CHAPTER - II

LITERATURE SURVEY AND REVIEW

Survey of literature and its review is the basis of further scientific research. The first stage is an exhaustive survey and collection of the related material on the problem of study. The second stage is an analytical review of the available material. In general parlance, the terms ‘literature survey’ and ‘literature review’ are often used interchangeably or synonym to each other. However, in the strict sense of the scientific works, a literature survey refers to the processes of acquiring and identifying the relevant subject matter. Whereas, the literature review refers to a critical appraisal and analysis of the existing relevant research material. A literature review is a critical evaluation of the available or obtained literature in the field of one’s research interests. The review of the existing research work on one’s area of enquiry helps in identifying the major issues of further enquiry. Literature review also helps in identifying the crucial gaps in the related research. This guides the research to plug these gaps. Exhaustive literature survey and critical review are indispensable to convincing research. A perusal of the existing and relevant literature provides necessary information about the nature of enquiry already undertaken to understand challenging problems more thoroughly and accurately.

With the help of present literature survey, the researcher has tried to explore the unnoticed areas. Literature survey is a major guideline to pursue a work with effective parameters. It helps in making comparative statements in the ongoing research with the effective and accomplished researches. Literature survey also helps in avoiding an unnecessary and cumbersome repetition. Literature survey and review helps in the critical appraisal of current knowledge and the substantive findings closely related to one’s own area of enquiry. The main objective of literature review is to locate the research under pursuance within the frame of scientific literature. A critical review enables the subsequent research to overcome the inadequacies of the scientific literature. A literature review may be precursor of a scientific research. A literature review is much more than a mere listing of separate articles, theses and books and journals.
A literature survey furnishes the spectrum of information on the existing nature of research work. The subsequent review of the acquired literature facilitates the researcher with a cogent understanding of the research problem. Literature survey helps to obtain deep insights on the prevalent trends in the field of enquiry. Literature review helps to identify the research methodology adopted by various scholars. Literature review is a source of formidable hypotheses building. Literature survey and review opens windows on the strength and weaknesses of the existing works. Literature survey is an integral part of building a plausible chapter scheme in a Ph.D. Thesis. Literature survey and review helps to recognize the scope and prospects of the research enquiry at hand. An exhaustive literature survey and an effective literature review helps in grooming the tangible line of argument in the research work.

Ackoff (1961) maintained that literature survey tends to clarify the objectives of the research by spelling out a scientific method of enquiry. According to Whittaker (2009), literature review refers to a critical evaluation and analysis of the relevant research material. A formidable literature survey is an integral part of a research thesis. A critical analysis of the existing literature is a pre-requisite to promote further research. According to Hunt (2005) a good literature survey is not just a list of references. It should in fact, consist of a carefully reasoned argument which references other’s work, analyses it, comments on it to the advantage of one’s own work. According to Guthrie (2010), literature review is a funnel that narrows down the specific topic of a research problem to a tangible frame of enquiry within the available means. Kumar (2011) asserts that a literature review helps the consolidation of a new research in a number of ways. It tends to bring clarity in formulating the research problem. It helps build up a focussed research methodology.


It helps expand the horizons of existing knowledge and it also helps to consolidate the findings. According to Raiyani (2012), a literature survey helps in defining the renewed objectives of the research and a guiding methodology.6

Landsberg (1956) on the behavior of urban rainfall observed that the average and extreme count of Aitken nuclei in the countryside were 9,500 per cubic centimeter and 33,000 per cubic centimeter respectively. In a city with a population of 1,00,000 the condensation nuclei numbers were 3,43,000 per cubic centimeter and 4,00,000 per cubic centimeter respectively. Whereas, in the cities with a population of over 1,00,000 these were 1,47,000 and 4,00,000 per cubic centimeter respectively.7 Condensation nuclei in such large numbers, he thought, would promote greater precipitation in cities. Similar studies have been taken up the world over by eminent scientists who have been working towards mitigating the abnormal urban climatic phenomenon. The climate of many cities in the U.S.A. has been investigated by the Environment Protection Agency (EPA) and other federal agencies. These are working towards heat island reduction strategies. One component of this initiative known as the Urban Heat Island Pilot Project (UHIPP) involves a voluntary partnership between EPA and the three US cities of Sacramento, Salt Lake City and Baton Rouge. Heat Island research and exploration of mitigation strategies are also under way in Atlanta.8 Such studies are also underway in the European cities and Japan.

Mapping of the urban temperature fields were undertaken perhaps for the first time in India during 1973 over the industrial city of Pune by Daniels and Krishnamurthy9 (1973), and the metropolitan city of Bombay by Philip et al.10(1973) using mobile surveys in winter months around the minimum temperature epoch. Mukherjee and Daniel (1976) studied the temperature distribution on a cool night over Bombay which included the study of vertical temperature distribution based on T.V.

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10 Ibid.
tower observations.\textsuperscript{11} Bahl and Padmanabhamurthy\textsuperscript{12}(1977, 1979) studied the heat and humidity islands at Delhi by mobile surveys. Krishnanand and Maske \textsuperscript{13}(1978) also undertook similar studies for Delhi by extending the observation over different months.

Sastry\textsuperscript{14} (1982) studied such effect in the case of the industrial city of Visakhapatnam. Pradhan and Menon\textsuperscript{15}(1986) studied the heat island effect over Bhopal and indicated that even over a small city like Bhopal, the effect of urbanization is pronounced and temperature intensity over the heat island was found to be of the order of 6.5°C during the winter months.

Hough\textsuperscript{16} (1984) dealt with the five major processes that affect the urban microclimate. They are:

1. Differences in materials in urban and rural environments, urban structures are multi-faceted and act as multiple reflectors.
2. Greater aerodynamic roughness of built-up areas reduces prevailing winds, thus, their cooling power diminishes.
3. Vehicles and industries pump large amounts of heat into the city resulting in higher temperature.
4. The heavy load of solid particles, gases and liquid contaminants that are carried in the urban atmosphere can reflect incoming solar energy and heat as well as retard the outflow of heat.
5. Rainwater is quickly carried away by storm water sewers. In the city, absence of moisture inhibits evaporation. Therefore, the energy that could have gone into the process of vaporization is available for heating. Among the influences the city has on weather, it is the presence or absence of wind that has the greatest impact on the comfort of the local climate.

\textsuperscript{11} Ibid.
\textsuperscript{12} Ibid.
\textsuperscript{13} Ibid.
\textsuperscript{14} Ibid.
\textsuperscript{15} Ibid.
Padmanabhamurthy (W.M.O., 1986) has analysed the isotherms and isopleths of dew point temperature on a typical day at Calcutta during the winter month, February of 1977. In all the above studies, existence of warm pockets and cool pools has been indicated. The magnitude of heat island intensities at these places vary from 0.6°C over Visakhapatnam to 10°C over Pune and to 11°C over Bombay. The size, shape, position and intensity of warm pockets vary depending upon the topography, urban morphology, proximity to large waterbodies, stability, intensity and depth of surface inversion and wind speed.


Aziz (1992) on the other hand is of the opinion that precipitation generally increases in a city. In Washington, 30 per cent increase in precipitation has been noted over four decades and in 8 cities of U.S.A. the summer rainfall has increased by 9 per cent to 27 per cent. Aziz is of the opinion that precipitation is more by 5 to 10 per cent and the number of rainy days by 10 per cent due to greater convection and uplift in the air as a result of the texture of the city and also because of a large number of condensation nuclei.

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Prof. B. Padmanabha Murthy\textsuperscript{23} (1999) conducted experiments and collected data on temperature, humidity and wind at two levels with a portable mast and radiation balance components at over forty locations spread over the entire length and breadth of the city of Delhi during two summers and winters of 1997-1998 and 1998-1999. He made the following specific observations:

Industrial and commercial sites are warm and serve as source of heat and pollution, while the nearby slums, urban parks or rural areas act as cool pockets. Sinks of heat and pollution are the characteristic feature of Delhi. This prevents long range circulation of the pollutants within the entire urban atmosphere.

Others in the field are Sarma and Sainath\textsuperscript{24}(1991), Srinivas and Sastry\textsuperscript{25}(1998), Suneja\textsuperscript{26} (1998) for New Delhi.

Ochi \textit{et al.}\textsuperscript{27} (2001) in their study entitled “Monitoring Urban Heat Environment using MODIS data for main cities in East Asia”, picked up five cities; Tokyo (Japan), Seoul (South Korea), Pyongyang (North Korea), Beijing and Shanghai (China) for analysing the heat environment, with different stages of economic development in different geographic locations. The land cover characterization and the “Heat Island Intensity” were analysed by comparing the summer images versus the night time images. The study concluded that the heat flux is most significant in Tokyo and it is about 100 times longer than that of Pyongyang in the summer day time and 70 times in the summer night time.

Shepherd and colleagues\textsuperscript{28} (2002) at NASA’s Goddard Space Flight Centre, using the world’s first space-based rain radar aboard NASA’s Tropical Rainfall Measuring Mission (TRMM) Satellite, found that the mean monthly rainfall rates


\textsuperscript{24} Ibid.

\textsuperscript{25} Ibid.

\textsuperscript{26} Ibid.

\textsuperscript{27} Ochi, S. (2001). ‘Monitoring Urban Heat Island using MODIS data for Main Cities in East Asia, \url{http://www.innovationmagazine.com.innovation/volumes/V3n2/free/controversy2.shtml}

\textsuperscript{28} \url{www.gsfc.nasa.gov/topstory/20020613urbanrain.html}
within 30-60 kilometres downwind of the cities were, on an average about 28 per cent greater than the upwind region. In some cities, the downwind area exhibited increases as high as 51 per cent. It was also found that, on average, maximum rainfall rates in downwind regions often exceeded the maximum values in upwind regions by 48 per cent to 116 per cent. These results were very consistent with earlier related experiments in St. Louis, Missouri and Atlanta. During the warmer months, the added heat creates wind circulations and rising air that can produce clouds. These clouds can evolve into rain-producers or storms. It is suspected that converging air due to city surfaces of varying heights like buildings, also promotes rising air needed to produce clouds and rainfall.

According to John Houghton29(2002), “The Physics of Atmospheres” provides state of the art review of their subject. Kumar and Singh30 (2003) in their book entitled “Urban Development and Anthropogenic Climate Change: Experience in Indian Metropolitan Cities” have tried to cite the problems with policy perspectives in the Indian Metropolitan Cities. Urban induced Climate Change has been the key global issue in the recent years. Urban landuse and landcover changes are the main driving forces of changes in atmospheric conditions and bio-geochemical cycles. They have cautioned that large cities have developed microclimates, which modify atmospheric temperature, precipitation, humidity, wind velocity, visibility and radiation intensity. They have pointed out that the rural-urban temperature differences vary with the city size, population density, industrialization, vehicularization and local topographic and climatic conditions.

It is important to identify the various reasons which render the cities significantly warmer than the country side. The obvious reasons could be related to the differential heating and cooling processes of the cities and their surroundings. Urban heat island is the function of high density built-up areas. The cities which are the three dimensional surfaces of concrete, steel, glass, stone and asbestos have differential heating and cooling properties than the surrounding countryside. The vertical growth of buildings prevents radiative cooling by nights. Hence, the night


temperatures are 4°C - 7°C higher than the rural surroundings. During the day in rural areas, the solar energy absorbed near the ground evaporates water from the vegetation and soil. Thus, while there is a net solar energy gain, this is compensated to a considerable extent by evaporative cooling.

In cities, where there is less vegetation, the buildings, streets and side-walks absorb the majority of solar energy input. Because the city has less water, runoff is greater because the pavements are largely non-porous (except by the pot holes). Thus, evaporative cooling is less which contributes to the higher air temperatures. Exhaust heat from city buildings, automobiles and trains is another factor contributing to warmer cities. Heat generated by these objects eventually makes its way into the atmosphere. This heat contribution can be as much as one-third of that received from solar energy. The thermal properties of buildings add heat to the air by conduction. Tar, asphalt, brick and concrete are better conductors of heat than the vegetation of the rural area. The canyon structure of the tall building enhances the warming. During the day, solar energy is trapped by multiple reflections of the buildings while the infrared heat losses are reduced by adsorption.

I Definition and Concept of the Megacity

According to the Census of India\textsuperscript{31} (2011) definition, among the Million Plus Urban Agglomerations (UAs) /Cities, there are three very large UAs with more than 10 million persons in the country, known as Mega Cities. These are Greater Mumbai UA (18.4 million), Delhi UA (16.3 million) and Kolkata UA (14.1 million). The largest UA in the country is Greater Mumbai UA followed by Delhi UA. Kolkata UA which held the second rank in Census 2001 has been replaced by Delhi UA. The growth in population in the Mega Cities has slowed down considerably during the last decade. Greater Mumbai UA, which had witnessed 30.47 per cent growth in population during 1991-2001 has recorded 12.05 per cent during 2001-2011. Similarly Delhi UA (from 52.24 per cent to 26.69 per cent in 2001-2011) and Kolkata UA (from 19.60 per cent to 6.87 per cent in 2001-2011) have also slowed down considerably.

\textsuperscript{31} Census of India (2011)
Based on the Random House Dictionary (1970), megacity is defined as a city having a population of one million or more.\textsuperscript{32} The Census in 1981 classification introduced for the first time the term mega-cities which is defined as those cities with a population more than 5 million. At 1991, there were four megacities (Mumbai, Kolkata, Chennai and Delhi) in India. Likewise out of the total 77.99 million population in the metropolitan cities, 37.46 millions are in the four megacities constituting 52.78 per cent of the total metropolitan cities population. In 2001, Bangalore and Hyderabad were included under the banner of Indian megacities.\textsuperscript{33}

The Cambridge Business English Dictionary defined megacity as a very large city that has a population of more than 10 million people and that is often made of two or more urban areas that have grown so much that they are connected. \textsuperscript{34}

As per the European Association of National Metrology Institutes (EURAMET\textsuperscript{35}, 2013) the term “mega-cities” was defined for metropolitan agglomerations which concentrate more than 10 millions of inhabitants. Mega-cities are important in tackling climate change. They are responsible for emitting 2.9 billion tonnes of carbon emissions and to take a decisive action. Doing it collectively, the potential impact will be huge. Renewable energy, energy efficiency and management of energy will be a great challenge for the Mega-cities. Globally, the cities represent 2 per cent of earth’s surface, but use 75 per cent of its resources. In consequence, mega-cities are concerned by the 3 following main dimensions:

1. The social dimension (cultural diversity and variety, education, art, living conditions, transport, security, health care, innovation, etc.)
2. The economical dimension (work & mass unemployment, improvement of infrastructure, new technologies, decentralization, repartition of wealth, capital equipments and the like.)

\textsuperscript{32} Random House Dictionary, © Random House, Inc. 2014.


\textsuperscript{34} Cambridge Business English Dictionary © Cambridge University Press.

3. The ecological dimension (energy sources, sustainable development, air and water pollution, noise pollution, traffic jam, water supply, urban sprawl, urban environment protection, public transportation, waste management and many more.)

The term “Mega-cities” has been a little bit enlarged. At the present time, it is considered as “mega-cities” the 40 most populated cities, and they formed an association “C40” to propose some common projects, collective actions and to share innovative solutions.36

A megacity is usually defined as a metropolitan area with a total population in excess of 10 million people.37 Some definitions also set a minimum level for population density (at least 2,000 persons/square km). A megacity can be a single metropolitan area or two or more metropolitan areas that converge. The terms conurbation, metropolis and metroplex are also applied to the latter. The terms megapolis and megalopolis are sometimes used synonymously with megacity.

In 2000, there were 18 megacities, conurbations such as Mumbai,38 Tokyo, New York City, and Mexico City had populations in excess of 10 million inhabitants. Greater Tokyo already has 35 million, which is greater than the entire population of Australia and New Zealand combined.

In 1800, only 3 per cent of the world's population lived in cities, a figure that has risen to 47 per cent by the end of the twentieth century. In 1950, there were 83 cities with populations exceeding one million; by 2007, this number had risen to 468.39 If this trend continues, the world's urban populations will double every 38 years. The UN forecasts that today's urban population of 3.2 billion will rise to nearly 5 billion by 2030, when three out of five people will live in cities.40

38 http://en.wikipedia.org/wiki/Megacity
Lamb and Harmon\textsuperscript{41} (2005) assert that a megacity is a city and/or metropolitan area with a very high population or average density. A megacity is generally considered to be an urban agglomeration with a population of at least 10 million, though the United Nations defines it as a metro area that is home to at least 5 million people living in an area of consistent urban-level density. Most of the world's megacities are in the developing world - particularly sub-Saharan Africa and South and East Asia - which is rapidly urbanizing to the same high percentage that is seen in the United States, Latin America, and Western Europe. However, these cities are generally built with little in the way of construction regulation or public infrastructure. By the year 2030, it is estimated that more than 60 per cent of the world's population will be urban.

According to a Times of India report dated 5\textsuperscript{th} August 2002, Mayor Himmatsinh Patel urged the government to grant a 'mega-city status' to Ahmedabad. Advocating a case for mega city status, Patel said Ahmedabad qualified for a central grant for infrastructure development as the city and its surrounding areas have a combined population of 45.19 lakh. Besides this, Ahmedabad is also the nerve centre of social, commerce, educational and industrial activities in the state. \textsuperscript{42}

With reference to an article on Climate and Energy in a Complex Transition Process the role of Hyderabad as an emerging megacity was discussed. Hyderabad is an emerging megacity in Southern India. Rapid increase of population and fast economic growth cause expanding energy and resource consumption and constantly increasing greenhouse gas emissions. Climate change will lead to extreme weather events, disastrous floods, strong heat waves, extreme droughts and increasing water scarcity. One third of the population is living below poverty line and suffers from severe food and health problems. In this particular environment, responding to the anticipated climate change impact requires exploring greenhouse gas mitigation and adaptation strategies and ways towards increased energy efficiency and renewable energy. The core hypothesis of the Project is that “getting the institutions right” is one

\textsuperscript{41} http://www.urbandictionary.com/author.php?author=Shreve+Lamb+and+Harmon

\textsuperscript{42} Give Ahmedabad mega-city status: Mayor, TNN, August 5, 2002.
main key to solve the problems of sustainable resource use and to achieve a sustainable development of the Hyderabad region.\textsuperscript{43}

Similarly, the Karnataka government hinted at development of Bangalore as a megacity. It has promised of a Bangalore mega city with some of the most advanced technologies, living spaces and transportation system. \textsuperscript{44}

Likewise, Rotti (2013) in an article envisaged transformation of Bangalore as a megacity. With a total population of 96.21 lakh people, spread thick at 4,381 people per square kilometer, Bangalore is definitely a very crowded city. It is therefore not surprising that Bangalore is bursting at its seams and growing in every direction. The direction of the growth however can be reined in so that Bangalore can transform into a well-networked mega city. \textsuperscript{45}

II Megacity Population Growth Rate

As cities grow in population and size, the initial green, permeable and moist surfaces change and deteriorate into impermeable, dry and built-up landscapes. These changes are the harbinger of microclimatic transformation which is referred to as urban heat islands. This phenomenon renders the urban temperatures higher than their rural surroundings.

Urban Heat Island is not only a phenomenon of temperature variations between the city and its surroundings. Although most of the work on urban heat islands and climate change is relegated to the thermal characteristics, the fact remains that the urban heat island is an all encompassing climate change. All the variables of the climate get transformed in the urban scenario.

Over the last 50 years, the world has faced dramatic growth of its urban population. In 2007 the amount of urban residents has outnumbered the rural

\textsuperscript{43} Introduction to the Megacity Project, \url{http://www.sustainable-hyderabad.de/}

\textsuperscript{44}\url{http://www.oneindia.com/feature/2013/karnataka-govt-dreams-big-of-a-mega-city-1257098.html}

\textsuperscript{45} Rotti, J. (2013), Can Bangalore Become A Well Networked Mega City?
population for the first time in history and by the year 2030 already two-thirds of the world’s population is expected to live in cities\textsuperscript{46}. The number of so-called mega cities—cities with more than 10 million inhabitants—increased in the period from 1975 until today from 4 to 22, mostly in less developed regions\textsuperscript{47}.

The 2014 revision of the \textit{World Urbanization Prospects} by UN DESA’s Population Division notes that the largest urban growth will take place in India, China and Nigeria. These three countries will account for 37 per cent of the projected growth of the world’s urban population between 2014 and 2050. By 2050, India is projected to add 404 million urban dwellers, China 292 million and Nigeria 212 million. The urban population of the world has grown rapidly from 746 million in 1950 to 3.9 billion in 2014. Asia, despite its lower level of urbanization, is home to 53 per cent of the world’s urban population, followed by Europe with 14 per cent and Latin America and the Caribbean with 13 per cent. The report notes that in 1990, there were ten “mega-cities” with 10 million inhabitants or more, which were home to 153 million people or slightly less than seven per cent of the global urban population at that time. In 2014, there are 28 mega-cities worldwide, home to 453 million people or about 12 per cent of the world’s urban dwellers. Of today’s 28 mega-cities, sixteen are located in Asia, four in Latin America, three each in Africa and Europe, and two in Northern America. By 2030, the world is projected to have 41 mega-cities with 10 million inhabitants or more.\textsuperscript{48}

Tokyo remains the world’s largest city with 38 million inhabitants, followed by Delhi with 25 million, Shanghai with 23 million, and Mexico City, Mumbai and São Paulo, each with around 21 million inhabitants. Osaka has just over 20 million, followed by Beijing with slightly less than 20 million. The New York-Newark area and Cairo complete the top ten most populous urban areas with around 18.5 million inhabitants each. Although Tokyo’s population is projected to decline, it will remain the world’s largest city in 2030 with 37 million inhabitants, followed closely by Delhi, whose population is projected to rise swiftly to 36 million in 2030. While Osaka and New York-Newark were the world’s second and third largest urban areas.


in 1990, by 2030 they are projected to fall in rank to the 13th and 14th positions, respectively, as mega-cities in developing countries become more prominent.\textsuperscript{49}

A successful urban planning agenda will require that attention be given to urban settlements of all sizes. If well managed, cities offer important opportunities for economic development and for expanding access to basic services, including health care and education, for large numbers of people. Providing public transportation, as well as housing, electricity, water and sanitation for a densely settled urban population is typically cheaper and less environmentally damaging than providing a similar level of services to a dispersed rural population.\textsuperscript{50} Indian megacities are among the most dynamic urban centres in the tropics. During the last 50 years the population of India (today 1.2 billion) has grown by two and half times whereas, the urban population has grown as much as five times.

In India, the urban heat island studies have been conducted in the cities of Pune, Mumbai, Delhi, Kolkata, Vishakhapatnam, Vijaywada, Chennai and Bhopal. It has been noted that among these cities, heat island intensity is greatest in Pune. The degree of Urban Heat Island in Pune city is 10°C in comparison to its rural surroundings. This is particularly so, because the city of Pune has an almost salubrious climate because of its location on the Deccan Plateau of Maharashtra. In contrast to it, the lowest heat intensity was noted as 0.6°C at Vishakhapatnam. This rural-urban temperature difference is lowest in Vishakhapatnam largely because of the moderating influence of the sea.

In the megacities of Mumbai, Delhi, Kolkata and Chennai, the urban heat island intensity has been reported as 9.5°C for Mumbai, 6°C for Delhi, which is a city of extreme climate due to a geographical component of continental location. The urban heat island intensity for Kolkata is 4°C. Similarly, the urban heat island intensity for Chennai is also 4°C. The megacities of Kolkata and Chennai have less than half the urban heat island intensity in comparison to Mumbai which has the second highest intensity of 9.5°C. The vast difference in the urban heat island intensity of Chennai and Mumbai could be attributed to their differential location on the sea. Both Chennai and Mumbai are on the sea but Chennai is located on the Bay

\textsuperscript{49} Ibid.

\textsuperscript{50} Ibid.
of Bengal and Mumbai is located on the Arabian Sea. Further, Chennai which is located on the east-facing Bay of Bengal mostly experiences on-shore winds. These on-shore winds may have an air-mixing cooling effect. It is noteworthy that Chennai’s waterfront, that is Bay of Bengal has lower surface water temperatures. On the other hand, Mumbai which is located on the west-facing Arabian Sea mostly experiences off-shore winds. In contrast, Mumbai’s waterfront, that is Arabian Sea has higher surface water temperatures. The higher surface water temperature of Arabian Sea tends to induce a higher urban heat island intensity in Mumbai. In addition to the explanation of the natural factors urban heat island differential between Chennai and Mumbai, there is a more significant anthropogenic explanation. The megacity of Mumbai is more than twice the transportation, infrastructural and industrial-commercial layout in comparison to Chennai.

The last 100 years of human occupation of the earth’s surface has experienced an unprecedented growth of urbanisation. In 1901, the World Urban Population was around 150 million people in the towns and cities of over 20,000 inhabitants. This urban population comprised less than 10 per cent of the world’s population. At present, this urban population has grown to over 3.5 billion people with 54 per cent of the world’s population. In this scenario of rapid urbanisation a new environmental problem of urban heat island has emerged in the last 50 years.

A May 2010 Christian Science Monitor article on “megacities” predicted that by 2050, almost 70 per cent of the world’s estimated 10 billion people—more than the number of people living today—will reside in urban areas. The social, economic and environmental problems associated with a predominantly urbanized population are considerably different from those of the mostly rural world population of the past.

A megacity is an urban agglomeration (accumulation) with more than 10 million inhabitants. Sixty years ago in 1950, there were only two megacities—New York-Newark and Tokyo. In 1995, 14 megacities existed. Today, there are 22, mostly in the developing countries of Asia, Africa and Latin America. By 2025, there will probably be 30 or more. Today, the most rapid megacity growth is occurring in the

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world’s least developed and poorest countries—those least able to handle the political, social, economic and environmental problems associated with rapid urbanization. For people in developing countries, even the slums of cities like Mumbai, India, can offer more opportunities than their poor subsistence-based villages can. People gravitate to the cities because the potential for making money is greater there. While most of the economies in rural areas are agriculture-based with little cash flow, in the cities, people may be able to earn cash for work or retail sales.  

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The 10 largest cities in the world in 2010 and their projected populations by year 2025 are Tokyo, Japan (37.1 million), Delhi, India (28.6), São Paulo, Brazil (21.7), Mumbai, India (25.8), Mexico City (20.7), New York-Newark (20.6), Shanghai, China (20.0), Calcutta, India (20.1), Dhaka, Bangladesh (20.9) and Karachi, Pakistan (18.7). As the world’s population increases at the rate of 134 million per year, the urbanization process is pushing more and more people into the cities. Such frenetic rates of urbanization and intense poverty of large urban populations strain resources. Nonetheless, to poverty-stricken, landless people, cities offer visions of opportunity. The resulting massive urban underclass, particularly in developing countries, represents one of the world’s greatest social and economic challenges.  

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The rapid urban expansion entails a dense network of roads, residential buildings and industrial-commercial infrastructures. The massive transformation of natural lands into urban-cultural landscapes has profound meteorological impacts by creating urban microclimates. It is this microclimate of increased temperatures which is referred to as urban heat islands.

Urban Heat Island is a condition of increased surface temperatures in some areas of a large city which are caused by ever changing microclimate. The difference between the maximum temperature at the city centre and the surrounding city-side is called the urban heat island intensity.

52 voices.nationalgeographic.com/2014/02/17/geography-in-the-news-the-growth-of-megacities/

53 Ibid.
In general, the urban microclimates do vary from their surrounding countryside in terms of solar radiation, thermal regime and the wind velocity direction and patterns. A large urban centre such as a megacity may have local climatic variations in the form of microclimates. In the urban climates, the degree of sun-shine varies within the built-up surface in accordance with the pollution intensity, urban density and the street orientation as well as the shade provided by tall buildings.

Oke, T.R. (1976) identified five main differences between the urban climate and the rural surroundings. These are radiation budget, sub-surface heat flux, advection, anthropogenic heat release which is the most important component and the turbulent heat transfer. Differences between the city climate and rural surroundings also occur in the context of urban canopy layer and the urban boundary layer.

Williamson and Evell (2001) pointed out that the Urban Heat Island is an outcome of the brisk absorption of incoming short-wave solar radiation by the built-up surfaces and the reduced emission of long-wave infrared radiation due to greenhouse effect. Oke (1981) identified the urban heat island largely as a result of reduced long-wave heat loss.

The anthropogenic factors are major stimulant of urban heat island. The fuel combustion and air-conditioning exhaust are some of the major sources of urban heat which does not exist to any comparable magnitude in the rural surroundings. The per capita energy consumption in the cities is also an important concentrate of urban heat. The per capita energy use is generally proportionate to the city size with its highest index in the megacities. The urban transport system is another major propellant of the urban heat island.

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III Megacity Area Growth Rate

The concentration of the world’s population in urban areas is growing at an enormously rapid rate. Within this phenomenon, further projections call for even more rapid growth of megacities. United Nations (UN) currently defined the megacities as the entity of over 10 million people. From 1975 to 2015, the number of megacities will have grown from five, (including three of them in the developing world) to 26. Out of these 26 megacities, as many as 22 were estimated in the developing world (UN, 1998). The large urban agglomerates we call megacities are increasingly a developing world phenomenon that will affect the future prosperity and stability of the entire world. The definition of what is a megacity is often arbitrary, as the population concentration that differentiates megacities from other urban areas changes with time and context. In the ancient world, Rome, with its over 1 million inhabitants, was a megacity, and today, Chicago could be considered a megacity, even though it falls below the 10 million UN threshold.

Although there are numerous examples in the developed world, megacities are primarily a phenomenon of the developing world. If one considers population projections for the 11 largest urban agglomerates in 2015, in 15 years most of the largest cities of the world will be in the developing world, a significant change from the largest city populations in 1980 and 1994. Although Tokyo will remain the largest city in the world, New York, at second place in 1980 and 1994, is projected to be at the bottom of the list by 2015, while Mumbai will have climbed from sixth to second place, and Jakarta from last to fifth place. Both Tokyo and New York are experiencing relatively modest population increases, and a number of other large cities in the developed world are experiencing population declines. In contrast, the populations of developing world megacities are typically growing from one to five per cent per year, although these rates are expected to abate somewhat in the next 15 years (UN, 1998). However, if all the megacities of the world – developed and developing alike; have one factor in common, it is the great diversity in many of their


58 Ibid.
salient indices, from cost of living to mobility, that often reflects differing approaches to public policies (Parker, 59 1995).

The major reason to pay attention to megacities is that they are key instruments of social and economic development. In a world concerned with the growth of the global population, megacities are strong indicators of both present and future conditions. They have become instruments for dramatic birth rate reductions in comparison to other regions of the countries in which they are situated.

Megacities, both in the developed and the developing world, are places where social unrest often originates, as demonstrated in Jakarta, and historically in Paris and St. Petersburg, the megacities of their time that sparked the French and Russian Revolutions. Such unrest affects the rest of the world, as do other phenomena of megacities, including the rate at which their residents emigrate to other areas, and the competitive challenge presented by their cheap labour forces. Last but not least, the ecological impacts of sprawling megacities extend to other regions of the world, as seen with the air pollution generated by millions of households burning soft coal, or with the disposal of waste, a universal problem epitomized by the odyssey of New York City’s waste-laden barges.

The problems in megacities are exacerbated by what are usually serious deficits in the realm of knowledge. There is a reduction in the generation of knowledge, such as the research necessary to address the problems of the megacity, and in the dissemination of knowledge, e.g., in the educational systems. Similarly, there are deficits in the utilization of knowledge by the relatively poor and uneducated populations of the megacities. As megacities are larger than many nations, they need to address these deficits in knowledge with the same seriousness with which nations address them, through research, education, and other instruments for the generation, diffusion, and utilization of knowledge.

For understanding the role of the megacities in the present scenario, we need to understand their dynamics. A megacity is a complex organism and its development is largely a spontaneous process. It is not an entity that can be totally designed, as has

been learned from a number of planning failures, exemplified by Brasilia, or, in New York and several other U.S. cities, by the so-called projects for low-income tenants. However, if it cannot be totally designed, the megacity can be guided in its evolution through realistic planning.

The problems of megacities include:

• Explosive population growth.

• Alarming increases in poverty that contradicts the reasons why a megacity attracts (World Bank, 1991). A concentration of the poor and jobless occurs both in the developing world and, on a smaller scale, in the developed world, as evidenced by the number of unemployed in New York City.

• Massive infrastructure deficits in the delivery of telecommunications services, the availability of transportation, and the presence of congestion. For example, traffic congestion in Bangkok is so bad that the average commute now takes three hours (World Resources Institute, 1996).

• Pressures on land and housing. China concentrates 5.7 persons per room, as compared to 0.5 persons in the United States.

• Environmental concerns, such as contaminated water, air pollution, unchecked weed growth due to the destruction of original vegetation, and overdrawn aquifers. For instance, Mexico City’s aquifer is being overdrawn and is sinking by about 1 meter per year (World Resources Institute, 1996).

• Disease, high death rates, drug-resistant strains of infection, and lethal environmental conditions. For example, 12.6 per cent of the deaths in Jakarta are related to air pollution causes (World Resources Institute, 1996).

• Economic dependence on federal or state governments that constraints the independence of megacity administrations.

• Capital scarcity, the factor that shapes the economy of the megacity and

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62 Ibid.

63 Ibid.
aggravates its other problems, from infrastructure to environmental deterioration.

These problems are increasingly intractable because megacities are experiencing very rapid growth with which they cannot cope. Coincident with rapid growth, these problems are occurring in environments where the populations, having flocked to the megacities in hopes of a better life, have ever higher expectations which are generally greater than the ability of a megacity to respond to them.

A vicious circle in the development of a megacity is that of attraction, growth, and distraction, as exemplified by Bangalore, a city that offers a good base for growth in terms of a favorable climate, a skilled population, and a good transportation system (Niath, 1996). That base has led to a strong migration into Bangalore, which, in turn, has led to high real estate costs, the creation of slums, health care problems, environmental problems, and shortages of water and energy.

The dilemma of the balance of focus between a megacity and the rest of the country is that, the extent to which megacities should receive the lion’s share of attention, as often happens to the detriment of other urban areas and the rest of the country. Another question is how to slow down the growth of megacities in order to give them the breathing space necessary to provide adequate jobs and infrastructure to their existing populations. There is a need to find alternatives to megacities by creating or strengthening smaller cities that would offer most of the advantages of a megacity but fewer problems, or by finding other ways of anchoring to the countryside the population that would like to migrate to the megacities.

In conclusion, the large urban agglomerates we call megacities are increasingly a developing world phenomenon that will affect the future prosperity and stability of the entire world. It is important for both the developing world and the developed world to understand megacities’ dynamics, their immense problems and needs, and the economic and market development opportunities they may offer. The evolution of megacities in the developing world will shape patterns of national and global economies, will continue to affect the settlement of vast populations, and will

influence the social and political dynamics of the world. Although the megacities are not different in many respects from other urban concentrations, they play a key role on the global stage by virtue of their very size. The megacities of the developing world, confronted by nearly intractable problems, have a pervasive and crucial need for policies and socio-technological and socio-economic approaches that must be devised in a different context than that of the developed world - a context with different settings, different needs, different challenges, and different opportunities.

Rather than a bad case of urban sprawl, the physical expansion of China’s megacities may be viewed as a combination of ‘urban spill over’ and ‘local urban sprawl’. Beginning in the 1980s, China’s urbanization entered a period of hyper-rapid growth (Zhou and Ma, 2003; Shen, 2005). The most remarkable growth occurred in coastal city-regions, especially in those large cities whose urban centers are surrounded by secondary cities and rural townships (Deng and Huang, 2004). The population of some of these has reached uncontrollable dimensions of more than 10 million.

China’s megacities reveal a different pattern of urbanization. At the city’s edge, in the so-called peri-urban areas, there are many high-density types of development along with plenty of open space, a result of the joint actions by city governments and real-estate developers. Meanwhile, the low density, less open space pattern can be seen at the township and village levels which are mainly associated with local development. So the urban growth pattern of China’s megacities should rather be defined as a combination of urban spill over (USO) and local urban sprawl (LUS).

Another driver of USO is the proliferation of residential developments in suburban areas, which are composed mainly of large gated communities for middle class families. LUS, on the other hand, refers to the many ‘development zones’ built by governments at district, township, and village levels, which are often discontinuous with the main urban area (Lin, 2001; Liang and Zhou, 1993).

An urban area ("built-up urban area," urbanized area or urban agglomeration) is a continuously built up land mass of urban development that is within a labour market (metropolitan area or metropolitan region). An urban area contains no rural land (all land in the world is either urban or rural). In some nations, the term "urban area" is used, but does not denote an urban area as a built-up urban area.

An urban area is best thought of as the “urban footprint” - the lighted area that can be observed from an airplane (or satellite) on a clear night. National census authorities in Australia, Canada, Denmark, Finland, France, the Netherlands, Norway, Sweden, and the United Kingdom (where "built-up urban area" is the new urban area term now used by National Statistics) have used this definition. In Canada, "population centre" and "urban centre" are preferred terms in these countries. The term "urban area" is used (or translated into English) in China and New Zealand. However, in these countries "urban areas" extend well beyond the built-up urban area and are thus more similar to metropolitan areas.

72 "Built up urban area" is the new urban area term now used by National Statistics in the United Kingdom. It may be the most descriptive short term for urban areas.
73 Called a "population centre" in Canada and an "urban centre" in Australia. The term "urban area" is used (or translated into English) in China and New Zealand. However, in these countries "urban areas" extend well beyond the built-up urban area and are thus more similar to metropolitan areas.
74 In China, sub-city or sub-regional districts called “shixiaqu” (市辖区) are sometimes referred to as urban areas. Shixiaqu, however are more akin to labour markets (metropolitan areas) and extend well beyond the urban footprint. Similarly, urban areas as defined in New Zealand are more akin to labour markets (metropolitan areas) because they extend beyond the urban footprint.
Sweden, the United Kingdom and the United States designate urban areas. Except in Australia, the authorities use a minimum urban density definition of 400 persons per square kilometre (or the nearly identical 1,000 per square mile in the United States).  

An urban area (built-up urban area or urban agglomeration) is different from a metropolitan area. A metropolitan area is a labour market and includes substantial rural (non-urban) territory or area of discontinuous urban development (beyond the developed urban fringe). Urban areas draw employees from a labour market area larger than the area of continuous development. For example, INSEE, the census authority of France defines the Paris urban area ("unité urbaine") as 2,845 square kilometres and the Paris metropolitan area (aire urbaine) as 17,100 square kilometres. An urban area is different from a municipality (also often called a city or a local government authority). Municipalities have political boundaries that usually include only a part of the urban area. For example, the city of Seoul represents less than one-half of the population of the Seoul-Incheon urban area, which extends well beyond the municipality. On the other hand, a municipality may be considerably larger than an urban area and therefore contain considerable non-urban (or rural) territory. Zaragoza, Spain is an example. A large part of the municipality of Mumbai is rural, composed of the Rajiv Gandhi National Park and thus not included in the urban area.

The world’s largest cities, particularly in developing countries, are growing at phenomenal rates. As a growing landless class is attracted by urban opportunities, meager as they might be, these cities’ populations are ballooning to incredible numbers.

IV Megacity Density Differential

Population density and built-up density are other anthropogenic attributes of urban heat island. The urban environments vary from high density inner-city surfaces of masonry, concrete, asphalt, glass and steel structures to the sub-urban surfaces of dense vegetation and lawns. A large Indian city is characterized with high population

75 http://demographia.com/db-define.pdf
76 Ibid.
77 http://www.nationsonline.org/oneworld/bigcities.htm
density, inadequate open spaces leading to high built-up densities, traffic congestion, atmospheric pollution, noise pollution and degradation of urban environment.

High population and built-up densities are the result of lower purchasing power of the urbanites in the scarcity economy of the developing countries like India. Theodoridou et al. (2007) emphasized that the morphological features of the built-up environment have a special bearing on the urban microclimate. These morphological features are built-up density and building system, geometry and orientation of urban streets canyons, thermal admittance of building material and the open air spaces.

London and Athens have similar population densities. Yet, the core densities in Athens are considerably higher than in London. The Athens suburbs, however, are among the least dense in the world. The Essen-Dusseldorf and Milan urban areas have almost identical densities, yet core densities are considerably higher in Milan. Demographia World Urban Areas defines the population and density of urban footprints, regardless of their internal density profiles. Average density and the geographical expanse of urban areas is important. For example, the differences in urban density profiles make only marginal difference in urban transport planning. This is because with the geographical expanse of nearly all modern, high-income urban areas, automobiles provide by far the greatest coverage, with considerably shorter travel times than public transport. For example, in Phoenix, more than 99 per cent of motorized travel is by car, while automobiles account for only 96 per cent of Boston, with its steeper density gradient. Automobiles account for 88 per cent of travel in the Essen-Dusseldorf urban area, somewhat more than the 77 per cent in Milan, with its steeper density gradient.  

Perhaps no idea is more widely accepted among urban core theorists than the notion that higher population densities lead to more productivity and sustainable economic growth. Yet upon examination, there are less than compelling moorings for

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79 Ibid.
the beliefs of what Pittsburgh blogger 80 Jim Russell calls “the density cult,” whose adherents include many planners and urban land speculators.

For the most part, the world’s densest megacities are the poorest. Take the densest, the Bangladeshi capital of Dhaka. Its 14 million residents are squeezed into an area of 125 square miles, making for a population density of 1,15,000 per square mile.81

Three other megacities - Mumbai, Karachi, Delhi - have population densities that are between three to seven times as high as the biggest megacity, Tokyo-Yokohama, which has a density of 11,000 per square mile. Tokyo is also much richer; the region’s per capita GDP tops $41,100, while the three ultra-crowded metropolises on the subcontinent have GDVs under $10,000 per capita. In contrast the two most spread out megacities, Los Angeles and New York, have population densities about half or less of Tokyo’s, but their per capita GDVs rank number rank first and third ($63,100 in New York and $54,400 in Los Angeles).82

New York University’s Shlomo Angel 83 has pointed out; virtually all major cities in the world are growing more outward than inward, and becoming less dense in the process. This is not only true in the United States, but also in Europe and, even more surprisingly developing countries as well. For example, over the past four decades, everyone’s favorite dense core city, Paris, has seen its urban land area expand by 55 per cent, while its population has risen only to 21 per cent. Today, the geographical extent of urban Paris is more than 25 times that of the Ville de Paris, home to most of the familiar tourist attractions.

This is not to say that the higher-density enclaves of urban areas do not have an important place. In terms of culture, finance, media and certain other transaction-based industries, a number of dense urban cores remain unassailable in their

80 http://www.newgeography.com/content/003634-density-boondoggles

81 http://demographia.com/db-worldua.pdf

82 Ibid.

83 http://www.amazon.com/Planet-Cities-Shlomo-Angel/dp/1558442456
efficiency and appeal. But in the United States, and much of the rest of the high-
income world, this is accomplished by bringing residents from the periphery to the
core - by car, train, bus and increasingly through telecommunications, even as most
jobs are located elsewhere in the urban area. The future shape of the city is likely to
continue expanding, even as some urban cores grow. Visit any burgeoning city in the
developing world from Shanghai to Mexico City and the same reality emerges: as
cities get larger, they spread out, as people begin to aspire, as best they can, for the
quality of life that most North Americans and Europeans already take for granted.  

Urban heat island changes the natural surfaces that were once permeable and
moist into impermeable and dry built-up surfaces. Every city has its own
microclimate and as does the city size and morphology change, so does its climate.
The mega cities of Ahmedabad, Hyderabad and Bangalore have witnessed a
consistently high population growth for the last few decades. This high population
growth rate and urban function is coupled with rapid infrastructural development.
This excessive urbanisation has brought about a definite microclimate change in the
form of rising urban heat dome.

Rose and Devadas  

85(2009) also noted that the phenomenon is the result of
increase in population density, increase in built-up surfaces, increase in three-
dimensional surface area, reduction in the open spaces and decrease in the green
cover. The thermal admittance of the built-up surface deteriorates the urban
environment which causes health problems.

The most apparent anthropogenic activities impact on city’s local climate is
the modification of the atmospheric environment by land-use of cities. Howard (1833)
asserts that the city’s land-use pattern destroys existing microclimate and creates great
complexity. The local weather condition in the city area is different from that of the

84 http://demographia.com/db-worldua.pdf

85 Rose, A.L. and Devadas, M.D. (2009). Analysis of Land Surface Temperature and Land
Use/Land Cover Types Using Remote Sensing Imagery-A Case in Chennai City, India,
Proceedings of the Seventh International Conference on Urban Climate, 29 June-3 July 2009,
Yokohama, Japan.
surrounding rural area, at least in terms of reduced visibility and increased temperature.  

Although the magnitude of surface urban heat island varies between the summer and winter seasons in the cities of the continental interiors but in the present enquiry of the three megacities of Peninsular India such as Ahmedabad, Hyderabad and Bangalore there is hardly a cognisable difference between the summer and the winter seasons. These three Indian megacities have not only longer summers but also a namesake winter months particularly in Hyderabad and Bangalore. The surface urban heat islands are largest in the summer season of tropical cities.

To identify urban heat islands, scientists have used both direct and indirect methods as well as numerical modelling and empirical findings. Remote Sensing is usually a technique of indirect measurement of surface temperatures. The thermal imageries are interpreted to produce the surface temperature estimates. But remote sensing techniques have their own limitations in the long-term understanding of the urban heat island phenomenon.

Scientists proclaim that the atmospheric urban heat islands are usually feeble from late morning to almost throughout the day. This heat island intensity begins to grow after the sunset because of the slowed down heat radiation from urban infrastructure and the overlying greenhouse lid effect.

Within the atmospheric urban heat island, there are two categories. One is the canopy layer urban heat island which exists above the tree tops and roof tops. Another is the boundary layer urban heat island which is above the canopy layer up to the level of influence of the urban landscape to the air temperature. The boundary layer urban heat island vertically extends up to 1.5 km from the ground level. (Oke\textsuperscript{87}, 1982)

Surface urban heat island and the air heat island are not the two entirely unrelated phenomena. In fact, the former is complementary to the latter particularly in the Canopy Layer which is closest to the surface layer.


The phenomena of urban heat islands represent a condition of local climate change. It differs fundamentally from the phenomenon of global climate change. Still, however, it cannot be ignored that urban heat islands are the nuclei of global warming.

Solar reflectance, thermal emissivity and heat capacity of the built-up surface considerably influence the nature and character of urban heat island. The solar energy reaching the earth’s surface that influences the urban heat island consists of ultra-violet rays, visible light and infrared energy. Christen and Vogt \( ^{88} (2004) \) have measured that 5 per cent of the solar energy reaching the built-up surface is in the ultra-violet spectrum and 43 per cent of the solar energy striking the built-up surface is in the visible region of the spectrum. The remaining 52 per cent of the incoming solar radiation is infrared energy. All these wavelengths contribute to the creation of urban heat island by different measure.

The topography and climate which are determined by a city’s geographic location influence the formation of urban heat island. For instance, large water bodies moderate the temperatures and generate winds, which cause the convection of heat away from cities. Nearby mountain ranges can either block the winds from reaching a city or create wind patterns that pass through a city. The raised temperatures of urban heat islands in the summer season of tropical climates adversely affect the environment and the quality of life.

V Meteorological Indicators of Urban Heat Island

The following meteorological indicators have been taken under review.

1. Mean Monthly Maximum Temperature
2. Mean Monthly Minimum Temperature
3. Mean Monthly Average Temperature
4. Mean Monthly Rainfall
5. Mean Monthly Relative Humidity
6. Mean Monthly Wind Velocity
7. Number of Calm Days
8. Mean Evaporation Changes

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Karl (1991) also noted that the mean monthly maximum (daytime) temperatures had a little change as compared to mean monthly minimum (nighttime) temperatures. The revelations of nocturnal warming in the United States, former Soviet Union and China indicate that most of the warming in their cities has occurred at night (Monastersky, 1992). In view of the newly reported increase in night temperatures, Hansen et al. (1981) subscribed to the idea of greenhouse warming.

Most of the studies on urban heat island including the one of Mohan et al. (2009) for the city of Delhi reveal that the nocturnal heat island intensity is greater than the rural surroundings by 3.8°C. This is because of the more pronounced greenhouse effect during the nighttime.

According to Shepherd (2005), the urban heat island, city structures and pollution levels interact to alter rain storms around cities. The real question is which combination of these is the most important factor. Which of these takes the most precedence at the beginning? Is there one of those that takes more precedence at the end, once rainfall gets started?

Burian and Shepherd (2005) used the historical rain gauge data to confirm that the per cent occurrence of rainfall around Houston had increased in post-urban Houston as compared to pre-urbanized Houston. Hence, they revealed that the city of Houston may have shifted the time of likely occurrence of storm until later in the afternoon. The rainfall had increased downwind of the city. The pre-urban rain-gauge

data shows a spread in rainfall over a greater part of the day. Whereas, the post-urban rain gauge data revealed that more of the day’s rain was concentrated in a narrower time window that peaked at around 4:00 p.m.

Giridharan et. al. (2004)\textsuperscript{95} discovered that in the study conducted on 13\textsuperscript{th}, 23\textsuperscript{rd} and 24\textsuperscript{th} August, 2002 for Hong Kong, the relative humidity ranged between 58 per cent and 83 per cent for a residential private housing development. Whereas, the study conducted on 27\textsuperscript{th}, 28\textsuperscript{th} and 29\textsuperscript{th} of August, 2002 for a public housing development revealed that the relative humidity lied between a range of 66 per cent to 86 per cent with clear sky and light winds.

In a similar experiment conducted for another public housing development on 2\textsuperscript{nd}, 4\textsuperscript{th} and 5\textsuperscript{th} September, 2002, the relative humidity ranged from 51 per cent to 76 per cent with fairly clear sky and light winds. Thus, the Urban Heat Island Effect may be clearly identified in the presence of cloudless, clear sky and the light and variable winds.