LSE India Observatory

Working Paper Series

Sustainable Urban Development in India: A tale of two Mahindra World Cities

Ruth Kattumuri with Sunil Kurian and Mahindra World Cities Team

Sustainable Urban Development in India: A tale of two Mahindra World Cities

September 2017

Ruth Kattumuri Co-Director, India Observatory, LSE

Sunil Kurian Mahindra World City, Jaipur, India

All rights reserved. Apart from any fair dealing for the purpose of research or private study, or criticism or review, no part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means without the prior permission by the publisher or author (2017).

About the India Observatory

The India Observatory (IO), established in 2006, has a strong public policy engagement in, and with, India. The IO also works in collaboration with international partners for the generation and exchange of knowledge on India and its position in the world. It has a global focus, especially with respect to emerging economies. This is to enable sharing knowledge and experiences between India and other countries with common synergies for better understanding and mutual benefit. The Observatory regularly organises programmes for training future leaders from emerging economies.

The IO is involved in developing, enhancing and undertaking multi-disciplinary and interdisciplinary research at the LSE and beyond. It has strong links with academic institutions, public and private sector institutions to further knowledge exchange and contributes to the debate on broader policy issues by promoting and supporting an active engagement around economic and social policy.

For further information, please contact:

India Observatory
London School of Economics & Political Science
Houghton Street
London
WC2A 2AE
United Kingdom

E-mail: india.observatory@lse.ac.uk
Web: sticerd.lse.ac.uk/india

Sustainable Urban Development in India: A tale of two Mahindra World Cities

Ruth Kattumuri[1] with Sunil Kurian[2] and Mahindra World Cities Team

About fourteen percent of the total world population lives in India. Approximately 350 million people live in urban and *peri*-urban areas. With the country's urbanization rate currently being 2.5 per year, it is estimated that around 600 million people will be living in towns and cities by 2030. Developing sustainable urban conglomerations is a key priority for India's growth and development. The Jawaharlal Nehru National Urban Renewal Mission (JNNURM) launched in December 2005, Atal Mission for Rejuvenation and Urban Transformation (AMRUT) launched in June 2015, Smart Cities Mission launched in 2015 are all evidence of the government's active engagement toward economic and social development of cities in India.

There is growing awareness of the great potential that exists in business development models that are environmentally sustainable. Additionally, following a low-carbon development path with help toward achieving various Sustainable Development Goals including #3 (good health and wellbeing), #6 (clean water and sanitation), #7 (affordable and clean energy), #9 (industry, innovation and infrastructure) and #11 (sustainable cities and communities).

Some private sector organisations in India have been actively involved in business practices, which are environmentally sustainable for a long time and there is a growing commitment to these issues, by many others. The business leaders who have engaged in sustainable practices for many years in India are companies who have taken a long-term perspective (Kattumuri et al. 2013). Even the newer large business organizations often say that environmentally sustainable practices make business sense based on cost benefit analyses.

The public and private sector working together can enable improved implementation. Additionally it can help enhance the potential and opportunities for sustainable urban development. This paper studies the Mahindra World Cities (MWC) models of sustainable townships, which have been developed through public private partnerships in India.

[1] The meticulous research support from Yukie Hosoda is greatly appreciated.

[2] MWC Jaipur

INTRODUCTION

The Mahindra Group reportedly began to explore initiatives to participate in the future of nation-building and ventured into urban infrastructure since the early 1990s. The Mahindra Lifespace Developers Ltd. (MLDL) was set up for the development of sustainable urbanization with its mission statement of "transforming urban landscapes by creating sustainable communities". MLDL was founded with a core objective of developing green designs and sustainable urban infrastructure and improving quality of life, and purposes to strike a balance between environment, economy and equity. This philosophy has been extended through the development of 'Mahindra World City' (MWC), which are integrated township models in Chennai (formerly Madras) in Tamil Nadu and Jaipur in Rajasthan. Chennai metropolis has an area of 1,189 sq.kms and population of 9 million and Jaipur has a population 3 million and an area of 484 sq.kms.

The MWC model has been conceived as public private partnerships to build and facilitate ecosystems based on a professional master plan and in-built public utilities. These townships in Chennai and Jaipur have been established as joint ventures with the respective state industrial development boards: MWC – Chennai with TIDCO (Tamil Nadu Industries Development Corporation) and MWC - Jaipur with RIICO (Rajasthan Industries Investment Corporation).

THE MAHINDRA WORLD CITY PHILOSOPHY

The central philosophy of MWCs is to enable economic and social development together with being environmentally responsible (Table 1). The business model is for sustainable urbanisation through the development of green communities in large urban centers for the creation of new economic centers of 3 L's (Livelihood- Living-Life) to enable positive change for customers, stakeholders and the wider community (http://www.mahindraworldcity.com/about-us/overview.aspx).

The MWC concept is to build communities through integrated business cities based on 3-L's:

(i) Livelihood, with an initial focus for facilitating wealth creation through industrial development which then generates revenue, exports, and employment;

(ii) Living, the focus is on enhancing the 'living' experience through developing residential and social infrastructure;

(iii) Life, is intended to augment quality of life through social events (such as sports, marathons, music and cultural festivals) to strengthen the community.

The two Mahindra World Cities in Chennai and Jaipur are located in 4,600 acres, with over 125 well-known global companies that employ approximately 50,000 people and generate exports worth over USD 1.5 billion and enhance the economic and social development of neighbouring towns and villages.

The size of the population going through the two MWCs (Chennai and Jaipur) is estimated to be around 100,000. As of 30th Apr 2017, 38000 people were employed (direct employees only) at MWC-C, and about 1000 families' lived within the city, which adds up to over 70,000; in MWC-J 29000 people were employed (including indirect employees), living spaces are currently in development.

PLANNING AND DESIGNING THE CITIES

The first integrated business city was developed in Chennai in 2002 as a public private partnership between the Mahindra Group and Tamil Nadu Industrial Development Corporation (TIDCO), which is a government of Tamil Nadu enterprise, with 89:11 partnership. The joint sector endeavour provided the impetus to develop effectively and credibly with essential government support. It is reportedly the country's first integrated business city and India's first Indian Green Building Council's Gold Certified Green Township.

A joint venture between Mahindra Lifespaces and Rajasthan Industrial Investment Corporation (RIICO), a Government of Rajasthan Enterprise, the 3000-acre second Mahindra World City at Jaipur established in 2006, replicates the Chennai model and expands the scope of business opportunity and enterprise. The plans have been drawn by Jurong Consultants, Singapore and it was landscaped by Site Concepts, Singapore. It became the first project in Asia to receive Stage 2 Climate Positive Development certification from the C40 Cities Climate Leadership Group and has also received Gold rated pre-certification under Green Special Economic Zone (SEZ).

The premise is anchored on economic development and employment generation by creating global standard infrastructure to attract best international corporations to invest in facilities within these spaces; and creation of residential and social Infrastructure to catalyse a self-fulfilling ecosystem. These multi-purpose developments provide large public places, open grounds, good ventilation and natural light, decongested streets and no more than a twenty-minute commute between home and work (thus enabling more time with friends and family

and better quality of life) and easy access to high-ways, airports, major cities and other infrastructure.

Mahindra World Cities have been planned in accordance with the guidelines and policies and adaptable to global scenarios with the flexibility to accommodate the changing dynamics of future economic scenario and market trends. The sites were developed after detailed study of topology, geography, hydrology, existing infrastructure, micro-climate and eco-system of the neighbourhood. They are developed to harmonise with the prevalent environment in the region and considering other aspects such as roads, streets, zoning, ease in commuting, flood plains, natural features, nearby communities, public transport, drainage & sewage, water supply networks, and power infrastructure. Efforts are made to preserve existing natural topography such as water bodies and green spaces.

MWCs subscribe to government of India's Ministry of Urban Development concepts for sustainable cities, namely: (i) competitiveness of city in terms of ease of doing business; create employment opportunities, attract investments, experts, professionals and people; and the quality of life it offers. (ii) sustainability including social, environmental and financial sustainability. (iii) quality of life including safety and security, inclusiveness, entertainment, ease of seeking and obtaining public services, cost efficient healthcare, quality education, transparency, accountability and opportunities for participation in governance.

The following fundamental practices in MWCs have been developed in keeping with Indian traditions and modern knowledge and principles of sustainability:

- judicious use of energy
- elements and spaces to be multifunctional to effectively support their use.
- to be flexible and adaptable over time with changing traditions and future visions as growth and change are inevitable.
- to conceive and develop built-forms around a community's lifestyle and aspirations.
- planning for institutional buildings as engines of growth
- to provide sense of identity and choices of expressions such that communities can thrive.
- traditional built-form that encourage individual expression and planning frameworks that allow freedom for positive interactions.

The following sections describe the economic model and the social development programmes, followed by the processes being undertaken for environmental sustainability at Mahindra World Cities.

THE ECONOMIC MODEL

The premise of the MWC business model incorporates the following aspects (see Table 1):

- Thoughtful and proactive master planning/design
    - Using local and natural resources,
    - Intuitive/responsive planning to enable the layout to lend itself to flexibility and dynamic economic scenario
    - Include various aspects of a city such as - governing centers; utility centers; living centers; learning and livelihood centers; and leisure centers and breathing spaces.
- Inclusive and heterogeneous communities
    - Not built as urban islands but maintaining orderliness even without borders, and for symbiotic living with the neighbourhood.
- Embedded technology for networking, transportation, security and other services
- Location being away from but accessible to the main city
- Having in-built flexibility to revisit and re-design at each stage according to customer or stakeholder requirements.

Anand Mahindra, Chairman of Mahindra Group states, “the Mahindra World City Project represents our pioneering spirit in providing state of the art facilities for global and Indian businesses to thrive. The intent thus was to create integrated development with high quality infrastructure to attract investors from across the globe. It epitomizes the synergies that will address the need for focused investments in the Indian infrastructure sector” (Balsavar, 2012).

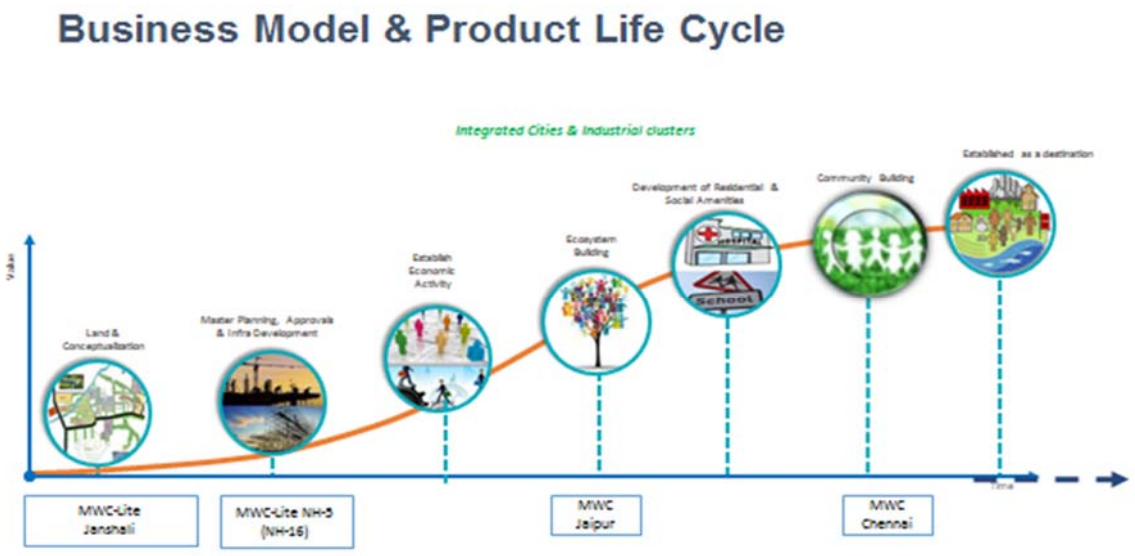
The key processes in the business model are divided into 7 stages. It is estimated that MWC-C&J would reach their full potential in about 20 years from their launch.

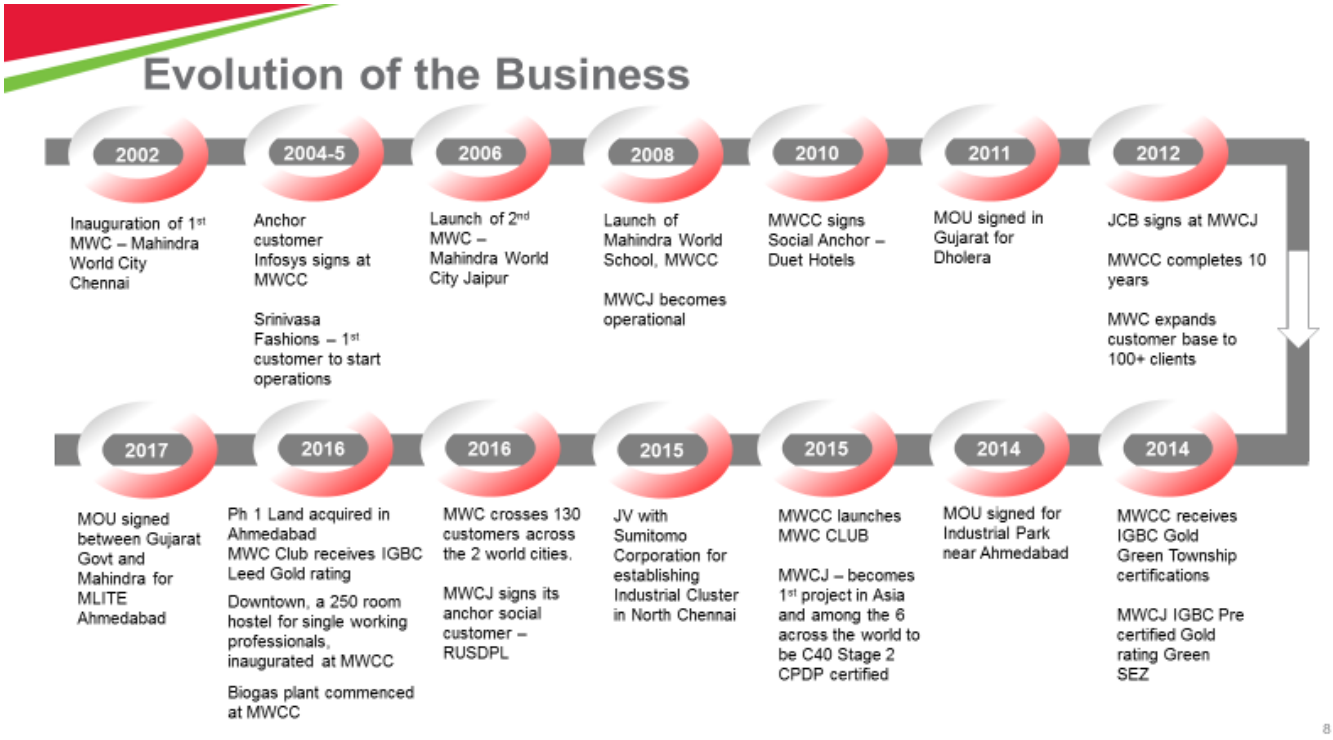
1. Land acquisition & Conceptualisation
2. Planning & Infrastructure Development
3. Develop economic activities - Client Acquisition / Job Creation
4. Building Ecosystem

5. Building residential and Social Amenities
6. Community Building
7. Realising full potential

- **MWC-Chennai (MWC-C)**; established in 2002 is currently in stage 6 and is involved in establishing its social and retail infrastructure and strengthening its community building initiative.

- **MWC-Jaipur (MWC-J);** started in 2006 is in stages 3 and 4 and is involved in client acquisition and building its ecosystem.





SOCIAL DEVELOPMENT INITIATIVES

A key component of achieving sustainable urbanization has been through the development of green communities through the provision of quality housing at affordable prices. The residential zone at MWC-C provides accommodation for over 6000 families across various economic strata and a further 2500 homes are under development. This township also includes an international school and other schools, medical centres, multiplex, retail malls, hotels, recreation and leisure facilities.

Community Development and CSR Initiatives

Concerted effort are made to integrate MWC with the local communities through setting up outreach programmes and bringing diverse communities together. MWC-C is without boundary walls and the infrastructure and other benefits of the city are accessible to the local community. Local communities are also invited to attend music, dance theatre and art performances in the courtyard; participate in the annual quiz programme Mindquest; Champions Trophy - an inter-company sports tournament; the MWC run in support of the girl child.

Community development programmes provide education, training and skills development programmes for youth from the surrounding communities, which enable them to find jobs, are developed regularly working in collaboration with NGOs. Over 5000 persons have been trained through such initiatives. MWC in collaboration with CAP Foundation has set up a community college for administering further training programs and create further opportunities.

The establishment of MWC has enabled the overall development of communities in the area. These include infrastructure development, providing opportunities for entrepreneurs such as retail and food outlets. Others have found work within companies located in the townships, which have greatly enriched them and their families. MWC-C has extended its infrastructure development including the access roads to help the seven villages in the neighbourhood and involving NGO's, the schools in the villages have been improved with provision of furniture and play equipment. Thus MWC contributes to raising the standards of living of the local community, which is part of the social development priorities. This model of inclusive and responsible development further contributes to the success of MWC.

Education programmes: Gyandeep is an informal school for children of local community and migrant workers, which is envisioned to provide flexible and conducive learning opportunities. They also adopt some local schools, which are supported by painting the inside walls of the class rooms with educational and entertainment materials, setting up a play area within the school premises and renovating the washrooms and provide water coolers. MWC-J in partnership with Akshaya Patra
Foundation, sponsors five schools for mid-day meal programmes.

Health: Initiatives such as general health camps, eye check-up camps, cleanliness drives and health awareness drives, which promote awareness and healthy lives, are provided free for MWC workers and also extended to their families and neighbourhood communities.
Kunnavakkam public health centre (PHC) located near MWC-C services five villages and 20 panchayats in the neighbourhood which were identified and evaluated in collaboration with World Vision India in order to identify gaps and needs in the services being provided by the PHC. MWC then supplied some of the required emergency equipment and also renovated their infrastructure and thus helps the villagers in the neighbourhood access to advanced medical services free of cost at the PHC.

Skill development: a key focus of the CSR initiatives is for developing skills to enable employability and sustain quality of life. These help to rejuvenate and revitalise local economy, empower youth and women. In 2009, MWC-J conducted a need assessment study with its implementation partner NGO, Technology Business Incubator (TBI). Based on the findings, MWC-J team set up 'from Parda to Prosperity' programmes to empower women and make them employable in MWC. These include – training in landscape maintenance; tailoring to facilitate women to work with campus clients in handicraft zone; primary education and basic computer training was also provided. Additionally self-employment based training such as self-help group (SHG) trainings, beautician courses are also conducted. To date 75 SHGs with 800 members have been established. Twelve of the SHGs have a financing capacity of over INR 50,000. This enhances the purchasing power of these women and enables them to buy products like sewing machines and beauty products that are essential for their occupations.

LOW-CARBON DEVELOPMENT PROCESSES

Mahindra World Cities have been planning and developing low-carbon models of urban development. They regularly monitor their energy consumption in order to develop a carbon-neutral ecosystem.

The following initiatives have been reported by MWC's.

C-40 cities climate leadership group: connects over 75 world cities, representing over 500 million people and a quarter of global economy, of which MWC has been one of the 17 founding members. MWC is committed to C40 principles for tackling climate change and support urban development that reduces greenhouse gas emissions and climate risks, while increasing the health, wellbeing and economic opportunities of urban citizens. And its projects are focused on developing measureable and sustainable aspects on climate change. In recognition of its climate positive roadmap detailing its plans and commitment to achieve a net-negative carbon emissions outcome, Mahindra Group Chairman Anand Mahindra, has been presented (4th June 2015) a commemorative award by the President of the C40 Board and UN Secretary-General's Special Envoy for Cities and Climate Change Michael R. Bloomberg.

A performance-based framework designed to create models for how cities can grow in low carbon ways showing detailed plans for how they will reduce energy, waste and transportation related carbon emissions onsite and expand the impact to the surrounding community in order

to achieve a climate positive outcome, the Stage 2 Climate Positive Development certification was given to MWC-J from the C40 Cities Climate Leadership Group (C40) in June 2015. It was the first project in Asia to receive this certification.

Green Buildings: Green buildings are significantly more efficient at utilization of resources, including energy and water, and a key component of sustainable urbanisation. More recently, the MWC Club at Chennai became the 1st Club in India to receive a Gold IGBC LEED NC certification and the Mahindra World School, the IGBC Platinum Green School certification.

Most buildings developed within MWC are based on the principles of Green development and some of the customer campuses have received IGBC/LEED Gold/ Platinum ratings for Green development. All the residential / retail / social establishments developed by MWC and MLDL within Mahindra World Cities are rated IGBC Gold / Platinum. Iris Court (Residential), Evolve IT Park (Commercial), Aqualily (Residential), Sylvan County (Residential).

Solar Power Plant: Mahindra World City has been a pioneer in commissioning an off-grid solar power plant in the state of Tamil Nadu. Located in 'The Canopy'- the commercial center, the 75 kW power plant has the capacity to generate 116,000 units of clean electrical energy annually, offsetting almost 60 tons of CO2. MWCJ recently commissioned 210kWp rooftop solar project on BOOT model that meets 5% of electricity demand for commercial operations. The annual energy savings at MWC-Jaipur through rooftop solar PV plant is estimated to be 300,000 kWh, which would reduce CO_2 emissions of 270,000 kg. and provide annual saving of INR 560,000 (Mahindra Sustainability report 2015-16)

Use of LED/Induction lights: Approximately 50% of the common power consumption is from street lighting. Hence in order to reduce power consumption all the sodium and mercury lamps in street lighting system in MWC Chennai and Jaipur are being replaced with LED/ Induction lamps. It is estimated that MWC-Jaipur would save energy of 99,450 kWh annually and reduce CO_2 emissions of 89,510 kg. with an annual savings of INR 175,800 (Mahindra Sustainability report 2015-16).

In the following section we have examined water and waste management as well as measures of air quality in MWC to evaluate its environmental footprint.

Water Management

In this section we examine existing processes in MWC for sustainable water management by considering water supply, rain water and storm water management and waste water

management. This is also suggested according to the Sustainable Water Management Improves Tomorrow's Cities' Health (SWITCH) which is a project conducted by a cross-disciplinary team of 33 partners, including Europe, South America, Asia and Africa between 2006 and 2011 and was co-funded by the European Union (Howe et al. 2011).

Water supply

MWC's have been planned to ensure the balance of demand and supply of water in order to meet water requirements of clients and across all the needs of the cities. Based on its core value of sustainable development MWC-J meets 65-70% of its long-term water requirement through recycled water. For instance, the total water demand at MWC-J is 60 MLD, of which 40 MLD water is met from recycled water. Half of recycled water is self-generated and remaining is secured from Delawas STP and PHED (Government of Rajasthan).

As the cities grow and water demand increases, MWC plan to increase their water supply. They will also have to ensure that water is distributed efficiently across the economic sectors and households and also that water is consumed efficiently. The measurement of water consumption per capita as well as per industry will further enable MWC to enable improvements in their performance according to global standards in the pursuit of sustainable water management.

Rainwater and storm water management

At MWC-C, all companies within MWC have installed rainwater harvesting facilities within their campuses. Rainwater harvesting facilities have been made for the public spaces comprising the park. A network of storm water drains have been constructed along all the roads, such that all run-off water can be flowed into the Kolavai Lake, which is located at the southern periphery of the park.

The storm water management system has been constructed effectively taking into account the geographic characteristics such as the natural slopes; lay of the land and historical floodwater levels in the region.

Storm water could pose a risk of water pollution as it can convey contaminants such as oils, heavy metals, nutrients and sediment into water supply sources (Howe et al 2011). Additionally, this can increase the cost of treating the water to drinking quality. As manufacturing and engineering industries are located within MWC, hence it is important to regularly examine storm water quality to ensure that it does not pose any pollution threat.

Evergreen landscape

Xeriscaping, a process for growing plants that consume less water, is practiced in all their projects. Recharge pits have been built to collect rainwater, which is used for watering the plants and lawns in the park. Further, they plant native plant species that do not consume much water and are drought resistant. At MWC-J the landscape that was designed to inspire struggled to survive the intense heat in Jaipur and most saplings withered away. The team overcame these challenges by identifying and selecting plant species, which could survive in the climate prevalent in the region. Through research and execution, they established an in-house nursery for these plants that has become a repository of best practices in horticulture. The nursery also supplies plants for the companies in MWC-J. In additions to environmental benefits, other advantages include cost reduction, potential revenue stream and also relationship building with clients.

Resilience to extreme weather events

The unprecedented floods of December 2015 in Chennai were reported to be the severest in 100 years, when about 500 people died and 110,000 people were displaced. Rainwater levels during 1st to 9th December 2015 ranged between a maximum of 1808 mm and a minimum of 554 mm. The damage caused by these floods brought Chennai to a standstill for at least one week.

In spite of being surrounded by seven lakes, MWC-C evidenced the benefits from its well-planned water management infrastructure. The storm water management system designed to be environmentally responsible and responsive and has been developed consistent with the natural slopes and lay of the land and taking into account historical floodwater levels in the region. As part of their regular maintenance, pre-rain activities had been conducted within and around MWC. These storm management planning, rapid response and dedicated work force at MWC-C enabled the township to be resilient, it ensured the safety of all on-site companies, employees and residents and recovered to normalcy within 24 hours from one of the severest storms experienced in the region.

The water levels in and around MWC was increasing as the drains were running full and all the water bodies were at HFL (Highest Flood Levels) ever recorded. As all communication networks were down, and entry in to MWCC & Exit from site as not possible due to the flooded highways and railway lines.

Though rains caused minimal water logging within MWC, the water logging got aggravated due to sudden breach in one of the water bodies on 01 Dec morning around 1000hrs.

The MWC team present on site and residing within MWC gathered all available manpower and co-ordinated operations 24 by 7 for 5 days after the floods. They divided all activities into 3 groups to implement rapid restoration. The first group coordinated with Tamil Nadu Electricity Board, the Central Disaster Management, Public Works Department and maintained regular communication with Police officials and the occupants of MWC and evacuated people from flooded locations using buses, trucks as well as construction machinery such as tippers and tractors. The second group worked on clearing the drainage systems to ensure free flow to restore regular activity in special economic Zone 1. They also worked on traffic control to enable normal movement of vehicles within and outside of MWC. Group 3 worked on clearing the drainage systems all other areas in Zone 2 within MWC as well as for the neighbouring villages. They monitored the water levels in the 7 surrounding lakes and regularly cleared water from the roads and prevented overflowing.

As stated by Ashok Iyer, a resident of Aqualily (a gated residential community within MWC-C, *"we had witnessed unprecedented rains over 4-5 days. Rivers were in spate; tanks were bursting at their seams; Chennai city was under a deluge of water; people went through severe hardship and had to deal with sewage-contaminated water in their homes. Aqualily, Sylvan County and Iris Court within MWC-C have a great drainage system. The situation in Nova was also pretty good. Our Aqualily road adjacent to clubhouse had 4 inches of water, several times during heavy downpour and in less than 15 minutes water drained off. The service staff cleared the storm water drains to facilitate the "benchmark" flow for apartment's complex.*

In comparison, a close friend who lives in a different residential project outside of MWC, had his cars submerged in 2 feet water and a compound wall has capsized.

If it had not been for the design and construction of the roads and storm water drains and the quick response and efficient work by service staff even in difficult circumstances, we remained clean, green and virtually dry."

Following the extreme weather event of December 2015, further plans have been implemented in co-ordination with the Water Resource Organization, for strengthening the lake bunds. They have conducted major repairs and clearance of all internal and peripheral storm water drains to ensure free draining of water into the lake. During monsoon season, a CFT (Cross Function Team) is deployed in MWC-C to ensure all drains are free flowing and heavy machinery is also kept on standby to ensure efficient clearing operations if required.

Waste Management

The waste water and food waste recycling practices are described below.

Wastewater recycling

MWC Developers Ltd (MWCDL) have installed a centralized Sewage Treatment Plant (STP) of 2 MGD capacity and Tertiary Treatment Plant (TTP) of 1 MGD capacity at MWC-C, designed according to Tamil Nadu pollution control standards, which are capable of treating water having raw domestic sewage. Sanitary sewage generated flows through 20 km of sewer pipe by gravity to the STP. A wastewater pipe network has been laid all across the township and this treated water generated from TTP is used for landscaping and gardening in common areas and the campuses within MWC as well as for re-charging the reservoir.

Further propositions to improve wastewater management are in the process of being implemented. These include – extracting nutrients from wastewater and reusing locally through recycling of urine and creation of bio soils from faecal sludge; digestion of by-product sludge to create biogas, which can be converted to bio soils for use as fertiliser and soil conditioner instead of being run-off; and using natural treatment process to enable low energy consumption for treatment, production and pumping of wastewater.

Recycling of Food waste: MWC-C generates an average of 8 tons of bio-degradable waste every day of which ~5 tons is food waste. A bio-methanation Plant was set up as a partnership between Naandi Foundation, Mahindra Research Valley and MWC-C. This biogas plant, spread across 1,000 square meters converts the 8 tons of food and kitchen waste generated daily at MWC, into 1000m3 of raw biogas which is enriched to yield 400kg/day of purified CNG grade fuel which is then used to operate the shuttle buses and tractors collecting food waste and DG sets running with CNG and facilitates powering the STP operations and street lights of the area. A byproduct is 4 tons of organic fertilizer being produced each day, which is used by farmers to enhance soil fertility.

Air Quality

In this section we have considered air quality index (AQI) based on the levels of PM_{10}, $PM_{2.5}$, SO_2 and NO_2 particulates in the atmosphere in MWC. We also consider these measures in relation to other eco-cities, from the global standard.

According to WHO reports, PM levels affect more people than any other pollutant. The major components of PM are sulphate, nitrates, ammonia, sodium chloride, black carbon, mineral

dust and water. The most health-damaging particles are those with a diameter of 10 microns or less, ($\leq PM_{10}$), which can penetrate and lodge deep inside the lungs. Chronic exposure to particles contributes to the risk of developing cardiovascular and respiratory diseases, lung cancer. The microns can even lodge themselves in the brain and are reported to increase the risk of dementia.

WHO Guidelines also use levels of NO_2 and SO_2 to measure ambient air pollution and impact on health. NO_2 is the main source of nitrate aerosols, which form an important fraction of $PM_{2.5}$ and of ozone in the presence of ultraviolet light. Epidemiological studies have shown that symptoms of bronchitis in asthmatic children increase in association with long-term exposure to NO_2. Reduced lung-function is also linked to NO_2 at concentrations currently measured in cities of Europe and North America. SO_2 is a colourless gas with a sharp odour. It is produced from the burning of fossil fuels (coal and oil) and the smelting of mineral ores that contain sulphur. SO_2 can affect the respiratory system and the function of lungs, and cause irritation of the eyes. Inflammation of the respiratory tract causes coughing, mucus secretion, aggravation of asthma and chronic bronchitis, making people more prone to infections of the respiratory tract.

Air quality indicators in MWC-C

We examined yearly changes of air quality indices within MWC-C based on data available from 2013. These have been compared with corresponding measures of the air quality in Chennai, the major city where it is located. We compared these also with WHO guidelines (2005). As a newer city in the early stages of its development, the air quality index is not yet available for MWC-J.

The Air Quality Index (AQI) is being published for India by the Central Pollution Control Board (CPCB) since 2014 (Appendix 1). We compare air quality indices of MWC-C with available data for Chennai city since 2013. Table 2 shows PM_{10} in MWC-C has increased from 2013 to 2014 by 10.5% and thereafter it has decreased during 2015-16. The initial increases could be due to expansion in the township such as construction activities, which then appears to have been improved through implementing initiatives to improve air quality. In comparison, PM_{10} had increased by 26.3% between 2013 and 2014 for the city of Chennai.

WHO suggests that $70\mu g/m^3$ is a common measure of PM_{10} in developing countries. On this basis, PM_{10} level of $55.57\mu g/m^3$ at MWC-C in 2015-16 is categorised to be at satisfactory

levels. However on the basis of WHO global guideline of 20μg/$m^{3,}$ further improvements would be required.

On average the measure of $PM_{2.5}$ has improved by 14.66% each year between 2013 and 2015 (Table 2). It has improved from satisfactory to 'good' in 2015/16 and is much less than the corresponding level in Chennai. However, it is higher than 2.7 times that of WHO global guidelines.

SO_2 in MWC-C has decreased more than 50% between 2013 and 2014, and decreased further by 27.3% in the following year. WHO guidelines for SO_2 are indicated as 24-hour mean, as this is not comparable with the data we have, we are not able to refer with these measures. SO_2 and NO_2 are categorised as 'good' in this township. MWC-C and Chennai city recorded NO_2 levels to be lower than WHO guidelines and it is important to continue to maintain these.

Air quality measures in other eco-cities

In this section we consider air quality measures in some eco-cities around the world, so as to benchmark further improvements for MWC-C. We consider AQI for seven eco-friendly cities, namely - Singapore, Yokohama in Japan, Vancouver in Canada, San Francisco in the U.S., Curitiba in Brazil and Copenhagen, Denmark in Europe.

Singapore is one of the largest commercial, financial and trade hubs in Asia. It recorded a population of 5.69 million in 2016 with annual growth of 1.3% and land area of 719.2 km². This city-state has taken strong initiative to become eco-friendly with clean water, clean air and clean waste and is well-known to be one of the greenest cities in Asia. The National Environment Agency (NEA), established on 1st July 2002, is the leading public organisation responsible for improving and sustaining a clean and green environment. Its mission includes pollution control, solid waste management, energy efficiency, public hygiene and cleanliness and several other programs. Its extensive and efficient transport system enables residents to use public transport instead of private vehicles. The amount of waste produced per person in Singapore is lower (307 kgs) than the average in Asia (380 kgs).

Yokohama is appointed as one of the future environmental cities in Japan. They are expected to provide successful models, which generate social and economic innovation to solve common issues among some developed countries, such as environmental sustainability and aging population. This policy framework was implemented in 2011 and will be reviewed after 5 years. The population of Yokohama is around 3.73 million (2016) with land area of 435 km²

and is located 27 kms from Tokyo. The primary industries are services, real estate, wholesale and retail and manufacturing. Yokohama aims to become a low-carbon emission city by utilizing renewable energy and promoting energy management system and electric cars. In addition, they aim to improve technology for waterworks and sewage bureaus and export the technology abroad.

Vancouver is Canada's greenest city. Its population was 603,502 in 2011, with land area of 115 km². Due to its geographical location, their major economic sectors are trade, natural resources, film, technology and tourism. Vancouver has been a leader in clean technology innovation such as wind, solar, wave and tidal energy to significantly reduce fossil fuels. Their greenhouse gas emission is already the lowest among major North American cities and their goal is to secure 100% of their energy from renewable energy by 2050. Their ambition is also to become a zero waste community by 2040. In addition, as Vancouver ranks 1st in North America and 5th best for quality of life globally in the latest ranking, the metro areas are rich in greenery, with more than 200 parks and over 18 miles of waterfront.

San Francisco is also known for its greener environmental initiatives in North America. Its population was about 864,816 in 2015, with land area of 121 km² and its economies have diversified across a wide range of service industry including financial services, tourism and incremental high technology. It was the first US city to introduce coloured bins recycling system in homes and workplaces as well as to ban plastic bags to reduce waste. Their goal is to become 'waste-free' by 2020. It is also known for its convenient and eco-friendly infrastructure and public transport, locally known as 'MUNI'. For instance, more than half MUNI buses and light rails are zero emission and the rest will be in transition to hybrid diesel by 2020. Further, San Francisco practises a strong sustainable food movement with more and more restaurants and grocery stores mainly use and provide food harvested by ecological farming, which preserves biodiversity.

Curitiba is the capital of the Brazilian state of Paraná and located in the South East of Brazil. It is among the most eco-friendly cities in the world for its efficient public transportation system, large green spaces and waste recycled system. Its population was around 1.88 million in 2015, and land area is 430.9 km². Curitiba is an important cultural, political and economic centre in Latin America. It has been developed as a sustainable urban area with political initiatives since 1960s. For example, 85% of people living in the city use the affordable and efficient public bus system. Another important feature is the large green land per head of 52

km², which is unusual for any city. They also have a high levels of waste recycling, with 70% of Curitiba's waste being recycled by the residents. One of the programs contributing to its being among the top green cities in the world, is their Green Exchange employment programs, where for example, low income families living in favelas, shantytowns out of reach of the city's dustcarts, can exchange their rubbish bags for bus tickets and food.

Copenhagen covering an area of 74.4 km², is the capital of Denmark with a city population of 591,481 (2016). It is one of the major financial centres of Northern Europe and its economy has seen rapid developments in the service sector, especially through initiatives in information technology, pharmaceuticals and clean technology. Copenhagen is a transport pioneer, aiming to encourage cyclists and evidence suggests that 35% of habitants in the city cycled to their workplace or schools in 2010. This city aims to become carbon neutral by 2025. An estimated 75% of reductions in CO_2 emissions are intended to be achieved through several energy efficiency initiatives involving an increase in the share of renewable energy in the city's district heating. Furthermore, many buses in the Danish capital are electric with zero exhaust fumes emissions and there are many eco-stores selling ecological clothing and food.

Conclusion

The initiatives being implemented to be energy efficient are helping to improve air quality in the cities we have considered above as shown in Table 3. It is evident that air quality index (AQI) in MWC-C is better in comparison with the index for Chennai city. The SO_2 and NO_2 levels in MWC-C are comparable with other global eco-cities. However, there is some way to go in order to improve PM levels to reach the standards in other global eco-cities and a long way to go to reach WHO guidelines. The main challenge for improving PM levels further is in that MWC-C covers a small area of 6.27 km² near Chennai city, so that the air quality in MWC-C would be impacted by the air quality of Chennai metropolis.

The AQI in Chennai is approximately similar to the WHO PM_{10} indicator of 70μg/m^3 for developing countries. According to the WHO (2016) reported pollution index based on $PM_{2.5}$ measure, Chennai is ranked 29th most polluted in South Asia and 53rd most polluted in Asia. Strong efforts are needed to improve air quality in Chennai to meet global standards. MWC-C has demonstrated that air quality can be improved in the region. However, further improvements are required to reach global standards. In order to be able to achieve further improvements, MWC-C will have to exercise its influence with Chennai administrators and policy makers and co-ordinate efforts to improve the air quality of the metropolis as well.

Further this offers greater market opportunities for MWC-C as well as other public-private co-operations.

MWC's have made early start toward following low-carbon development path for clean, green, efficient townships toward achieving aspects of sustainable development goals. The environmental performance report suggests that greenhouse gas emissions from burning fuel for energy in MWCs have reduced by 41% during 2015-16 (MWC Sustainability Report, 2015-16). They also provide concrete evidence of the benefits for others seeking to progress toward sustainable development. Thus these eco-township models clearly demonstrate gains and advantages in pursuing environmental sustainability goals and setting up the required processes. Thereby they provide concrete evidence of the benefits and a model for others seeking to pursue sustainable urban development in India.

Table 1. MWC's Economic, Environment and Social Agendas

1. Economic Agenda:	
A profitable revenue generation venture	• MWC-C and MWC-J are built across 4,600 acres, with offices of over 125 global companies that employ over 50,000 people and generate exports worth over 1.25 billion US dollars • Long term lease (99 years) – One time land lease premium payable at the time of execution of the lease agreements • Medium term lease (15 years, 35 years) – Rentals for IT Special Economic Zone space (MWC-J), Evolve, Hospital, Schools • Revenue through club memberships (Corporate, individual) • Short-term Monthly rentals for Commercial Space (Canopy-Commercial complex – Banks/ATM, Food court, Clinic/Pharmacy etc., and Evolve- ready built up IT park SEZ with 1.41mil.sq.ft.) • Operation & Maintenance services for the park provided on cost plus basis. The agreement with customers also caters for the replenishment plans in future. • Water as supply commodity at nominal charges.
New economic centers	At least 40,000 direct and 1,00,000 indirect jobs created Over Rs. 10,000 crores of cumulative investment Over Rs. 8,000 crores of exports
Leveraging regional strengths	Local entrepreneurial talent brought together with world-class infrastructure Access to potential business partners through events Opportunity to learn global practices
2. Environmental Agenda:	
Alternate Thinking	•Pioneered to set up first off grid 75kw Solar Power Plant in Tamil Nadu. •200KWp solar roof top installed at MWC-J on a Zero Capex model. •Electricity saving through usage of LED street lighting at MWC-C & Retrofit in Evolve for Basement lighting at MWC-J
Innovation and implementation	•**First developer** to receive stage I- **Gold Certification** for MWC-Chennai under IGBC Green Township rating system •MWC- Jaipur is Asia's 1st and world's largest project to be C40 Stage 2 Certified o One of 16 founding projects worldwide for C40 Clinton Climate Initiative's "Climate Positive" program.
Making the planet a responsibility	•Extensive water conservation and re-use planned and modelled at both Chennai & Jaipur. o Grey water pipeline network at both locations. o Residential and commercial clients also use grey water for flushing in Chennai. o Planned Utilisation of treated water from Delawas STP at Jaipur facilitates recycled water utilization up to 60% for MWC-J.

	•Xeriscaping - Use of native drought resistant plant species to reduce water consumption.
3. Social Agenda:	
Approach to land acquisition	•Sharing developed land with original landowners.
Socioeconomic development	•Gyandeep- school for labourer's children (at both Chennai and Jaipur) •Direct and indirect employment •Vocational training for local youth (both locations) •Women empowerment by creating of 75 Self Help Groups (SHG) and benefited over 800 members at Mahindra World City Jaipur •Community lighting project with distribution and installation of 800 LED fittings in Mahindra World City Jaipur •Midday meal scheme provides lunch for children studying in neighbourhood schools in the vicinity of MWC-J. •Two mobile public toilets benefiting over 8 villages near MWC-C
Workforce welfare programmes	•Support – Medical check-up camps, self-help groups, donation drives •Entertainment – Sports, festival celebrations

Table 2

Air Quality Index (annual mean, µg/m^3)	2013-14	2014-15	2015-16
PM-10			
MWC Chennai	51.77	57.19	55.57
AQI category	Satisfactory	Satisfactory	Satisfactory
Chennai	57	72	-
WHO Guideline	20		
PM-2.5			
MWC Chennai	37.16	31.41	27.06
AQI category	Satisfactory	Satisfactory	Good
Chennai	-	44	(47)
WHO Guideline	10		
SOx			
MWC Chennai	18.91	9.45	6.87
AQI category	Good	Good	Good
Chennai	12	14	-
WHO Guideline	-		
NOx			
MWC Chennai	23.94	19.45	20.31
AQI category	Good	Good	Good
Chennai	21	22	(15)
WHO Guideline	40		

* The figures in the bracket were measured in July-September in 2015.

Sources:

- CPCB: Annual report: http://cpcb.nic.in/annualreport.php
- WHO AAP database http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/
- Greenpeace Clean Air Nation http://www.greenpeace.org/india/Global/india/2015/docs/India-NAQI-PRESS.pdf

Table 3

Air Quality Index (annual mean, µg/m^3)	PM-10	PM-2.5	SOx (SO_2)	NOx (NO_2)
MWC Chennai (2015) Chennai city (2014)	55.57 72	27.06 44	6.87 14	20.31 22
Singapore (2014)	30	18	12	24
Yokohama (PM-10 in 2012, others in 2014)	29	14.7	5.24	30.08
Vancouver (PM-10 in 2012, Others in 2013)	12	6.3	2.36	21.01
San Francisco (PM-10, PM-2.5 in 2014, NO_2 in 2015)	16	9	-	22.56
Curitiba (PM-10, PM-2.5 in 2012, others in 2013)	24	11	3.92	24.27
Copenhagen (2013)	17	11	2.05	17
WHO Guideline (2005)	20	10	-	40

Appendix 1

AQI Category (Range)	PM_{10} 24-hr	$PM_{2.5}$ 24-hr	NO_2 24-hr	O_3 8-hr	CO 8-hr (mg/m^3)	SO_2 24-hr	NH_3 24-hr	Pb 24-hr
Good (0-50)	0-50	0-30	0-40	0-50	0-1.0	0-40	0-200	0-0.5
Satisfactory (51-100)	51-100	31-60	41-80	51-100	1.1-2.0	41-80	201-400	0.6 –1.0
Moderate (101-200)	101-250	61-90	81-180	101-168	2.1- 10	81-380	401-800	1.1-2.0
Poor (201-300)	251-350	91-120	181-280	169-208	10.1-17	381-800	801-1200	2.1-3.0
Very poor (301-400)	351-430	121-250	281-400	209-748*	17.1-34	801-1600	1201-1800	3.1-3.5
Severe (401-500)	430 +	250+	400+	748+*	34+	1600+	1800+	3.5+

**One hourly monitoring (for mathematical calculation only)*

Source: CPCB National Air Quality Index http://cpcb.nic.in/FINAL-REPORT_AQI_.pdf

References

- Balsavar, D. (2012). Mahindra world city – Celebrating 10 years of Excellence.
- City of Vancouver (2016). Renewable City Strategy: Our Future to 2050. Retrieved from http://vancouver.ca/green-vancouver/renewable-city.aspx
- Culture Trip (2016). The Top 5 Reasons Why San Francisco is California's Sustainable City. Retrieved from https://theculturetrip.com/north-america/usa/california/articles/top-5-ways-san-francisco-is-environmentally-friendly/
- Dac and Cities (2014). Curitiba: The Green Capital. Retrieved from http://www.dac.dk/en/dac-cities/sustainable-cities/all-cases/green-city/curitiba-the-green-capital/
- Ellermann, T., Nøjgaard, J.K., Nordstrøm, C., Brandt, J., Christensen, J., Ketzel, M. Jansen, S., Massling, A. & Jensen, S.S (2015). The Danish Air Quality Monitoring Programme. Annual Summary for 2013. Aarhus University, DCE – Danish Centre for Environment and Energy, 72 pp. Scientific Report from DCE – Danish Centre for Environment and Energy No. 134
- Environment European Green Council (2014). 2014-Copenhagen. Retrieved from http://ec.europa.eu/environment/europeangreencapital/winning-cities/2014-copenhagen/
- 'Future City' Initiative. Yokohama city. 2016. Retrieved from http://future-city.jp/torikumi/yokohama/
- Government of Canada, Environment and Climate Change, Canada(2016). Retrieved from https://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=FDBB2779-1
- Green Uptown (2015). Top Ten Greenest Cities in the World for 2015. Retrieved from http://www.greenuptown.com/top-ten-greenest-cities-world-2015/
- Grist (2007). 15 Green Cities. Retrieved from http://grist.org/article/cities3/
- Howe, C.A., J. Butterworth, I.K. Smout, A.M. Duffy and K. Vairavamoorthy (2012). Sustainable Water Management in the City of the Future. Finding from the SWITCH Project 2006-2011. UNESCO-IHE Institute for Water Education.
- Kattumuri, Ruth with Matthew Cantegreil and Dweep Chanana (2013). Revealing Indian Philanthropy. Alliance Publishing Trust.
- Mahindra Sustainability Report 2015-16. Urboonisation.
- Ministry of the Environment and Water Resources, Singapore, National Environmental Agency (2015). Factsheet on More Measures to Improve Singapore's Air Quality.
- New Internationalist. World Development Book Case Study: Sustainable Urban Development in Curitiba. Retrieved from https://newint.org/books/reference/world-development/case-studies/sustainable-urban-development-curitiba/
- POP UP CITY (2016). 5 Most Eco-Friendly Cities Around the Globe. Retrieved from http://popupcity.net/5-most-eco-friendly-cities-around-the-globe/
- The Danish Ecological Council (2014). Clean Air Copenhagen – Air Quality Challenges and Solutions. Clean Air Copenhagen
- Vancitybuzz (2016). Vancouver Ranks 5th Best for Quality of Life Globally. Retrieved from http://www.vancitybuzz.com/2016/02/vancouver-5th-best-quality-of-life-world/
- Worldette (2012). Visit San Francisco: Is This the World's Most Eco-Friendly City? Retrieved from http://www.worldette.com/ignite-your-travel-life/travel/2012/visit-san-francisco-worlds-eco/
- World Health Organization (2016). Ambient (outdoor) Air Quality and Health. Retrieved from http://www.who.int/mediacentre/factsheets/fs313/en/

- Word Health Organization (2016). WHO's Urban Ambient Air Pollution database ver 0.2.
- Yokohama City. Yokohama Statistics Portal Site (2014). Ambient Air Pollution. Retrieved from http://www.city.yokohama.lg.jp/ex/stat/index2.html#27