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A Case Study on Sustainable Development in India

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Abstract: **-- The concept of Sustainable Development is an attempt to combine growing concerns about a range of environmental issues with socio-economic values. To aid understanding of these different policies a classification of different trend of thought is necessary. To meet the ever increasing needs of the rapid urbanization one such area that needs to be developed is the airport. Airports are the air transport system's nodes and have major impact on a region's economy, social conditions and environment. An Airport can only be considered to be operating sustainably if all three dimensions are balanced. Airport Sustainability can be evaluated at global, national and regional levels.**

This paper emphasizes the importance of regional level planning in analyzing airport sustainability. The paper presents a detailed case study of Chhatrapati Shivaji Mumbai International Airport and evaluates its sustainability on regional level under different growth and reduction scenarios. The airport concentrates on the environmental performance, global connectivity, local employment, resource optimization. Moreover, the basic concepts like waste water, air quality and noise management, solid waste management are been stressed. The construction of the airport posed a lot of hindrance for the engineers as they had to tackle the geographical and climatic conditions around the airport. Also to tackle the wildlife incursions and strikes into the airside a close watch is kept on all the birds. The increase of roadways around the airport has elevated the overall transportation capacity. Managing water resources, waste water treatment and using the recycled waste is one of the prominent traits of the airport, the peacock shaped feather skylights for natural lighting and the use of energy efficient materials in construction has led the Mumbai Airport from a worn airport to one of the world's top airport giving it a gold certification from LEED[4].

Index Terms:-**Airport, Energy efficient materials, Environmental Performance, Sustainable Development.**

I. INTRODUCTION

According to the Confederation of Indian Industry (CII) the global environmental status has scientifically proven to be increasingly threatened by climate destabilization, and use of energy efficient materials plays a pivotal role in helping bring balance to the ecosystem as well as human economies. One such illustration is the construction of new terminal at Mumbai airport which is a model of sustainability and environmental management. Chatrapati Shivaji International Airport (CSIA) is the second busiest airport in country in terms of National and International passengers and traffic after Delhi. The airport encountered a lot of complications to achieve sustainable growth and in becoming one of the best airports in the world. The project refers to the expansion and modernization of Chatrapati Shivaji International Airport by M/S Mumbai International Airport Private Limited. It concentrated on the development of existing terminals, expansion of aprons and parking bays, construction of taxiways, parking and the services including sewage treatment plant, etc. Moreover the waste water treatment, power management and use of recycled waste have been dealt with near and in the airport premises. Also the control of pollution, air quality monitoring, noise monitoring, and treatment of solid wastes and proper disposal of hazardous wastes in and around the airport has led it to be one of the cleanest and environmentally stable under the norms specified by the Government [1].

In this paper, a case study of the Chatrapati Shivaji Mumbai International Airport is presented describing its approach towards sustainability and how it confronted the existing challenges and went on to become a symbol of excellence and cultural heritage contributing towards the nation's social, economic and cultural aspects.

II. CASE STUDY

A. Project Background

Mumbai International Airport Pvt. Ltd., or MIAL is a joint venture between the GVK-led consortium and the Airports Authority of India which was awarded the mandate to modernize and upgrade the Chatrapati Shivaji International Airport also known as CSIA to a world-class airport. The Architecture and Design was awarded to the firm-'Skidmore, Owings & Merrill LLP'. As a part of CSIA's massive expansion plan, sustainability was the uttermost priority for the planners. According to the sustainability report 2012 published by the MIAL handling movements of 750 aircrafts per day over an operational area of 750 hectares with average of 25-40 million passengers per year was

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the design model for newly developed international airport. For achieving sustainability, plans were designed to overcome the situations and obstructions. The whole ideology behind the design plans was to design a system which uses energy and resources and does not compromise the natural environment or ability of future generations to meet their own needs [1].

Fig.1 Aerial view of the Mumbai International Airport (Esri Arc GIS online)

The challenges faced in the construction of Terminal 2 were:-

Geographical challenges

CSIA is the landlocked airport in one of the populous and dense cities in the world. Most difficult challenge was to achieve land for expansion of airport, i.e., subsequently modernization of airport. Of the802.3 Hectares total available land approximately 125 hectares were occupied by squatter camps which made it difficult to acquire the land and construction. Another major challenge faced was to construct this massive piece of infrastructure in the very heart of Mumbai – where every square inch of space is a luxury. Space and time constraints along with slum rehabilitation of 600 acres had to be dealt with very carefully. The upcoming project could not disrupt either the regular operations of an already-bustling Sahar airport or the steady flow of traffic on the Western Express Highway of Mumbai [1][12][13].

Fig.2 Aerial View of all the Terminals of the Airport (Esri ArcGIS online)

Climatic conditions

Climate of Mumbai is tropical wet and dry type with the unpredictability of high rainfalls and floods at any time. Moreover the risk of high tides as the airport is located offshore. The emergency preparedness plan had to be designed to mitigate these risks and reduce unwanted impacts [1].

Greenhouse gas emission and energy

Emission of greenhouses is dangerous and use of sources for energy generates this gases. Airport required around 5.5 million of units' electricity per month with 300 thousand liters' of diesel, 70 thousand liters of petrol and 1,000 kg of CNG to meet its operational needs. Since the project cost had to be limited, an energy saving approach was adopted for consumption of entire for the entire terminal. The terminal boasts 4 Km of LED lighting used to illuminate façade combined with strategically placed 30,000 sq. ft.Skylight glass throughout the check-in hall, these reduced T2's energy consumption by 23%. The terminal also has a Level 2 accreditation on carbon management by ACI [1][4][13].

Acoustics problems

Due to the frequent aircraft movements, it was necessary to provide an acoustic barrier from noise pollution due to noise from landing and takeoff of planes and also from internal noise pollution due to vehicles and service in terminal[1][4].

Waste water management

Due to increasingly strict environmental regulations, the treatment of raw sewage water was required before it was allowed to flow into the natural ecological system. The project required extensive design complexity, as the space allotted for the plant was unusually shaped and smaller than what was required for a plant of high capacity. A plant of half the size was allotted of what was required and due to the hindrance posed by the irregular shape, completely surrounded by utility buildings and an adjacent river allowed no space for potential expansion. Also the incoming water to the plant was of variable quality, the water was expected to have high turbidity and silt density index. To combat this, combined biological and membrane process system was adopted [3].

Adjacent River

Construction of the new terminal near River Mithi was a serious and challenging issue. One of the runways at the airport is built over River Mithi. The original channel, which allowed the river to flow

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underneath, couldn't withstand the torrential rains that beat down on the city in 2005—the runways were flooded under almost 2.5ft of water, and muck had settled into the radio and lighting equipment. When the construction was in full swing, a decision was taken to build a second channel that could take excess water. The existing underground waterway was also widened to allow more water to flow through. The water-recycling and rain water harvesting techniques save up to 20 percent of water[4][13].

Security challenges

Airport security was one of the major concerns identified. Mumbai city, being the financial hub of the country has on occasions become target to unlawful acts that threaten safety and security of the region. Every kind of security lapse had to be dealt with as the Sahar airport was operating with full time workers and staff members[1][4].

B. Approach towards Sustainability

The following approaches were adopted on the project towards achieving the goal of sustainability:

Water recycle project

As a part of CSIA's massive expansion plan, a 10 million liters per day (MLD) wastewater recycle project was contracted to cater to the growing requirements of the expanded airport. As the airport had a lack of fresh water availability for its requirements, it needed to recycle and reuse the treated sewage water for its operations, such as toilet flushing, horticulture, and HVAC cooling makeup water. According to the report published by Aquatech-the firm awarded for the water recycling project approximately 4 MLD of the treated sewage water was used as HVAC cooling water, 3 MLD was used for flushing, and 3 MLD was used for horticultural and operational purposes. The MIAL wastewater treatment project had some key design and water quality challenges that Aquatech-the company to which the contract was awarded successfully overcame through an innovative process and system design. It was assigned to supply a 10 MLD sewage treatment and recycle system on a complete turnkey basis for the new airport terminal.There were challenges for the construction of new wastewater plant as mentioned earlier and also since the wastewater entering the system was mainly from the airport and not usual city sewage; it was expected to be rich in Total Kjehldahl Nitrogen (TKN). Considering all the possible solutions the new plant was setup and a combination of biological and membrane process system was used[3].

Methodology

The engineers designed an innovative wastewater treatment system based on the limited plot size allotted. The MIAL plant was an integration of many technologies – a combination of biological treatment followed by advanced tertiary treatment based on UF and RO processes. The primary treatment consisted of coarse and fine bar screens followed by a grit chamber. The secondary treatment consisted of an AECOM Cyclic Activated Sludge System (CASSTM) sequencing batch reactor (SBR) biological treatment technology followed by disinfection. The tertiary treatment included anultra-filtration (UF) pretreatment system followed by a reverse osmosis (RO) system, after which the water was reused and distributed for the airport's various purposes. The engineering team devised a circular design that took advantage of the basin shape to fit two SBR basins into the triangular plot. However, this design left a very small amount of space to place the recycle system in. To address this issue, the engineers placed the chlorine contact, feed, and permeate tanks (eight total) in a vertical configuration with the pressure sand filters, UF system, and RO system placed on top of the tanks. A typical wastewater treatment system calls for all of these components to be constructed in a series, but this configuration was not possible in this plant. The vertical engineering design not only allowed the MIAL wastewater plant to adhere to the strict space requirements, but it also provided a more economical and optimized solution that would successfully provide high quality water over many years. The site was fully operational and performing well in auto mode. The sewage wastewater treatment plant has been in operation for more than a year and is successful due to its innovative design and integration of optimized and advanced treatment technologies[3].

Fig. 3 The yellow line showing the plot allotted for the construction of wastewater plant (Project case study by Aquatech)

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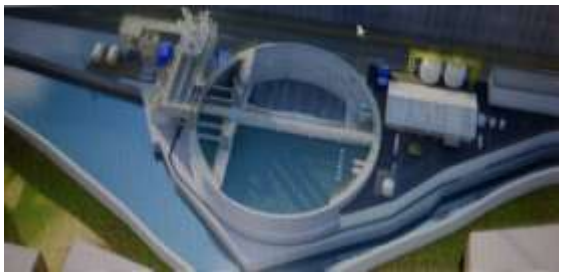

Fig.4 Wastewater treatment plant (Project case study by Aquatech)

Biological Treatment

Reliable SBR with Innovative Design-The engineers selected an SBR system that operates both biological treatment and solid-liquid separation in a single reactor basin that alternates operation modes, eliminating the need for final clarifiers and high return activated sludge capacity. This SBR system was designed to minimize the plant footprint while optimizing process performance and energy efficiency[3].

Effective RO Pretreatment- Combats Variable Feed Water-Aquatech evaluated both UF and conventional media filtration for pretreatment to MIAL's RO system. Since the water feeding the pretreatment system was sewage wastewater, the pretreatment step needed to be designed to handle variable water qualities and extremely high turbidity levels. The primary goal of the RO pretreatment system was to reduce the silt density index (SDI) and turbidity of the water feeding the RO to a point where RO cleaning would be minimized. A UF system followed by an RO system was integrated into the system to provide a complete treatment solution[3].

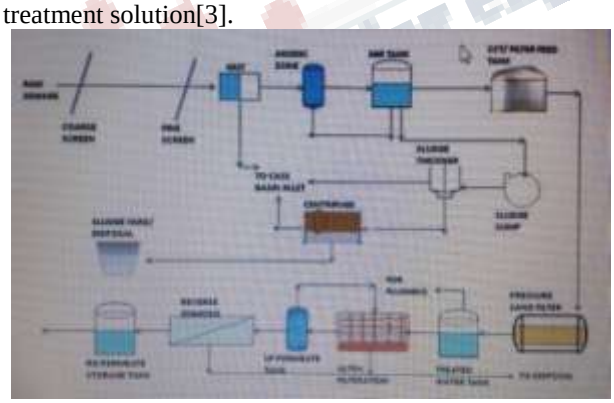

Fig. 5 Process flow diagram (Project case study by Aquatech)

C. Infrastructural Solutions

The Following solutions were derived to cope up with the Infrastructure related problems which were the major issue of the city:

Elevated Sahar Access Road

As per Sustainability report 2012 published by MIAL To reduce the time travel to the airport in the city's congestion a new elevated road was constructed to connect Western Express Highway to the common user terminal; the two kilometer long, six lane elevated road had four entry points and two exit points and reduced the travel time by about 80%[1].

Drainage Projects

Mumbai faces substantial torrential monsoons every year and can receive 37 inches of rain in a day so to tackle this construction of new drainage systems were done in and around the airport[1].

Upgrade of Primary Runway

To accommodate larger aircrafts and to increase the number of aircrafts landing and taking off from the airport up gradation of runway was done.

Construction of new Terminal

New Terminal 1C was constructed in order to cope up with the increasing number of passengers.

Safety and Security

Regular audits and inspections are conducted both internally and externally. The safety management system also tracks the number of instances where the medical unit has administered medical services to employees, passengers and other visitors to the airport. Also Health and Safety committees was setup to address, control and monitor all safety concerns, covering employees, passengers and other users of the airport.

D. Wildlife Management

As per Sustainability report 2012 published by MIAL Wildlife Management practice was designed to minimize incidences of bird and animal hazards at the airport. To implement this some steps taken were-

i. Birds and animals at the airport were continuously monitored and trained bird scarers were used to scare away birds near the runway using firecrackers.
ii. Highly specialized bio-acoustics were used that produced loud animal noises.
iii. Barriers were constructed across potential

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nesting sites and water drains were covered at all the places.

iv. Collection of garbage or waste at the airport was controlled, cleaning of drainage and control of rodents and insects were done.

v. Site modification was done by cutting or relocation of trees or plants that attract wildlife[1].

E. Environmental Concerns

Located at the major economic, financial and commercial hub and growing demand for air travel it was necessary to fit in the right combination of features considering the future. To minimize the negative environmental impacts, strategies were developed to reduce the energy consumptions, Green House Gases emissions and natural resources usage minimizing the environmental footprint.

As global climate change grows exponentially, a collective global effort is required. The sustainability report of the year 2012 and 2014 published by MIAL clearly mentions that to reduce direct and indirect greenhouse gas emissions of the airport, several measures have been taken. A GHG accounting system as per the GHG protocol has been developed and installed for decision-making. The tool is accessible through intranet allowing users to enter monthly fuel and electricity consumption data which is then converted to equivalent CO2 tonnage. A Carbon Accounting andManagement System have been established to keep a check on the carbon emissions and maintain the quality of data. Workshops and audits are conducted regularly to be well updated with the impact of GHG on the environment. A Clean Vehicle Program was also prevalent to reduce fuel consumption which used highly efficient cars which emitted 15% less than ordinary vehicles [1].

Also published in Sustainability report 2014 are the areas in which managing power resources have been done efficiently; in 2013 a total of 300 light bulbs of 70W HPSV and 250 WMH used for perimeter lighting have been replaced with 45W LED bulbs which has led to reduction of perimeter lighting energy consumption by 60% while achieving better overall lighting of perimeter fences. Likewise to achieve energy efficiency; all the terminals at MIAL have been designed to maximize use of natural light. The central lobbies were provided with open glass reflector ceilings and walls to make maximum use of sunlight while minimizing heat. This helped in reducing air conditioning load during daylight. By switching the Highmast lighting system used at the aprons during non-operational hours resulted in energy savings to about 45% per year. Maintaining ambient air quality in and around the airport premises is scrutinized. For proper Waste Management the waste was segregated and stored at different locations until disposal. For proper Management of water, water taps were fitted with aerators to reduce water flow. All toilets had auto flush facility which not only removed the need of human contact but also optimized water flow; water discharged from airport was constantly monitored for quality. Discharged waste water was sent to sewage treatment plant which recycled the Water for reusing in flushing and cooling towers for HVAC. Rainwater Harvesting was also practiced to recharge the groundwater[4].

A Radiation management initiative had been implemented at the airport to create a healthier and radiation friendly environment. Radiation managing chips were provided to all the staff included with the projects office for their electronic devices like cell phones, laptop, etc. For maintaining a greener future a green belt had been developed around the airport establishment. For supporting the plantation activities, MIAL had its own nursery where they grew all the saplings required which is spread across an area of 80,000 square feet and can support 10,000 saplings at a time; it helps in reviving and replacing damaged plants and storing uprooted plants to be used in relocation projects. More than 65 different species of plant were grown at the time. All these measures have made it a globally recognized airport known for its unique ways to combat environmental issues faced at an international level and making The New Terminal 2 LEED Gold certified[4][8].

F. Awards Won

The Project has won many awards for adopting innovative methods and carrying out the task with excellence. A few are listed here:

1. 2015 International Structures over $100M, Outstanding Project, National Council of Structural Engineers Association (NCSEA) [6]
2. 2015 Award of Excellence for Architectural Engineering Integration, Architectural Engineering Institute (AEI)
3. Architectural Engineering Institute (AEI), Award of Excellence for Architectural Engineering Integration
4. ArchDaily, “Building of the Year 2015”, 2015

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5. Architecture Update Magazine, "An Infrastructure Renaissance", 2014
6. Architectural Record, "Airport Terminal is a Trove of Art", 2014
7. Golden Peacock Award 2014 for Sustainability

III. CONCLUSION

Sustainable development does not merely mean to adopt environmental friendly practices and develop according to the present needs without compromising the needs of the generations to come; it also means the optimum utilisation of the resources available for the development. Chatrapati Shivaji International Airport (CSIA) is a striking example which portrays the core essence of sustainable development. With limited land, water and energy available for its construction, the CSIA adopted water recycling, effective RO pretreatment and biological treatment practices in order to make it efficient in parameters like water efficiency, water use reduction, proper waste collection facilities and use of environment friendly materials in construction of terminal. The Airport is also making more efforts to become more environmentally friendly. This is a great example of being Eco Friendly by an organization in the transportation Industry. All other airports in India should consider this as reducing the impact on environment by human activities is a very important cause. Mumbai International Airport is truly globally benchmarked for its architecture, design, quality and cost. It is unique in terms of the synergy of aesthetics and functioning and is easily one of the most sustainable airports in the world.

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