

# Urban Development in Developing Countries: Analysing Current Policies for Mumbai

Hugh Byrd

School of Architecture and Planning  
The University of Auckland, [h.byrd@auckland.ac.nz](mailto:h.byrd@auckland.ac.nz)

Anindita Mandal

School of Architecture and Planning  
The University of Auckland, [aman141@aucklanduni.ac.nz](mailto:aman141@aucklanduni.ac.nz)

**ABSTRACT:** Urban areas in developing countries have been growing exponentially. In a list of cities with 5 million people or more, Mumbai did not feature in 1950, but in 1975 it occupied the 15<sup>th</sup> position which changed to 5<sup>th</sup> in 2000 and is expected to be 3<sup>rd</sup> by 2015. The rapid and continued growth of Mumbai and its sprawling metropolitan regions has put considerable strain on the city's infrastructure and caused environmental degradation.

Not only is Mumbai one of the most crowded cities in the world, its residential floor space consumption per person is one of the lowest in the world. With a population of about 14 million and growing daily, the task of providing adequate housing is becoming an increasing challenge in Mumbai, especially due to the geographical constraints of the Island City.

Most research on the subject has advocated a high density and compact city. However, this research has not taken account of the finite sources of water, energy and food for which the city is dependent on its hinterland or the potential of any new development to harness its own water or energy from renewable resources. High-rise residential buildings are being promoted as a sustainable solution by the government and researchers alike, with almost no consideration of the environmental impact of increased density.

This paper will review current research and critically analyse the Municipal proposals for Mumbai. A method of using an ecological footprint will also be discussed. The footprint allows an analysis of the environmental impact of density based not only on resources and consumption within the city but also on the depleting resources from outside the city that feed the population and power the economy.

**Keywords:** Mumbai, sustainable, density, ecological footprint

## 1. INTRODUCTION

In Mumbai there is a formal commitment to sustainable development. However, in practice the priority, at both the state and local levels, is economic growth. The institutional framework for environmental management is weak and uncoordinated in comparison to many developed countries and there is an apparent lack of planning and accountability as well as a lack of co-ordination among various government bodies (Sinha, 2010).

Mumbai<sup>1</sup> is India's centre of finance and culture. It is the second largest of Asia's mega-cities in terms of population and its growth process has been linked with the national and global processes of colonization, industrialization, development and underdevelopment. The potential to offer a higher standard of living and employment opportunities has resulted in substantial influx of population from various parts of the country, especially rural areas resulting in a city of many

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<sup>1</sup> In 1995, the official name of the city was changed from Bombay to Mumbai.

cultures, communities and religions<sup>2</sup> (MMRDA Planning Team, 1996 - 2011)<sup>3</sup>. But the rate of growth of population and urbanisation is greater than the rate of infrastructural development of Mumbai, leading to environmental degradation and a declining quality of life. However, there is a national desire to establish Mumbai as a 'World Class City' and project it as an image of societal welfare and technological progress in the country.

This paper is a part of a research project that is examining the current government policy that is promoting taller built form in order to achieve a higher density in Mumbai (MMRDA, 1996-2011). The purpose of the research is to evaluate the impact of higher densities and taller built form on the environment as well as the infrastructure.

Since no development under the current rules has yet been implemented, this research project has selected typical 'clusters' requiring redevelopment in the old part of the city and applied the new rules that determine building height, footprint, parking requirements and standards for open space. The new designed developments are then compared with the existing 'clusters' for key indicators of environmental sustainability including energy consumption, density, Carbon dioxide production and sequestration as well as the ability to collect rainwater and solar energy.

This paper presents the initial findings for a small 'cluster' and concludes that, although it is physically possible to increase density by tall buildings, there is a high price to pay due to an increased ecological footprint and reduced scope for incorporating renewable energy technology or rainwater collection. These factors, combined with a net increase in Carbon dioxide production resulting from such a development, question the sustainability of this built form.

## **2. MUMBAI'S CAPACITY FOR DEVELOPMENT**

Figure 1 indicates the population density of sectors of the city. The Island City's share of Mumbai's population has reached its capacity, but that of the suburbs is ever increasing. However, the Municipal Planning Team have stated, *"Urban growth needs to be physically confined to well defined areas based on the desirable densities and population distribution, and rest of the region be conserved as*

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<sup>2</sup> According to a sample survey of households in the Mumbai Metropolitan region in 1989, 46% of households were migrants and the mother tongue of nearly 50% households was Marathi.

<sup>3</sup> Mumbai Metropolitan Region Development Authority (MMRDA)

agricultural/rural area”(MMRDA Planning Team, 1996 - 2011). The intention is to redevelop the Island City at an increased density in order to reduce urban sprawl.

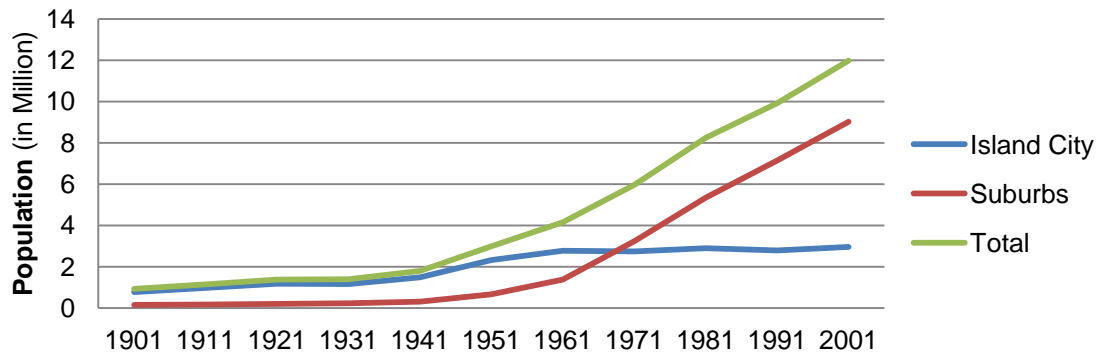


Figure 1: Population variation of Mumbai over 100 years (1901 and 2001)  
Source: Adapted from (MCGM, 2005 to 2025)

Though the liberalisation policies of the Government of India are expected to enhance the economic growth of Mumbai, it is largely dependent on the availability and development of quality infrastructure services that are currently under considerable stress. Mumbai is dependent of areas far beyond its municipal limits, for deriving its resources and disposal of its wastes. Thus, it has an ecological footprint much larger than its actual size, one that is likely to get bigger with further economic growth. The following subsections review the current state of these resources.

## 2.1. Water

Provision of an adequate quantity and quality of water is Mumbai's major challenge; as is evident from Table 1.

Year	Projected Population (Million)	Increment (Mld)	Supply (Mld)	Demand (Mld)	% Ful-filment
2001	11.84		3025	3975	76
2005	-	150	3175	4150	76
2007	-	200	3375	4300	78
2011	13.79	477	3852	4526	85
2016	-	455	4307	4800	90
2021	15.61	765	5172	5068	100

Table 1: Water supply and demand projections  
Source: Adapted from (MCGM, 2005 to 2025)

The supply of water is based on certain projected populations, which has already been crossed for the year 2011 (World Gazetteer, 2010)<sup>4</sup>. The city is facing water shortages, with parts of the city receiving direct supply of water for only a few hours

<sup>4</sup> According to extrapolations carried out by the World Gazetteer in 2010, Mumbai has a population of 13,830,884.

in the day and water connections to any new tower, clusters or townships being suspended till the Middle Vaitarna water supply project is completed (Sen, 2009).

## **2.2. Drainage**

The discharge of all the storm water and treated sewage is into the Arabian Sea. Tidal variation has a major bearing in the system of storm water drainage resulting in flooding and water logging during heavy rains and high tides (MCGM, 2005 to 2025). This is likely to get worse with the risk of sea level rise due to climate change. The sewage system of Mumbai is inadequate<sup>5</sup>, resulting in discharge of large amount of untreated sewage into creeks (MCGM, 2005 to 2025), resulting in degradation of coastal water quality, contamination of the adjoining beaches and seafronts (Kumar, Subramaniam, & Patil, 2000). Also most of the sewer lines are in a dilapidated condition resulting in leaks and contamination of ground water and piped water supply.

## **2.3. Solid Waste**

Most of Greater Mumbai's collected solid waste (7,025 MTPD)<sup>6</sup> is disposed of as mere dumping and levelling at the landfill sites at Deonar, Mulund and Gorai that have almost outlived their carrying capacity. Though the Government of Maharashtra has allotted MCGM a disposal site in Kanjur Marg, it is likely to be inadequate for the projected solid waste generation (MCGM, 2005 to 2025).

## **2.4. Electricity**

Maharashtra consumes almost 12% of India's electricity, having the highest consumer base in the country (DNA Reporter, 2010), it also tops the list for more deficit compared to other states. Consumption of electricity is growing faster than production capacity. The depletion of 'easy to find' coal combined with higher energy demands from industry and air-conditioning is leading to electricity blackouts on a regular basis (BBC News, 2002; BS Reporter, 2006; Rediff News, 2007).

## **2.5. Food**

Mumbai receives most of its supply of food for around the state and the country. However, the reduced agricultural productivity (Renton, 2009) due to an increasing

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<sup>5</sup> The sewage system of Mumbai currently covers only 42% of population, of which about 60% of sewage flow is adequately treated before being disposed off.

<sup>6</sup> Only about 100 to 150 Metric Tons Per Day (MTPD) is treated to localised vermin composting, biogas generation, etc.

shortage of availability of productive land<sup>7</sup> (Bhaskar, 2010; MCGM, 2005 to 2025) and water for irrigation (BS Reporter, 2009), the cost of food items in the city has been soaring. In the food group alone, the Consumer Price Index (CPI) increase in 2010 was 15.5% (Jaisinghani, 2010; Tembhekar, 2010).

## **2.6. Transport**

Though 85% of Mumbai's travel demand is still carried out through mass transport systems, the use of personalised vehicles<sup>8</sup> has been rising (MCGM, 2005 to 2025). In addition to outdated and poor condition of public transport vehicles, poor riding surfaces, inadequate road widths and choking intersections have resulted in slow traffic and environmental pollution<sup>9</sup> (MCGM, 2005 to 2025).

## **3. DENSITY vs. SUSTAINABILITY**

Households in Mumbai consume an average of 2.9 square meter of floor space per person which is one of the lowest residential floor areas per person in the world. It has a negative effect on the health of the inhabitants and according to Bertaud (June 2004), the city should aim to at least double this figure.

High density urban areas are believed to produce smaller per capita ecological footprints because of more efficient land-use and infrastructure and reduced transportation needs (Wackernagel & Rees, 1996). Other research on higher household density in Mumbai (Dave, 2010) has indicated that density has mixed perceived impacts. A positive impact on the access to facilities and amenities, no impact on the sense of safety and negative impact on the amount of living space; accounts for more employment opportunities and cost-effective infrastructure but often has a negative influence on affordability; mostly positive relation with amount of open spaces and parks, opportunity for walking/cycling, recycling of household wastes and use of public transport, but negative relation with air and water pollution. Further, most researchers agree (Dave, 2010; Dempsey & Jenks, 2010; Lindsay, Williams, & Dair, 2010; Raman, 2010; Williams, Joynt, & Hopkins, 2010) that layout, design, minimum standard of living space and culturally acceptable amount of mix of uses are important factors affecting social, economic and environmental sustainability and vary considerably between different developing countries.

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<sup>7</sup> Between 1971 and 2001, the built up area changed from 25% to 52% and land under forests and agricultural/plantations changed from 32% to 19%, in Greater Mumbai.

<sup>8</sup> The number of registered motorcycles and cars in Greater Mumbai limits has grown at a rate of over 9% and 3% per annum, respectively.

<sup>9</sup> 50% increase of TSP concentration and 25% increase in Nitrogen Dioxide between 1981 and 1990 has been reported

The options and analysis described above all point towards a greater urban density being more 'sustainable' and efficient. In spite of experiencing some of the highest urban densities in world, researchers, governing bodies and NGO's, all support increasing the floor space index (FSI) of Mumbai further, not only to increase the availability of housing, but also to increase the consumption of floor space per person. The capacity of the city to contain a greater number of people is based on:

- a) an analysis that is focussed on the perception of density and environmental indicators within the city.
- b) a particular urban form (high rise) that has the spatial capacity to contain more people

Unfortunately, no figures are given concerning an optimum, sustainable or maximum density in the studies above. Also the lack of a measuring tool for the implications of the densification of cities has led to policies that favour an almost unending increase in density. Without adequate resources, discussions of the density of a city become irrelevant.

A city requires a flow of resources into it and the waste to be removed at a certain rate in order to be considered 'sustainable'. The greater the population, greater is the flow of resources. In the case of Mumbai, the vast majority of the resources are produced outside the city. Water collection, food production and electricity generation are external to the city. To measure a city's sustainability, the rate, frequency and security of supply need to be measured. However, account must be taken of the security of future resource supply. A maximum supply of food or electricity at the present may not be sustainable in the future. In order to analyse this, the security of the supply chain of these energy sources needs to be investigated.

A given area of a city has certain basic input requirements in order to be resilient including: food; energy for household appliances and communal facilities; energy for infrastructure (pumping water & waste, street lighting); energy for transport. All of these can be considered in the form of energy demand and converted to a rate of energy consumption; KWhs/m<sup>2</sup>. This type of analysis has been used for comparing different low density areas in a city (Ghosh, 2004).

If there can be an adequate and secure supply of food, fuel and water into a city, then regenerative energy within a city has less importance. However, in both developed and developing countries both adequacy and security are now challenged by increasing population size, peak fossil fuels and climate change.

Sustainability of the city relies on its ability to reduce demand for the resources and look to ways of capturing these resources within the city. High density, on the other hand, reduces the per capita access to renewable energies and harvested water.

Rainwater can be collected from roofs, ground water replenishment, and electricity generated from photovoltaics attached to buildings. Similarly, urban food production can play an important role in reducing dependence of food imported into the city. But all these resources require surface area that is near horizontal.

High-rise buildings are associated with various disadvantages, such as, higher cost of operation<sup>10</sup>, low utilization of solar hot water system, (Roaf, Crichton, & Nicol, 2009; Yeang & Richards, 2007) and low scope of rainwater harvesting and collection of renewable energies due to low ratio of external building/roof surface area. However, tall buildings take up less of a footprint on the ground and therefore provide more open space on the site. This space may be used for food production, water collection and energy collection, though some of these are mutually exclusive. Mumbai has by far the largest number of skyscrapers in India, with 1146 existing buildings and 253 under construction and many more planned (Emporis, 2010). The World Conference, 'Remaking Sustainable Cities in the Vertical Age' in Mumbai (Shivdasani, 2010), highlighted the role of tall buildings in achieving higher density while also providing larger open spaces on ground. The event was jointly organised by Council on Tall Buildings and Urban Habitat<sup>11</sup> (CTBUH) and Remaking of Mumbai Federation<sup>12</sup> (RoMF). However, most speakers agreed that simply increasing density and building tall buildings is not the ideal solution, without first developing the infrastructure to support it.

#### **4. POTENTIAL FOR FUTURE DEVELOPMENT**

MHADA identified 19642 old and dilapidated buildings, called "Cessed Buildings", in the Island City. In order to encourage the redevelopment of these buildings through public-private participation, the government provided additional FSI<sup>13</sup> ranging from 50 to 70% of FSI required to rehabilitate the existing occupiers, as an incentive,

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<sup>10</sup> Tall buildings also require more energy for communal facilities such as lifts, lighting common areas and pumping water to storage tanks.

<sup>11</sup> CTBUH is an international not for-profit organisation supported by professionals from architecture, engineering, planning, development and construction areas, that facilitates exchanges between people involved in all aspects of the planning, design, construction and operation of tall buildings.

<sup>12</sup> RoMF is a non-profit federation of around 50 stakeholder individuals, associations and institutions working towards urban renewal of Mumbai.

<sup>13</sup> Floor Space Index (FSI) is the ratio of Built-up area to the Plot area.

depending on singular plot or cluster development, enabling more built up area for amalgamation of plots (MCGM, 2007).

The proposals are architecturally based and promote the demolition of large areas of low rise development in the city in favour of high rise development (Nandy, 2010). Once the existing cluster is demolished, the redevelopment is constrained by a set of rules that include such things as height-to-boundary ratios, open areas, perimeter clearance and parking standards that impact on the height and bulk of the building. This promotes an urban form of high rise blocks with open area around them. However, there is little guidance on the use of the newly created open space (in excess of the 30% of plot area as amenity open space); whether they should be paved or unpaved, used for planting trees, or simply used as car parks.

## **5. METHODOLOGY FOR ESTABLISHING A SUSTAINABLE URBAN DENSITY**

The most appropriate method of analysis for this is the ecological footprint. Electricity and biomass (both food fuel and materials) can be measured in terms of their energy content and compared with the energy requirements of the city. By comparing the demand of energy with supply, it is possible to establish a maximum level of population that can be sustained.

Since no redevelopment under these rules has yet taken place, the aim of this research was to determine, firstly, what built forms could be achieved that maximised the potential of a site and, secondly, to compare the characteristics of both the existing cluster and potential redevelopment in terms of its ecological footprint.

A typical cluster (Figure 2), in the old-dilapidated part of the island city (C-Ward), was selected based on the detail of data that has already been collected for its built form and density. The bulk of a hypothetical building was then designed based on the requirements and guidelines (Figure 3). While there are many permutations possible, the highest density solution was selected on the basis that this would be the same approach that a developer would take.

The comparative results are indicated in table 2. The 'cluster' of mixed existing buildings ranging from 2 to 5 storeys could be redeveloped as a 30 storey building in addition to car parking on the lower floors.



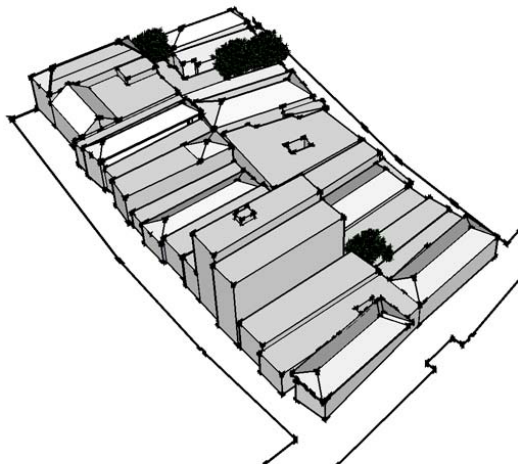


Figure 2: Existing Cluster

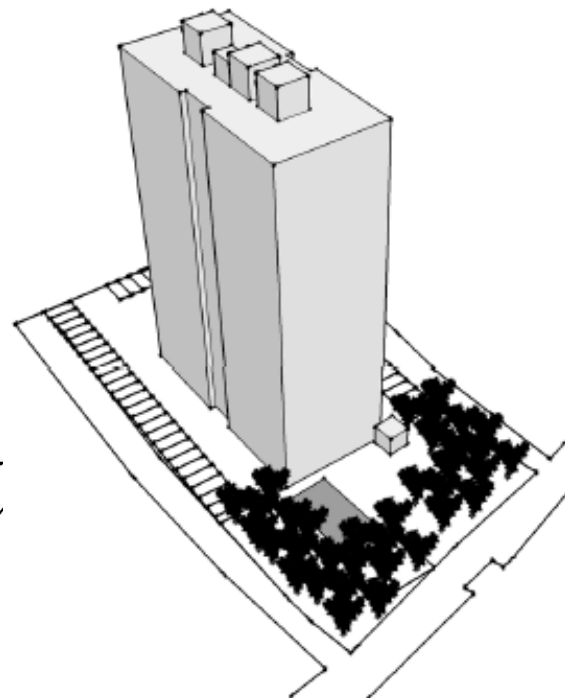


Figure 3: Proposed Cluster

	Existing	Potential
Land Area	3725 sq m	3725 sq m
FSI	1.705	4.34
Built-up Area	6349.365 sq m	16181.88 sq m <sup>14</sup>
Avg. Tenement Size	13 sq m (140 sq ft)	27.8 sq m (300 sq ft)
		47 sq m (500 sq ft)
		75 sq m (750 sq ft)
Population (approx)	1030 <sup>15</sup>	1305 <sup>16</sup>
No. Of Storeys	2-6	30
Car Parking	< 10	35 - 80 (approx)
Estimated CO <sub>2</sub> produced by Cars <sup>17</sup>	>2340	8190 – 18720 Kg per year
Roof Area	3375 sq m	385 sq m
Amenity Open Space	Negligible	930 sq m
Side Open Space	350 sq m	2410 sq m
Trees	3-5	47 <sup>18</sup>
CO <sub>2</sub> Sequestering Potential <sup>19</sup>	69 – 115 Kg per year	1081 Kg per year

Table 2: Comparison of Existing Development and Potential Redevelopment

<sup>14</sup> Considering incentive of 55% on built-up area required to rehabilitate existing users

<sup>15</sup> Considering an average tenement size to be 140 sq ft (13 sq m) and average household density to be 4.5 persons

<sup>16</sup> Considering an average tenement size for rehabilitation to be 27.8 sq m, and additional built – up area used for tenement sizes of 47 sq m and 70 sq m; average household density to be 4.5 person

<sup>17</sup> Considering CO<sub>2</sub> for cars to be an average of 101gm/Kg and usage to be about 3 trips of 15 Km equivalent per week.

<sup>18</sup> At the rate of 5 tree per 100 sq m or part thereof of the said recreational space to be grown within the entire plot (as per DCR for Greater Mumbai, 2007)

<sup>19</sup> Considering CO<sub>2</sub> Sequestering Potential to be 23 Kg (50 pounds) per year per tree, and high leaf density tropical trees between 20-50 years of age.

## 6. RESULTS

The population density for the site increased by a little over 27% whereas the built-up area increased by 255%. This figure takes account of the redevelopment requirement to double the average size of the existing residential unit and providing bigger units for free sale.

It is difficult to assess the additional amount of energy used by cars that are accommodated on the site. Mumbai has a low car ownership at present. It is even lower in the study area because the existing street patterns and block layouts do not accommodate parking. However, vehicular ownership is strongly linked to social and economic aspiration and with improving technology and increasing affordability. The ownership of private vehicles is likely to increase exponentially. This will result in more parking spaces in the proposed development, leading to more hard surfaces, thereby reducing any replenishment of the groundwater. However, since most residential areas are well connected to the public transport system, the more likely the pattern of car use is for shopping runs and weekend use.

The energy used by the building, excluding air-conditioning, increased by 50%. This was largely due to the increase in energy required for a tall building which included additional pumping of water, lifts, common area and security lighting, in addition to the extra energy required for lighting and ventilating the increased tenement sizes. There is also likely to be an increase in hot water demand as the level of water consumption increases due to higher standards of bathing facilities and use of washing machines.

Air-conditioning uptake in the existing clusters is approximately 10% of households. This is due to a combination of low incomes and also mutual shading of the adjacent buildings that reduces the cooling need. The level of air-conditioning use in any new development can only be speculated at present but requires further research once redevelopment starts in the City. However, it may well increase due to increasing affluence, the desire for modern technology and the design of tall buildings that may have inadequate cross-ventilation or shading.

The large area of roof space available with the existing buildings is significantly reduced with the new development. This reduces the ability to use photovoltaics or thermal solar collectors. The proportion of available roof area of the proposed development is only about 10% that of the existing. While not all areas of the roofs are necessarily available, the proportional loss of solar collecting area will be similar.

Water use increases by approximately 80% due to a combination of an assumed 'take-back' (increased use of water due to improved bathing facilities), watering of trees and other landscaped areas and for washing the increased number of cars. However, water requirements for activities other than domestic use can be supplemented with recycling grey water and harvesting rainwater.

In the proposed development, the potential for rainwater collection decreased by 90% because of the significantly reduced roof area. However, in the existing development, there is no scope of providing rainwater tanks, wells or filtration plants for collecting rainwater, due to lack of ground space and structural instability of existing buildings. In the proposed development, there may be some potential for collecting rainwater from carport canopies. However, the additional cost of these makes them uncommon for developers to install.

Food consumption was assumed to increase in proportion to the increased occupancy on the site; 27%. Also, there is a potential to use the newly available open space on the ground for urban agriculture. However, it is much more feasible with larger plot sizes at neighbourhood levels.

The increased open space on the ground is also associated with increased number of trees on the site, which not only provide a natural environment and more shade (reducing impact of UHI), but also help in sequestering CO<sub>2</sub> (reducing pollution). However, it should be noted that sequestration by the additional trees has little impact on the increased Carbon dioxide production due to the cars.

## **7. CONCLUSIONS**

The above analysis of this one site in Mumbai indicates that a typical development will increase density by about 30% but would result in more than double the energy consumption, double the use of water, reduce the amount of rainwater that could be collected or returned to the ground and reduce the scope for collecting solar energy. Apart from adding to the already overloaded drainage infrastructure it would also encourage an increase in the number of private vehicles. While the number of trees required in the new development guidelines will sequester Carbon dioxide, the increased capacity for cars on the site will result in at least a tenfold increase in Carbon dioxide production.

In spite of the disadvantages related to the proposed development, it is necessary to redevelop these areas of the island city due to their dilapidated conditions. The advantages include increased number of housing, increased space per household, provision of amenity open space and most importantly, structurally stable buildings for the residents. However, in order to negate some of the disadvantages, there is a need to look at planning at a neighbourhood level, for better infrastructural development and shared costs.

The next stage of this research is to evaluate what 'sustainable' measures could be introduced to mitigate the above mentioned disadvantages and what overall value they would have in reducing the ecological footprint of the site. Apart from rainwater and solar collection, the scope of urban food production will also be considered.

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