Sustainable Smart City: Masdar (UAE) (A City: Ecologically Balanced)

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Abstract

Background/Objectives: In future, billions of devices are going to connect to Future Internet (FI) to provide quality life to citizens. However energy sources for devices connection are limited. In this context, building Sustainable Smart Cities on natural energy resources is essential. Methods/Statistical Analysis: The data is collected from secondary sources i.e. online databases during the period of 2/12/2014-1/5/2015. Google search engine is used mainly for questing the articles. The data is in qualitative format including text, pictures, sound and videos. Since this article is based on exploratory study and case methodology, content analysis is done. Thematic coding is done grounded on the main keywords relating to smart cities dimensions. Findings: Main objectives of this research article are to see the sights of Smart Cities concepts. This article is also focusing on the state of art of Sustainable Masdar Smart City (UAE). As city's name sounds "Masdar" which means "source" in Arabic, this city will be rich enough in renewable energy sources and sustainable buildings. The authors found that this Sustainable Smart City is completely energy efficient through solar. Furthermore, the authors discovered sustainable intelligent buildings of 1. IRENA's Global Head Quarter. 2. Siemens Smart Building and 3. Masdar Institute of Science and Technology. City is designed completely based on ecofriendly of water, air and soil. Applications/ Improvements: Sustainable Smart Cities are basically emphasize on optimum natural energy utilization in terms of solar, water, air and tidal. Soil and local materials are also place an important role in constitution of ecofriendly cities.

Keywords: Masdar City, Renewable Energy, MIST, Smart City, Sustainable City

1. Introduction

Our cities are fast transforming into artificial eco systems of interconnected, interdependent, intelligent digital organisms¹. Cities are the support of innovations, dynamism, growth, complexity and development. Integrated of urban development that combines social and economic development, resulting in a sustainable Quality of Life (QoL) for all citizens. In fact, the United Nations Organization (UNO) projects that there will be more than 10 billion people living on Earth by the year 2100.

Across the globe, the migration of population from country yards to urban places is increasing very fast. By the year 2050 more than 70% of the population will live in the cities². The resources being used to develop these cities will be finite fossil fuels and that will get only more

expensive as they run out over time. The higher volume of these fuels required to produce energy for this larger population will also negatively impact the air quality of cities. Cities almost consume 70% of the world's energy primarily by transportation and buildings. However these cities account for 75% of greenhouse emissions, while only occupying 2% of world's surface. Explosion in population is perhaps one of the greatest reasons why sustainable development is so important in cities nowadays. Growing worldwide urbanization, in adequate physical infrastructure, in sufficient social services, growing economical competitions, security snags and in appropriate ratio of Green House Gases (GHG) emissions are triggering importance of building or constitution Sustainable Smart Cities across the world like Masdar Smart City (United Arab Emirates).

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2. Need of Study

Do we want really the Smart Cities for economic development? Do we need really Smart Cities for resilience? Is it necessary to convert the existing Brown Field Cities to Green Field Cities? Or do we requisite the Smart Cities for Quality of Life (QoL)? The above upcoming Smart City projects will explain in crystal clear the need of Smart City projects and developments in this urban growth of 21st century. Nowadays more people started living in the cities than at any time in the human history. We know that a city is a complex system. Its complexity is due to the individuals' unpredictable interrelations. As complex systems, the cities have unpredictable behaviors and, when some actions are set up, reactions and feedbacks can be obtained. Cities are places where different interrelated ecosystems "live, and they are also communication systems³. These complex systems include transportation, education, firms, health and security, civic utility services like hotels, tourism, power, gas and waste among others. Besides parks, roads, air, water, soil and other ecosystems are also part of an urban system. Interconnection, data and communication is a lacuna among these individual systems, which causing inefficiency in urban citizen's facilities. As cities grow, planners devise complex systems to deal with food supplies on an international scale, water supplies over long distances, and local waste disposal, urban traffic management systems, and so on; (...) and the quality of all such urban inputs define the Quality of Life of urban dwellers"4. The ever increasing concentration of people and economic growth in the largest cities relative to the rest of the country has slowed down or even reversed in many of the developed European countries over the last decade⁵. In the same way the United Arab Emirates (UAE) country follows in resolving the same category of urban issues or problems using natural resources by example of Masdar City.

In this graceful the new urbanism principles started with the buzzword "SMART" in prefix to cities to bring a better life with the new phrase "Smart Cities". The development of new cities badging themselves as smart. Huge numbers of future IoT technologies are helping in building of these Smart Cities. These are increasing in rapidly growing countries. Masdar outside of Abu Dhabi is being developed by GE as the world's the first world carbon neutral city, Paredes in Portugal is where

the Microsoft are wiring an energy efficient city, Dongtan in the Yangtze Delta is being developed by Arup as a smart green eco-town and Songdo in South Korea is where Cisco are building a town wired at all levels⁶. Apart from these cities, if we consider, India per se developing 100 new Smart Cities from the scratch and 500 cities for rejuvenation into smart under the Prime Minister's vision. Besides, in India near Pune, Lavasa Smart City is sprouting up in the objective of sustainable city. At the same time one more example is GIFT Smart City near Ahmedabad is a good illustration of uplifting International Financial Services of India in the coming years. While coming to China, it had already set out more than 300 Smart City projects in order to deliver good life to all urban people. From a United States perspective, research on Smart Cities has also evaluated relevance of smart urban development in fighting urban sprawl⁷; used a cognitive approach in assessing the role of psychological and cognitive attitudes towards ICTs in reducing extent of the digital divide8; and verified on the field (a case study on a community project) whether concrete action can be taken against such a digital divide in poor urban areas^{9,10}.

3. Methodology

Research Type: Exploratory study, emerging concept

+ Qualitative

+ Descriptive

Data Collection: Secondary Data (Online)Databases: Google Scholar, EBSCO, KNIMBUSKeywords Used: Smart Cities, Masdar Smart City,

Sustainable Cities, Internet of Things **Data Types**: Texts, Pictures, Audio, Video

Analysis: Narration by Thematically (Old Method).

4. Smart Cities

Much has been said about Smart Cities in the recent years in the NEWS papers, magazines, government official reports, white papers, electronic media, posters, social media, workshops, conferences, symposiums etc. Singapore is a very good example of how to design, build and maintain an efficient urban environment for the Sustainable Smart Cities. Sustainable Smart City Putrajaya (Malaysia) starts with an appealing green and well-connected urban built environment that will attract high value adding jobs to move to Putrajaya and along with them people. In fact India is also not in exception of

creation of Smart Cities in a great way. One of the urban shifts in India is constitution of Lavasa Smart City. Much importance was given in the financial year of 2014-2015 with the cost of almost 7060 crore as the initial investment for Smart Cities in different parts of India. Recently Smart Cities - India 2015" conference cum exhibition which was held at Pragati Maidan in Delhi during 20-22 May, 2015 is a good example of projection on the importance of urbanization shift in India too. IBM, CISCO, HP, WIPROW, BOSCH, Schneider Electric, GREENEVO are a few to name Smart Cities technology developers and solution providers participated in this prestigious conference. One of the most important technologies used to support the Smart Cities strategy is ICT11. A huge number of European urban solution developing corporates too participated in this conference in order to provide demonstration of their products and services in building of Sustainable Smart Cities in India. Apart from these, many business tycoons, software developers, town architects, city mayors, researchers, are running behind in constitution of Smart Cities across the India and other nations. Cities around the globe are constantly looking for the ways to stand out from the crowd, draw investments and serve their residents like no other city has done before. A report by the International Data Corporations (IDC) in its December 2014 conference, says that some cities investing more than 25% of their external budgets in the Internet of Things (IoT). This investment is used to develop and manage robust IoT technologies that create sustainable, connected environments and communities.

Smart Cities is overlapping with different names including Intelligent Cities, Digital Cities, Sustainable Cities, Wired Cities, Connected Cities, Ubiquitous Cities, Green Cities, Internet Cities, and Livable Cities and so on. There is no standard definition at all, at the universal level for Smart Cities and defining the Smart Cities is like six blind people describing an elephant in six different means. Smart Cities can change the way urbanization develops in the country. The Smart Cities is defined as the "A city well performing in a forward looking way in the six characteristics of economy, people, governance, mobility, environment, and living, built on the smart combination of endowments and activities of self - decisive, independent and aware citizens"12. A Smart City must meet with all the requirements such as Quality of Life for citizens, safety, hygiene, intelligent transport systems, automated water, gas, power, waste management systems in place and ecologically balanced.

Smart Cities are expected to dramatically improve their citizens' Quality of Life (QoL), encourage business to invest, and create a sustainable urban environment¹³. In these cities plants would automatically spot problems and fix them, hospitalswould regulate medical devices remotely, lighting and temperature in a home/house would mould themselves to your preference and your car will send messages automatically regarding the road traffic. According to Frost and Sullivan the Smart City coponents diagram consists of14

- Smart Governance and Smart Education
- Smart Healthcare
- **Smart Building**
- **Smart Mobility**
- **Smart Infrastucture**
- Smart Technology
- **Smart Energy**
- Smart Citizen

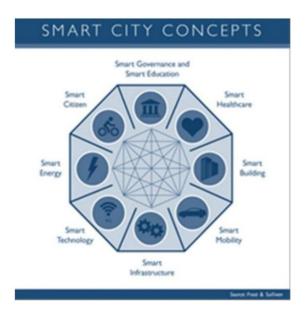


Figure 1. Smart City concepts.

Frost and Sullivan Smart City coponents if we put in our own way the Smart City can be defined as "Smart Cities are the cities in which they provide Quality of Life to the urban citizens along with economic development, ecologically balanced and sustainable for the future generations using complete automated Internet of Things (IoT) technologies. These technologies are generally marry with city sub systems of transportation, security, governance, public utilities like water, waste, gas, power management and other physical infrastructure to bring the operational efficiency. The technologies include Smart Cards, RFID, QR Codes, EPC, IPv6, Sensors, Actuators, Wi-Fi, Bluetooth, ZigBee, NFC, GIS, GPS, Social Media, BI, Ambience Intelligence, Cloud¹⁵, Tele Medicine, web 3.0, Big Data Analytics (BDA) etc."

5. Masdar Smart City

According to "Frost and Sullivan" research around 26 global cities and more than 90 sustainable cities are to be developed by 2025. Around 50% of these Smart Cities will be from North America and Europe, Masdar Smart City is among one from rest of the world. Masdar City was established with a ground breaking ceremony in 2006. The Masdar Smart City is located just a stone throw away from Abu Dhabi. We know that Abu Dhabi is the capital city of United Arab Emirates (UAE). The United Arab Emirates is an Arabian Peninsula nation settled mainly along the Persian Gulf that was formed from 7 sheikhdoms. This Masdar Smart City is well known to the globe along with other famous upcoming Smart Cities like Sangado (Korea), Meixi (China), Padova (Italy), SmartCity Malta (Malta), PlanIT Valley (Portugal) and Lavasa (India) which constitute from the scratch. Webb, Buscher, Doody, Cosgrave, Giles, HawesHewitt, Walt and Mulligan¹⁶ point out that in the age of the internet and the smartphone, together with an explosion in the use of new tools such as inexpensive sensors and mobile devices, the cities now have totally new options for integrating Internet of Things technologies into existing infrastructure and services. The Masdar Smart City Model Building shown in Figure 2.



Figure 2. Masdar Smart City.

Masdar City is a future brand new Smart City, which is mainly focusing to be the first zero carbon city in the world. A Smart City strategy aims at using the technology to increase the Quality of Life in urban space, both improving the environmental quality and delivering better services to the citizens¹⁷. The sub systems of this city including environment, transportation, security, governance, infrastructure and public utilities like power, water, gas, toilets and educational systems are marrying with Internet of Things (IoT) Technologies. IoT is defined by18 everyday objects include not only electronic devices we encounter and use daily and technologically advanced products such as equipment's and gadgets, but "things" that we do not do normally think of as electronic at all - such as food, clothing; and furniture; materials, parts and equipment, merchandise and specialized items; landmarks, monuments and works of art and all the miscellany of commerce, culture and sophistication". In the city we can find the land use is planned coherently with the transport planning along with GIS and GPS technologies. A wall around the city or green zones or high building densities around Public Transport (PT) stations. The Masdar City, aims to integrate the use of GIS in every aspect to plan the city: from ensuring the construction process is efficient and produces zero waste to planning the transport and energy network to meet potential demand, and building in monitoring systems into city physical infrastructure. Sustainability goals of Masdar Smart City are energy efficient, water management, CO, emissions reductions and waste management. In this city waste separation into dry recyclables; wet recyclable, residuals and solid waste. Hired retired and unemployed residents temporarily to clean up specific areas of the city where litter has accumulated19. Masdar City will be the latest of a small number of highly planned, specialized, research and technology-intensive municipalities that incorporate a living environment, similar to the KAUST (Saudi Arabia) and Tsukuba Science City (Japan). Masdar Smart City is intended to eventually house 40,000 citizens and almost accommodate 70,000 commuters. It is being built almost entirely with sustainable materials, uses layout and wind towers to channel breezes and reduce direct sunlight on sidewalks and every inch of roof surface is covered with solar panels. While cars will be accommodated in underground lots, transportation within the complex is via a fleet of intelligent, electric, driverless Personal Rapid Transit vehicles. Sustainable urban development may be defined²⁰ as a process of synergetic integration and coevolution among the great subsystems making up a city (economic, social, physical and environmental), which guarantees the local population a non-decreasing level of wellbeing in the long term, without compromising

the possibilities of development of surrounding areas and contributing by this towards reducing the harmful effects of development on the biosphere. The initial phase of the city houses a Research Institute and University. Current inhabitants, of which there are about 1,500, are generally divided among students, faculty, support staff and corporate researchers (General Electric, Siemens and other companies who work on these technologies and support the University). The Masdar Smart City will be home to roughly 1500 MNCs.

5.1 The IRENA

The International Renewable Energy Agency (IRENA)'s Global Head Quarter (HQ) is located in Masdar Smart City with an area of 32,000 square meters of commercial office space²¹. As a strategic and prestigious business address space, IRENA HQ will be a home to anchor tenants that range from large global corporations/MNCs to small and medium enterprises. Completion of the HQ has been set for summer of 2015 as per the previous scheduled. The strategic hub offers both business advantages and social opportunity including entertainment and companies or organizations of all sizes. IRENA HQ is an efficient, flexible and environmentally sustainable building via its innovative design and deployed of Internet of Things (IoT) technologies. The Internet of Things technologies are technologies that are used for connecting each and every physical object to Internet by embedding for operational efficiency, self-tagging, identification, monitoring, and automation of the things or objects or events.

The IRENA HQ 1,000 sq. meters of rooftop photovoltaic panels to generate electricity, while solarthermal water heaters supply 75% of the estimated total annual hot water usage. The landscape of the headquarter building has been designed to conserve water, promote biodiversity and create thermally comfortable outdoor spaces. Sustainable design strategies are anticipated to reduce the building's energy consumption by more than 40% and water by 53%, compared to a non-Estidama baseline building²². Fitted with sun-shielding fins, the outer skin of the buildings reduces solar heat gain without obstructing the view from inside. High-performance tinted glass and high-efficiency insulation are also used to optimize energy savings. Materials used during construction include locally sourced, low-carbon cement as well as recycled steel.

5.2 Siemens Middle East's Head Quarter

Siemens' new HQ at Masdar City (Abu Dhabi) is the first major building to be conceived, designed, built and LEED Platinum certified²³. It is designed by David Ardill from the enormously respected firm Sheppard Robson with crucial input from Masdar City's design Manager Chris Wan. The building incorporates a range of innovative features, materials and technologies. The feature which significantly reduce the consumption of power (63%) and water (52%). The building's facade is very carefully designed to prevent heat gain from excess light while still bringing in enough daylight to prevent the need for artificial lighting during much of the day. The building is oriented to maximize the flow of cool air, especially in the public space under the building, something very helpful in Masdar's extremely hot climate. Building materials aimed at maximizing energy efficiency and comfort are used throughout the building. The building also has automatically adjusts lighting and temperature, security systems, fire alarm, gas suppression systems from the Siemens Building Technologies on par with recent advanced global technologies. It will room for up to 800 employees with best comforts. The below picture shows Siemens Middle East's head quarter.



Figure 3. Siemens's head quarter.

5.3 Masdar Institute of Science and **Technology**

Masdar Institute of Science and Technology (MIST) is the first research Institute, dedicated to design, develop the alternative energy sources, environment friendly technologies, and sustainability. Aircuity is helping to implement Centralized Demand Control Ventilation (DCV) in the university's hostels, classes, conference rooms and library areas to vary outside air ventilation based on sensing occupancy and Indoor Environmental

Quality (IEQ)²⁴. Moreover, Institute is using Aircuity technology to implement lab Demand Control Ventilation (DCV) in the labs on campus. The air in the laboratory areas is continuously monitored and the amount of outside air being brought into lab is adjusted accordingly, providing a safe lab while significantly improving energy efficiency. As a result saves an estimated 55% annually of the total Heating, Ventilation, Air Condition (HVAC) energy consumption of affected lab and non-lab areas²⁵. The below picture shows sustainable building, MIST.



Figure 4. MIST building at Masdar.

5.4 Renewable Energy Resources

Renewable energy is generally defined as energy that comes from resources which are naturally replenished on a human timescale such as sunlight, wind, rain, tides, waves and geothermal heat²⁶. Renewable energy resources that are naturally replenishing but flow limited. They are virtually inexhaustible in duration but limited in the amount of energy that is available per unit of time. Most of the cities in the globe consuming almost 70%-80% energy. Still now the energy generation is producing in large based on non-renewal energy sources. We know that by 2020 circa 50 billion devices are going to connecting for human better life. That means by 2020 every person will have minimum 6 smart devices per head as per CICSO's prediction. These devices are will be on round the clock and brings real time life for each person and objects. So these devices requires huge amount of energy for 24×7 online mode. Smart Cities will make a radical shift as the urban utility and environmental resources will be optimally used. Masdar City will also have a sustainable, zero-carbon and, zero-waste ecology²⁷.

All the cities which are coming up will mount Smart Power solution with Smart Grid and ZigBee technologies which will concentrate on generation of power, transmission, distribution and consumption efficiently. Masdar Smart City will use a variety of renewable power resources. Masdar Clean Energy builds some of the world's most sophisticated and commercially driven clean energy projects. With a focus on mature technologies in solar and wind power, it generates nearly 1 gigawatt of clean power. Masdar Clean Energy aims to increase that to 1.5 gigawatts by 2020²⁸. Among the first construction projects will be a 40 to 60 megawatt PV solar power plant, which is built by the German firm named Conergy".

This will supply power for all other construction activities throughout the city. Later be this will be followed by a greater facility, and extra solar panels will be placed on rooftops to provide supplemental solar energy in toto 130 megawatts. Apart from these photovoltaics, Concentrated Solar Power (CSP) plants are too being explored. For example, so-called "beam down" Concentrated Solar Power plants have been constructed to test the viability of the concept for use in city²⁹. The sun is almost 365 days in sunny mode with high temperatures in entire United Arab Emirates country. The city is full sources of the solar power. Wind farms will be established outside the city's outer limits capable of producing up to 20 megawatts, and the city means to utilize geothermal energy as well. In accumulation, Masdar Smart City plans to host the world's largest hydrogen power plant³⁰. Water management has been planned in an environmentally sound manner as well. A solar-powered desalination plant will be used to provide the city's water needs, which is stated to be 60% lower than similarly sized communities. About 80% of the water used will be recycled and waste water will be reused "as many times as possible", with this greywater being used for crop irrigation, construction and other purposes. The current phase has reduced energy and water consumption by more than ½ and achieved a recycling rate of 90% by applying 4Rs (Reduce, Recycle, Reuse, Recovery) principles.

The next phase will comprise business townhouses and condominiums built nearby town squares and green spaces for sustainability and development is expected to complete by about year 2030. Masdar City was launched in order to create a sustainable city focused on green energies, technologies, smart grids and buildings and transportation³¹. Sustainable city uses technology to reduce CO₂ emissions, to produce efficient energy, to improve the buildings efficiency. Its main aim is to become a green city"³². Most of these renewable energies depend in one way or another on sunlight. So it is need of hour to work on renewable Energy Resources in the forth coming years for good life. Public Rapid Transits (PRT),

a system of transportation featuring compact, driver-less "podcars" in Masdar. In Masdar where the streets will be entirely free of automobiles, a network of these compact electric taxis will provide clean, quiet transportation to the city's residents, employees and commuters. The Public Rapid Transits model is dipicted as shown below.



Figure 5. Personal rapid transit system.

6. Discussions

The growing urbanization at the global level leading to increase the complexity in the lifestyles of urban citizens, scarcity of non-renewable energy resources and finally degradation of Quality of Life. Besides these huge number of smart devices is going to connect to internet to bring the comfortable life through various embedding Internet of Things (IoT) technologies in future. This indicates in the fourth coming years we require huge amount of electric power perhaps in megawatts of megawatts or we should develop low power consumption lighting solutions. In light of these issues and to overcome power supply shortage, Masdar Sustainable Smart City is a best example for natural resource utilization in construction of Smart Buildings and their energy consumption reductions along with "0" waste management. Transport is combination of Personal Rapid Transit (PRT) systems, clean energy vehicles and electronic cars. Private cars are strongly restricted to parking along the city's perimeter. City is completely powered by solar energy and renewable sources only. It is planned as a hub for cleaner technologies design, development and deployment. So Masdar Smart City is a living experiment with smart grid technology, ZigBee technologies, green buildings, radical urban design, and natural resource management to prove concepts and ultimately commercialize them. These high

city concept plans promise to predict crime, prevent accidents, save energy and make city living a glide. These cities more investment friendly, giving them better housing and 24×7 powers and water supply. They also concentrate on sanitation, clean air, education, sports, tourism and innovation. City is more technology oriented with the help of Public Private Partnership (PPP) model.

7. Conclusion

Sustainable Smart cities are generally planned, designed and planted for preservation of ecological system balance. Flora and fauna are maintained primarily in that region. In order to reduce global warming, pollution prevention through intervention techniques and biomimicry methods are in use practically. Green House Gases (GHG) is maintained in rich enough for natural conditions. Natural energy resources are maximally utilised in view of future generation's life especially depends on solar, wind, tidal and geothermal energy sources. So in the future we need to follow Masdar Smart City as a role model. Upcoming Smart Cities should try to utilize regional natural resources for the energy efficient, smart water management and mitigation of waste. For the construction of new buildings or built environment if we use local material that would more environments friendly and ecologically stable. We also need to determine efforts to upgrade the current landscape of world cities and make them liveable and sustainable for future generations. Let Us hope in the future according to "Frost and Sullivan" research, we will fortunate to have circa more than 90 sustainable cities in a solid state in order to provide better life. These Smart Cities will be economically, socially, technically, sustainable and feasible. Let us work together for sustainability for our mother earth. These kinds of Sustainable Smart Cities can be possible in India.

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