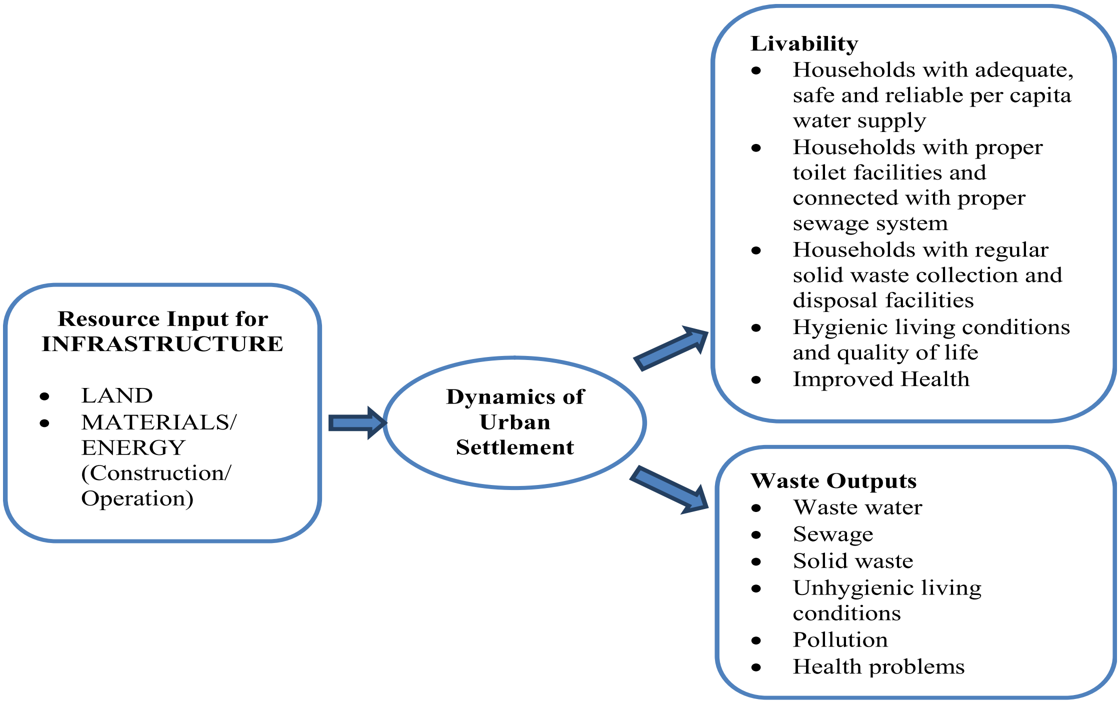

Fig. 6: Domain Model for Infrastructure (Source: Author)

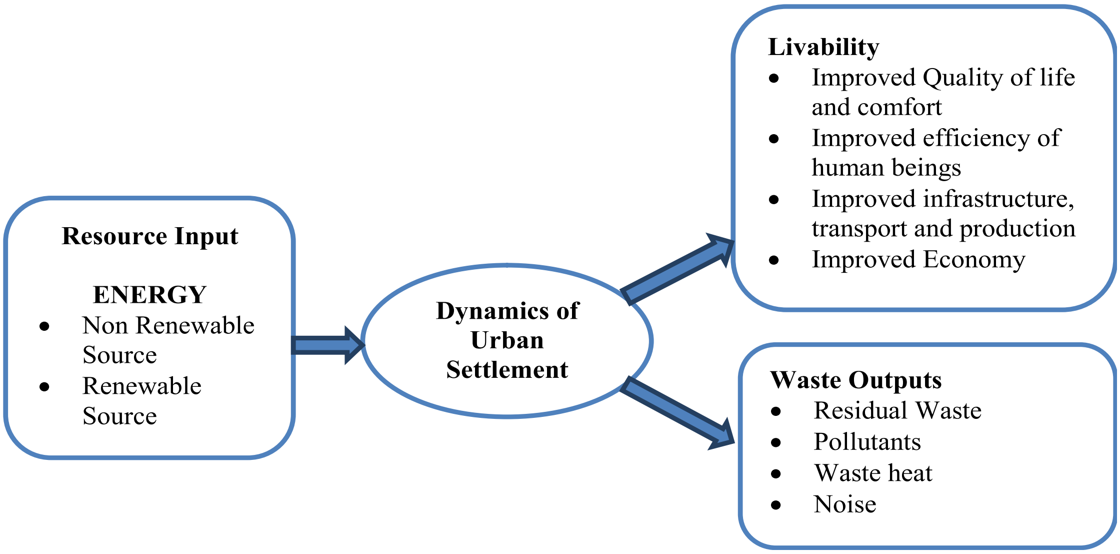

Fig. 7: Domain Model for Energy(Source: Author)

LIST OF INDICATORS

The list of identified environmental sustainability indicators at macro level and micro level along with the identified data sources are given below:

DOMAIN	MACRO INDICATORS (A)	MICRO INDICATORS (B)	DATA SOURCE
POPULATION Sustainable population growth and density for reducing the consumption pressure on resources and generation of waste	City Population (in Millions) Population growth rate (% / annum) Population density (person/ sq km)	Population of the Area (in absolute numbers) Floating Population (Residential Characteristics) Population Density (person/ sq km)	(A) Census of India (B) Municipality
AIR Maintaining air quality and reducing pressure on the atmosphere (tonne per capita)	SO2 emission (ug/m3) NO2 emission (ug/m3) PM10 emission (ug/m3) CO2 emissions per person residential energy use GHG emission/city GDP	SO2 emission (ug/m3) NO2 emission (ug/m3 PM10 emission (ug/m3) Air emissions from -Reconnaissance Survey Air emissions from commercial energy use Air emissions from industrial energy use Air emissions from vehicles Air emissions from burning of solid waste/dry leaves % of paved(black topped)road length /area of total road % of road with road-side green /plantation	(A) CPCB (B) -CPCB data of nearest air quality monitoring station -Stakeholders/Community feedback -Aerial Image/local maps
WATER Maintaining water quality and reducing pressure on the water systems	Average BOD/DO concentration in water sources Average COD concentration in sea or marine environment	Mode of Sewage disposal (municipal connection/ pit/septic tanks/open defecation/storm water drains) Solid waste disposal open dumping /dumping in storm water drains) Contamination of storm water runoff	(A) CPCB (B) "Municipality " Public Health Department " Reconnaissance Survey " Stakeholders/Community

DOMAIN	MACRO INDICATORS (A)	MICRO INDICATORS (B)	DATA SOURCE
		Contamination of storm water runoff (agricultural fields,/landfills/chemical working sites/others) Incidences of water borne diseases.	" Stakeholders/Community feedback
LAND Balanced built land use and urban green and reducing demographic pressure for development	Share of residential area (%) Share of area under roads (%) Share of green area (%) Green spaces/person (m2) Area of green cover (sq.m/1000 population) Contaminated/deserted land- under sanitary landfills, hazardous dumping etc (%)	Share of residential area (%) Share of area under roads (%) Mixed Landuse ratio (%) Share of green space in the total land area (%) Surface runoff based on the % of different types of surfaces Impervious surface ratio in the total land area (%) Measurement of Albedo of different surfaces by their area percentages Contamination of land- dumping of hazardous waste/chemicals	(A) CDP/Master Plans (B) "Zonal Plans/Local Area Plans " Aerial Images " Reconnaissance Survey " Stakeholders/ Community feedback
HOUSING Access to proper and durable housing for satisfaction of basic need of Shelter	Housing density (No. of houses/1000 population) Average household size (no.) Share of population living in pucca(durable) houses (%) Share of population living in slums (%) Share of population as Pavement dwellers (%)	Housing density (No. of houses/1000 population) Average Household size(no.) Durability & Condition of Housing Stock (Pucca/Kuttcha; Good/ Bad/Dilapidated)	(A) Census of India (B) " Municipality " Zonal Plans/Local Area Plans " Aerial Images " Reconnaissance Survey " Stakeholders/Community feedback
INFRASTRUCTURE Access to infrastructure for satisfaction of basic	Water supply per capita (lpcd)	Source of water supply(municipal supply/hand pumps/well/ community taps/water tankers	(A) " Census of India " CPCB

DOMAIN	MACRO INDICATORS (A)	MICRO INDICATORS (B)	DATA SOURCE
		Contamination of storm water runoff (agricultural fields,/landfills/chemical working sites/others) Incidences of water borne diseases.	" Stakeholders/Community feedback
LAND Balanced built land use and urban green and reducing demographic pressure for development	Share of residential area (%) Share of area under roads (%) Share of green area (%) Green spaces/person (m2) Area of green cover (sq.m/1000 population) Contaminated/deserted land-under sanitary landfills, hazardous dumping etc (%)	Share of residential area (%) Share of area under roads (%) Mixed Landuse ratio (%) Share of green space in the total land area (%) Surface runoff based on the % of different types of surfaces Impervious surface ratio in the total land area (%) Measurement of Albedo of different surfaces by their area percentages Contamination of land- dumping of hazardous waste/chemicals	(A) CDP/Master Plans (B) " Zonal Plans/Local Area Plans " Aerial Images " Reconnaissance Survey " Stakeholders/ Community feedback
HOUSING Access to proper and durable housing for satisfaction of basic need of Shelter	Housing density (No. of houses/1000 population) Average household size (no.) Share of population living in pucca(durable) houses (%) Share of population living in slums (%) Share of population as Pavement dwellers (%)	Housing density (No. of houses/1000 population) Average Household size(no.) Durability & Condition of Housing Stock (Pucca/Kuttcha; Good/ Bad/Dilapidated)	(A) Census of India (B) " Municipality " Zonal Plans/Local Area Plans " Aerial Images " Reconnaissance Survey " Stakeholders/Community feedback
INFRASTRUCTURE Access to infrastructure for satisfaction of basic	Water supply per capita (lpcd)	Source of water supply(municipal supply/hand pumps/well/ community taps/water tankers	(A) " Census of India " CPCB

DOMAIN	MACRO INDICATORS (A)	MICRO INDICATORS (B)	DATA SOURCE
adequate water and sanitation	Population with potable water supply service (%) Water demand met with piped water supply (%) Households with source of water within premises (%) Waste water generation per capita (litre/capita) Households with sewage connection (%) Households with access to proper toilet facilities within premises (%) Solid waste generation Per capita (kg/capita/year) Solid waste collected (%)	Piped water supply reliability (no. of hours of supply /day) Households with source of water within premises (%) Mode of Sewage disposal(municipal connection/ pit/septic tanks/ open defecation) Households with Toilets within premises (%) Type of solid waste generation (domestic/commercial/industrial/ hospital/hazardous) Frequency of solid waste collection(regular/irregular) Solid waste segregation Solid waste disposal (open dumping/bins/dalaos) Frequency of solid waste transportation from dalaos (regular/irregular)	(B) " Municipality " Zonal Plans/Local Area Plans " Reconnaissance Surveying " Stakeholders/ Community feedback
ENERGY Efficient energy use by sensible use of resources and minimisation of waste	Total energy consumption per capita Share of renewable energy in the total energy use(%) Households with electricity connection (%) Households with LPG connection (%)	Built form adhering to passive solar design principles Rain water harvesting provision Waste water recycling provision Design of pedestrians paths Access to public services and transport stops within 800m walking distance	(A) " Census of India " Ministry of Statistics and Programme Implementation, Govt. of India (B) " Municipality " Zonal Plans/Local Area Plans " Aerial Images " Reconnaissance Survey " Stakeholders/Community feedback

in 2011 India was the fourth largest consumer of oil and petroleum products in the world and relies heavily on imported crude oil, mostly from the Middle East. India became the world's sixth-largest liquefied natural gas importer in 2011.As electricity demand of the country is growing; India plans to increase its nuclear share of generation to 25%, up from 4% in 2011.

However, rural areas in India rely heavily on traditional biomass, as they lack access to other energy supplies. According to the 2011 India census, more than 80% of rural households and 22% of urban households use traditional biomass (including firewood and crop residue) as the primary fuel for cooking.

Selection of Indicators

Fig.7 illustrates the EUMM model applied to the Energy domain. From the environmental perspective stress is on efficient energy use by sensible use of resources and minimisation of waste and pollutants. The indicators chosen for assessment of intensity of energy use at macro level is total energy consumption per capita and for appropriate fuel choice is the share of renewable energy in the total energy use. The indicators for access to affordable and basic energy need are percentage of households having proper electricity connection and percentage of households having LPG connection.

At micro level qualitative indicators have been chosen to assess the energy efficiency achieved by the layout design of neighbourhoods and various measures for conservation of precious resources. The chosen indicators are built form adhering to passive solar design principles, rain water harvesting provisions, waste water recycling provisions, design of pedestrian paths to promote walkability and access to public services and transport stops within 800m of walking distance

Way forward

Evaluation of Indicators

Composite indicators or an index are increasingly been recognised as useful tools in policy analysis and public communication. Normalisation is required prior to any data aggregation as an index as the indicators in a data set often have different measurement units (OECD Handbook, 2008).

It is suggested to develop an *Environmental Performance Index (EPI)* for each city at national level in India, where each indicator under the identified domains at macro level shall be compared with a threshold value .i.e the national permissible or desirable standards set by various Government agencies for that particular indicator to arrive at the performance gap or adherence. The equation to be used is given below:

$$EPI_{qc}^{t} = \frac{\frac{1}{n}\sum_{i=1}^{n} X_{qci} - P_q}{P_q}$$

Where,

EPI^t_{qc}=Environmental Performance Index 'EPI' for Indicator 'q' for city 'c' at time 't'

X_{qci}= Observed value for indicator 'q' for city 'c' in the i^{th} year

n= Total number of years for which the value is assessed

P_q= Threshold Value for indicator 'q' arrived from National Standards and assigned a value of '0'

The threshold value shall be assigned a value'0' on the graph and the indicator values are judged from their distance above or below the threshold value. Thus the environmental performance of each indicator shall be judged from the deviation from the threshold value. The advantage of developing an EPI for each city is that it helps in monitoring indicator wise environmental performance, identifying the issues over time and developing clear and transparent domain based policies at national level.

Similarly a *Composite Environmental Performance Index* for each city may also be developed at National level to rank the cities according to their environmental performance and to introduce a reward based incentive mechanism to make them perform better and encourage them to include environmental management dimension in their decision making at all levels. It will involve the following steps:

Development of Comparative Indicator using a scaling technique- common scale with a mean of zero and eviation of one

$$CI^t_{qc} = \frac{\frac{1}{n}\sum_{i=1}^{n} X_{qci} - P_{min}}{P_{max} - P_{min}}$$

Where,

CI^t_{qc} = Comparative Indicator 'CI' for Indicator 'q' for city 'c' at time 't'

X_{qci} = Observed value for indicator 'q' for city 'c' in the i^{th} year

n= Total number of years for which the value is assessed

P_{min}= Minimum Threshold Value for indicator 'q' arrived from the range of data for indicator 'q' of the compared cities and assigned a value of '0'

P_{max} = Maximum Threshold Value for indicator 'q' arrived from the range of data for indicator 'q' of the compared cities and assigned a value of '1'

Development of Composite Domain Index- root mean square of the comparative indicators in a domain

$$CDI^t_{dc} = \left(\frac{\sum_{q=1}^{Q} CI^2_{qdc}}{Q}\right)^{0.5}$$

Where,

CDI^t_{dc}= Composite Domain Index 'CDI' for Domain 'd' for city 'c' at time 't'

CDI_{qdc} = Comparative Indicator 'CI' value for indicator 'q' belonging to Domain 'd' for city 'c',

q=1,2,……,Q

Q= Total number of indicators in a Domain

Development of Composite Environmental Performance Index

$$CEPI^t_{c} = \left(\frac{\sum_{d=1}^{D} CDI^2_{d}}{D}\right)^{0.5}$$

Where,

$CEPI^t_c$=*Composite Environmental Performance Index* 'CEPI' city 'c' at time 't'

CDI_d= Composite Domain Index 'CDI' for domain 'd' , d=1,2,……,D

D = Total number of Domains

The list of identified micro level indicators comprise of both qualitative and quantitative indicators. A colour coded Environmental Performance Matric shall be developed assigning a categorical qualitative score such as 'poor', 'moderate', 'good', 'very good' to each indicator under the identified domains based on the national standard threshold values wherever applicable and taking stakeholders and community opinion and feedback. A detailed action plan at local level for improvement of the critical areas shall be prepared with strong participation of the community and Residents Welfare Association and the concerned Municipalities, Corporations or Muncipal Bodies.

REFERENCES

1. World Commission on Environment and Development, "Towards Sustainable Development" from *Our Common Future* ,Oxford University Press (1987)
2. United Nations, "The Rio Declaration of Environment and Development" from *Agenda 21,* New York: United Nations (1992).
3. United Nations, *Indicators of Sustainable Development-Guidelines and Methodologies,* New York: UN publication (2007).
4. Organisation For Economic Cooperation And Development, *OECD Environmental Indicators Development, Measurement and Use-Reference Paper,* Paris, France :OEDC Environment Directorate (2003).
5. United Nations Human Settlements Progamme, *Urban Indicators Guidelines-Monitoring the Habitat Agenda and the Millennium Development Goals,* Kenya :UN Habitat publication (2004).
6. European Commision, *Towards a Local Sustainability Profile-European Common Indicators,* Luxembourg: European Commission publication (2001).
7. State Environmental Protection Administration, *Urban environmental Management in China,*

People's Republic of China: SEPA Publication (2000).

8. Japan: Ministry of Environment, *Report on Indicator related research for Kitakyushu Initiative,* Kitakyushu: MoE publication (2002)
9. Australia: Department of Environment, *Environmental Indicators for National State of the Environment Reporting -Human settlements,* Canberra: State of the Environment, Department of Environment publication (1998)
10. Bossel, *Indicators for Sustainable development: Theory, Methods, Applications*, International Institute for Sustainable development (IISD) (1999)
11. International Institute for Sustainable Development, *Compendium of Sustainability Indicators(http://www.iisd.org/measure/compendium/searchinitiatives.aspx))*
12. Newton,P. Urban Indicators and the Management of Cities, Matthew S.Westfall, Victoria A.deVilla (ed/s*), Urban Indicators for Managing Cities*, Philippines: Asian Development Bank (2001)
13. UN Population Division, Department of Economic and Social Affairs, with support from the Un population Fund (UNFPA) (http://www.un.org/popin/fao/land/land.html)
14. UN-HABITAT, *State of World's Cities 2008/2009-Harmonious Cities,* London: Earthscan (2008)
15. Newman,P.et.al, Human Settlements in Australia-State of the Environment 1996, Melbourne: Department of Environment Sport and Territories (CSIRO publishing) (1996)
16. Government of India: Ministry of Environment & Forests, *National Ambient Air Quality Status & Trends in India-2010,* New Delhi: Central Pollution Control Board publication (2011-12)
17. Government of India: Ministry of Water Resources (*http://wrmin.nic.in/)*
18. Government of India: Ministry of Environment & Forests,2009-10, *Status of Water Supply, wastewater Generation and Treatment in Class-I cities & Class-II Towns of India,* New Delhi: Central Pollution Control Board publication
19. Wang,Q.J.et.al., *Climatic Atlas of Australia Evapotranspiration*, Australia: Bureau of Meteorology (2001)
20. Akbari.H.et al., The Urban Heat Island: Causes and Impacts, in Akbari. H.et al.(ed/s), *Cooling Our Communities*, Washington: U.S. E.P.A (1992).
21. Census of India, (2001), (2011). Additional information available at http://www.censusindia.net/ and http://www.censusindia.gov.in/
22. Government of India: Ministry of Environment & Forests, *Status Report on Municipal Solid Waste Management,* New Delhi: Central Pollution Control Board publication (2012)
23. Sustainable Cities International, *Indicators for Sustainability-How Cities are monitoring and evaluating their success,* Vancouver, Canada: SCI & CIDA publication (2012)
24. U.S: Department of Energy, *Annual Energy Outlook 2013-with Projections to 2040*:U.S Energy Information Administration (EIA) publication (www.eia.gov/forecasts/aeo) (2013)
25. Organisation For Economic Cooperation And Development, *Handbook on Constructing Composite Indicators-Methodology and User Guide,* France :OEDC Publishing (http://www.oecd.org/std/42495745.pdf) (2008)