

# Sustainable Metropolitan Development using Carrying Capacity as a tool: a case of Mumbai Metropolitan Region, India

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**Abstract:** Diverse urban problems in the Indian Metropolitan Region occur due to over-development and over-concentration in the metropolitan city which exceed the carrying capacity. In achieving sustainable development through resolving such problems, practical approaches to include urban carrying capacity for managing urban development are required. Present research focused to assess metropolitan problems such as overconcentration of population, lack of future developable land, less FAR (Floor Area Ratio), decreasing natural areas etc. and these calls for assessing the carrying capacity through a case study of Mumbai Metropolitan Region (MMR) by applying the Sustainable Accommodation through Feedback Evaluation (SAFE) model. In present research an attempt has been made to decentralize urban growth from Greater Mumbai through SAFE model for balanced urban mosaic within MMR and has also indicated clues for the policy makers for sustainable metropolitan regional development.

**Keywords:** Carrying Capacity, FAR, Greater Mumbai, MMR, SAFE, Sustainable.

## I. INTRODUCTION

The rapid growth of urban population across the world during last four decades attracted the attention of many academicians, professionals and policy makers. Many megacities, particularly in developing countries, have faced overconcentration of population and as a result exceeded the inherent Urban Carrying Capacity of cities [1-3]. Urban India accommodated 377 million people (31.2% of total population) as per Census 2011, the second largest urban population in the world (after China), spreads across 7935 urban centers, including 53 Urban Agglomerations (UAs), which are defined as cities with over a million people [4]. According to United Nation's estimate today 54% of the world population lived in urban areas, a proportion that is expected to increase to 66% by 2050. By that period 50% of India's populations are expected to live in urban areas [5]. The concentration of economic activities and population in some of the mega cities in India required decentralization to reduce the strain on the delivery of services [6]. New challenges such as globalization, demographic change and shortage of future developable land made it necessary to tackle metropolitan regional growth in a rational manner particularly in Indian context. Greater Mumbai has covering a space of 10% geographical area and with a population share of almost 60% of Mumbai Metropolitan Region (MMR). Meheta (2012) in his research termed Greater Mumbai as 'Maximum city' [7]. It is a city of hope for large number people who flock to it every day in search of job and to pursue their dreams making Greater Mumbai one of the most densely populated metropolis in the world. With the present land mass to population ratio reaching a tipping point, any further expansion would become unmanageable. Greater Mumbai continues to see population increases although its capacity to hold them is

long gone [8]. Greater Mumbai surrounded by water along three sides has guided its limited spatial growth. An analysis of urbanizable land potential at Greater Mumbai shows that only 9.47 Square Kilometre (sq.km.) of land is available for future development [9]. The over-concentration of population and over-development beyond carrying capacity has creating adverse impact on sustainability for Greater Mumbai and MMR as a whole.

This paper proceeds in six sections. Following introduction, Section 2 presents theoretical aspects and past research related with carrying capacity and sustainability. Section 3 specifies the methodological framework and how it was applied. Section 4 presents current state of metropolitan growth, population overconcentration, lack of future developable land, rapidly decreasing natural areas, low FAR (Floor Area Ratio, ratio of combined gross floor area to the total plot area) etc. in Greater Mumbai and these calls for assessing carrying capacity by applying Sustainable Accommodation through Feedback Evaluation (SAFE) model. Section 5 focused on estimation of carrying capacity for all urban units of MMR including Greater Mumbai to find out potential urban units where additional urban load from Greater Mumbai can be allocated. Finally, Section 6 synthesizes the findings and presents policy implications.

## II. LITERATURE REVIEW

Metropolitan Regional sustainability ensures equitable sharing of resources and opportunities among its planning units for the benefit of future generations. If metropolitan regional planning aims for balanced development, a valid method is to understand carrying capacity and frame

strategies and policies accordingly. The concept of ‘carrying capacity’ originated from ecology and mainly focused of environmental and man-made physical factors over a long period of time [10-14]. Researchers worked on other non environmental factors determining carrying capacity particularly last four decades and accordingly many factors included in carrying capacity assessment. It includes technical, socio-economic and cultural components [15], human attitudes, values, behaviour [16], economic, social, environmental, and institutional [17-18]. Several evaluation methods and tools evolve for assessing carrying capacity such as infrastructure and land use based [19], Visual threshold carrying capacity [20], relative carrying capacity based on grey relevant degree [21], environmental carrying capacity theory and ubiquitous technology [22] but little progress has been achieved for comprehensive carrying capacity study.

### III. METHODOLOGY

Current Carrying Capacity assessment literatures mainly focus on urban area as one unit and little progress has been achieved on developing methodology focused at regional scale with different planning units together for assessing comprehensive metropolitan regional carrying capacity study. Through this research an attempts has been made to estimate carrying capacity of Greater Mumbai, all other urban units of MMR and rural MMR separately by applying SAFE model. SAFE model can be easily applied to any urban area [23] and in this research the same used for assessing carrying capacity of intra-urban units within metropolitan region. The carrying capacity of the area in the context of metropolitan regional development can be calculated using the following equation:

$$CC = A_U - (A_{ND} + A_{IF}) \times FAR/S$$

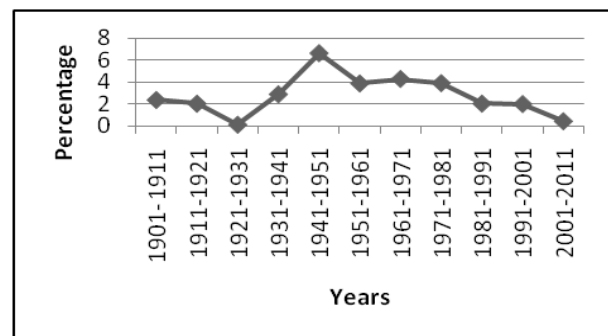
where, CC= Carrying Capacity,  $A_U$  = total urban area,  $A_{ND}$ = net non-developable area,  $A_{IF}$  = area for infrastructure development, FAR = Floor Area Ratio and S = Floor area requirement per head.

This model is used here to assess the carrying capacity of all urban units of MMR. Due to non-availability of more recent data, land use survey conducted in 2008 by Mumbai Metropolitan Regional Development Authority (MMRDA) is considered as base period source of information for present study. Municipal boundary expansion in future is not considered as scope of present study. However, if such expansion takes place in any urban unit, the population concentration, workers concentration and density and FAR will be adjusted accordingly. For detailed study purposes, MMR is divided into 15 urban units besides considering rural MMR separately. These 15 urban units consist of 8 Municipal Corporations (Greater Mumbai, Vasai-Virar, Thane, Kalyan-Dombivali, Navi Mumbai, Bhiwandi-Nizampur, Ulhasnagar and Mira Bhayandar), 6 Municipal Councils (Ambernath, Badlapur, Panvel, Uran, Khopoli and Pen) and all other urban constituents considered as ‘others’ (includes 3 Municipal Councils and 12 Census Towns). As per 2011 census, all urban centres within MMR with population less than 30,000 are included in ‘others’ category that has also been followed in this research. In

‘other’ category of urban units (includes 3 Municipal Councils and 12 Census towns) though land use details for 3 Municipal Councils (Matheran, Alibug and Karjat) are available, the same for 12 Census towns are not available. Thus non-availability of detailed land use data of 12 Census towns has been a limitation in this study.

### IV. MMR: THE CASE STUDY

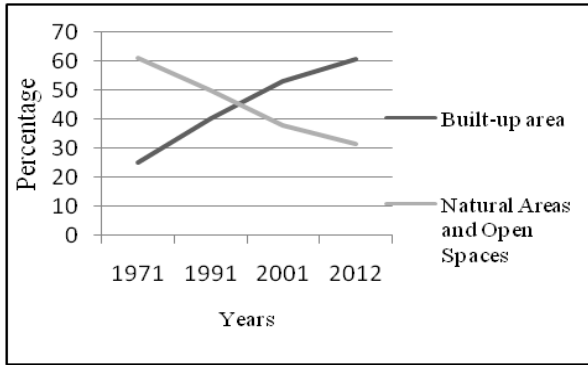
MMR covering a space of 4,355 sq.km., contains within its boundaries the old Island City of and Western and Eastern Suburbs of Greater Mumbai, the twin city of Navi Mumbai and its suburbs on the mainland, and adjacent parts of Thane District — including the cities of Thane and Kalyan, the Vasai-Virar and Mira-Bhayander areas, the towns of Bhiwandi, Dombivili, Ulhasnagar and Ambernath, as well as adjacent parts of Raigad district — including Panvel, Matheran, Karjat, Khopoli, Pen, and Alibaug [24]. As per 2011 census the population of MMR is 22.23 million (estimated) and MMRDA is responsible for planning and development of MMR. Since 1901 there is a continuous growth of population of Greater Mumbai till 2011 but the Annual Average Growth Rate (AAGR) has drastically reduced from that of 2.37% during 1901-11 to 0.44% in 2001-2011. In Greater Mumbai, a significant change in growth rate (4.28%) had taken place only after the year 1961-1971 but after that growth rate is falling over the last four decades and it is presumed that the same trend will continue for coming decades also (see Fig.-1).



**Fig-1: Population Growth rate of Greater Mumbai (1901-2011)**

Source: Census of India (1901-2011b) [25]

The share of Greater Mumbai's population in that of MMR, which was 76.63% in the year 1971, is found to have reduced to 55.96% in 2011. Although within MMR predominance of Greater Mumbai still exists in terms of population share. Within Greater Mumbai a distinct change in the spatial distribution of population is observed in the last four decades. Over 1971-2011 period, the gross density of Greater Mumbai increased from 13,391 persons per sq.km. to 28,420 persons per sq.km. This put a tremendous pressure on existing land use, environment and infrastructure. Mumbai has witnessed a rapid growth of built-up area within the last four decades. Built-up land has grown more than doubled from being 25% of total area in 1971 to 60.59% in 2012. Natural areas and open spaces (forest, water body, coastal wetlands etc.) have been rapidly decreasing from 61% of total land in 1971 to 31.5% of the same in 2012 (See Fig-2).



**Fig-2: Temporal Change of Built up area, Natural areas and Open Spaces at Greater Mumbai (1971-2012)**

Source: i) Transform Study, MMRDA ii) Draft Development Plan of Greater Mumbai (2014-2034)[26] Sridhar (2010) highlighted the list of 116 UAs and their land use regulations related to the maximum permissible residential and non-residential FARs. Average maximum residential FAR of 116 Urban Agglomerations (UAs) in India has been shown to be 3.5 whereas average maximum non-residential FAR has been 2.0 [27]. In planning for majority of Metropolitan cities the maximum FAR values considered is 3.0 whereas cities like Greater Mumbai the overall FAR value is 1.33. According to Bertaud (2008), Greater Mumbai FSI values are different from most major cities around the world. In Greater Mumbai FSI values are low, uniform over very large areas, not differentiated between commercial and residential areas and not linked to land market values. In most large cities the FSI varies from 5 to 15 in the Central Business District (CBD) to about 0.5, or below, in the suburbs. In Greater Mumbai, the permitted FSI is uniform and in 1991 was fixed at 1.33 for the Island City and 1.00 for the suburbs, although some higher FSI has been allowed in some isolated lots outside the Island City area through the program called Tradable Development Rights (TDR). Due to geographical constraints, scope of urban boundary expansion for Greater Mumbai is limited; the immediate possible solution is to redensify the space with increased FAR and later allocation of surplus population to the capable satellite towns for balanced development of entire MMR[28].

It is evident that, urban population of MMR has increased from 13.50 million in 1991 to 21.04 million in the year 2011. However, the AAGR for urban population in MMR has declined from 3.22% during 1991-2001 to 1.79% in 2001-2011. In case of Greater Mumbai, AAGR declined from 2% during 1991-2001 to 0.44% during 2001-2011. Satellite towns within MMR are growing in a faster rate. Vasai-Virar Municipal Corporation was formed in 2009 by including 4 Municipal Councils (Vasai, Virar, Nallasorara and Navghar-Manikpur) and 53 Gram Panchayat's. Although in Thane, Navi Mumbai, Mira Bhayander etc. AAGR declined but still they maintained a considerable growth rate of almost 5%. Navi Mumbai, a planned satellite town of Greater Mumbai show declining growth rate, means it will be saturated in near future.

**V. RESULTS AND DISCUSSION**

For applying the SAFE model required land and other infrastructure details have been taken from development Plans of respective cities/ towns and 'Transform' study conducted by MMRDA. Floor area required per head has been calculated from 2011 census. For Greater Mumbai and majority of the satellite towns where horizontal expansion and developable land is limited for future development, vertical expansion will be an alternative solution. Carrying capacity has been calculated with various FAR options (with existing FAR and with increased FAR) for Greater Mumbai and other satellite towns and the same are represented in Table no-1. For Greater Mumbai with FAR 1, the maximum carrying capacity has been estimated to be 8.27 million. In Greater Mumbai, particularly in island city the maximum FAR has been found to be 1.33 and with 1.33 FAR, the carrying capacity has been to be estimated 11.10 million. Greater Mumbai and Ulhasnagar has already crossed its carrying capacity and the same required immediate attention for policy makers. In case of Rural MMR the permissible FAR is 0.5. With Permissible FAR as 0.5, the carrying capacity is estimated to be 0.44 million population and with FAR 0.75, the carrying capacity has been estimated to be 0.66 million population. As per 2011 census the total population of MMR has been 22.23 million and with FAR 1 for urban units and 0.5 for rural area the estimated carrying capacity is expected to be 27.70 million. Population allocation for future decades has been based on space and floor area requirements for Greater Mumbai and its satellite towns. For the same, various FAR options (existing FAR and with increased FAR) are tested to find out the optimum FAR requirements for each city. Greater Mumbai, as per 2011 census, had 12.44 million population and accordingly suggested should be FAR 1.5. With 1.5 FAR the carrying capacity has been worked out to be 12.42 million and naturally the prime target remains as to decentralize additional population from Greater Mumbai. For Greater Mumbai since scope of urban boundary expansion is limited, accordingly channelizing the excess population to satellite towns of MMR is the ultimate long term solution. Additional population of Greater Mumbai can be distributed to Kalyan-Dombivali, Navi Mumbai, Vasai-Virar City and Bhiwandi-Nizampur where more space will be available after meeting their own population demand. Some industries should be reallocated outward Greater Mumbai through stimulatory subsidies under a decentralization policy. Regional linkages through public transport (bus and rail based) need to be improved for better interaction not only for Greater Mumbai with other satellite towns but also among satellite towns each other.

**Table 1: Carrying Capacity Assessment based on SAFE Model (with existing FAR)**

Urban Centers	Population - 2011 (in million)##	Carrying Capacity (in million)
Greater Mumbai	12.44	8.27*
Thane	1.84	3.65
Kalyan-Dombivali	1.25	3.48

Navi-Mumbai	1.12	1.51
Mira-Bhayander	0.81	1.27
Bhiwandi-Nizampur	0.71	1.02
Ulhasnagar	0.51	0.32
Vasai-Virar City	1.22	4.36
Ambernath	0.25	1.23
Badlapur	0.17	0.37
Panvel	0.18	0.24
Uran	0.03	0.06
Khopoli	0.07	0.21
Pen	0.04	0.09
Others #	0.40	1.18
<b>MMR Urban</b>	<b>21.05</b>	<b>27.26</b>
<b>MMR Rural</b>	<b>1.19 \$</b>	<b>0.44+</b>
<b>MMR Total</b>	<b>22.23</b>	<b>27.70</b>

Note: # includes 3 Municipal councils and 12 Census towns, \$ Estimated, \*with FAR 1.33 carrying capacity 11.10 million + FAR 0.5 considered  
Source: ## Census of India, 2011b

## VI. CONCLUSION

Many Indian large cities especially the large metropolises are facing a host of as challenges of urbanization challenges such as population influx, urban sprawl, poverty and inequality, congestion etc. MMR is no longer exception. The emphasis should be on compact sustainable urban form (shape, density and land use) that reduce over exploitation of natural resources, accelerate economic viability, assure livability, promote environmental quality and confirm social equality. Urban compaction aims to increase built area and residential population densities, to intensify urban economic social and cultural activities and to achieve sustainable benefits. Linkage of spatial aspects of urban development with economic, social and environmental components, in particular to achieve mixed use call for both vertical and horizontal integration required. The rapid influx of urban population is the immediate cause for the over development of Greater Mumbai. From this research it appears that carrying capacity of Greater Mumbai is already saturated and only 9.4 sq.km future developable land will not be able to take care of the urban load of Greater Mumbai in future. As FAR value of Greater Mumbai is very low, the same can increase from 1.0 (island city 1.33) to 1.5 accommodate existing residential demand. Greater Mumbai is part of MMR and satellite towns like Navi Mumbai, Thane, Vasai-Virar city etc. did not lay their expected role in sharing its over concentrated population and activity in Greater Mumbai. It is also necessary to frame a policy targets aiming at decentraliz-ation of metropolitan growth, particularly from Greater Mumbai, and allocation of surplus population to the capable satellite towns for balanced development entire MMR. However, the extent to which the urban population should be decentralized present research provides a clue for policymakers to take careful discussion. Rather than reviewing problems of individual urban units separately, it is imperative to consider MMR as single entity and thus assure promotion of balanced development of the whole MMR.

## REFERENCES

- [1] Oh KYJ, Lee D, Lee W, "An Integrated Framework for the Assessment of Urban Carrying Capacity". Journal of Korean Planning Association 37: 7-26, 2002.
- [2] Shi Y, Wang H, Yin C, "Evaluation Method of Urban Land Population Carrying Capacity Based on GIS—A Case of Shanghai, China". Computer, Environment and Urban Systems 39, 27-38, 2013.
- [3] Wei Y, Huang C, Lam P, Sha Y, Feng Y, "Using Urban-Carrying Capacity as a Benchmark for Sustainable Urban Development: An Empirical Study of Beijing". Sustainability 7: 3244-3268, 2015.
- [4] "Provisional population totals paper 2 of 2011 India series 1 India": Office of the Registrar General & Census Commissioner, India.
- [5] UNDESA (2014) World Urbanization Prospects, the 2014 revision. [Online]. Available: [http://esa.un.org/unpd/wup/Highlights/WUP\\_2014-Highlights.pdf](http://esa.un.org/unpd/wup/Highlights/WUP_2014-Highlights.pdf).
- [6] MoUD, (2008) Guidelines for scheme of urban infrastructure development in satellite towns/counter magnets of million plus cities. [Online]. Available: [http://tcpomod.gov.in/Divisions/MUTP/guideline\\_satellite.pdf](http://tcpomod.gov.in/Divisions/MUTP/guideline_satellite.pdf).
- [7] Mehta S, Maximum city, Bombay Lost and Found, Penguin Books, New Delhi: Oxford University Press, 2012.
- [8] Mumbai HDR (2009) Mumbai Human Development Report. [Online]. Available: [http://mhupa.gov.in/W\\_new/Mumbai20HDR%20Complete.pdf](http://mhupa.gov.in/W_new/Mumbai20HDR%20Complete.pdf).
- [9] "Comprehensive Transportation Study for Mumbai Metropolitan Region". MMRDA, Mumbai, Maharashtra, 2008.
- [10] Rees W, "Ecological footprints and appropriated carrying capacity: What Urban economics leaves out", Environment and Urbanization, 4(2):121-130, 1992.
- [11] Abernethy VD, "Carrying capacity: The tradition and policy implications of limits". Ethics in Science and Environmental Politics 23: 9-18, 2001.
- [12] Schneider DM, Godschalk DR, Axler N "The Carrying Capacity Concept as a Planning Tool". In Planning Advisory Service Report 338; American Planning Association: Chicago, IL, USA, 1978.
- [13] Liu HM, "Comprehensive Carrying Capacity of the Urban Agglomeration in the Yangtze River Delta, China". Habitat International 36(4): 462-470, 2012.
- [14] Oh K, Jeong Y, Lee DK, Lee W, Choi J, "Determining Development Density Using the Urban Carrying Capacity Assessment System". Landscape and Urban Planning 73:1-15, 2005.
- [15] Schroll H, Andersen J, Kjærgård B, "Carrying Capacity: An Approach to Local Spatial Planning in Indonesia". The Journal of Transdisciplinary Environmental Studies 11(1): 27-39, 2012.
- [16] Godschalk DR, Axler N, "Carrying Capacity Applications in Growth Management: A Reconnaissance". Department of Housing and Urban Development, Washington, DC, 1977.
- [17] Liu HM, "Comprehensive Carrying Capacity of the Urban Agglomeration in the Yangtze River Delta, China". Habitat International 36(4): 462-470, 2012.
- [18] Downs JA, Gates RJ, Murray AT, "Estimating Carrying Capacity for Sandhill Cranes Using Habitat Suitability and Spatial Optimization Models". Ecological Modelling 214:284-292, 2008.
- [19] Oh K, Jeong Y, Lee DK, Lee W, Choi J "Determining Development Density Using the Urban Carrying Capacity Assessment System". Landscape and Urban Planning 73:1-15, 2005.
- [20] Oh K, "Visual threshold carrying capacity (VTCC) in urban landscape management: a case study of Seoul, Korea". Landscape Urban Planning 39 (4): 283-294, 1998.
- [21] Xu L, Kang P, Wei J, "Evaluation of urban ecological carrying capacity: a case study of Beijing, China". Procedia Environmental Sciences 2:1873-1880, 2010.
- [22] Lee D, Oh K, "A Development Density Allocation Model based on Environmental Carrying Capacity". International Journal of Environmental Science and Development 3(5):486-490, 2012.
- [23] Urban Carrying Capacity: Concept and Calculation; Centre of Excellence: IIT, Guwahati, India. [Online]. Available: <http://www.iitg.ernet.in/coeiiitg/Urban%20Carrying%20Capacity.pdf>.
- [24] MMR Regional Plan (1996-2011) Mumbai Metropolitan Regional Development Authority, Mumbai, Maharashtra.
- [25] "Primary Census Abstract, UA/Towns 2011", Office of the Registrar General & Census Commissioner, India, New Delhi (compact disk form).
- [26] Draft Development Plan of Greater Mumbai (2014-2034) [Online]. Available: <http://draftdp.mcgm.gov.in:8080/mcgm/index.html>.
- [27] Sridhar SK, "Impact of land use regulations: Evidence from India's cities". Urban Studies 47(7): 1541-1569, 2010.
- [28] Bertaud A (2008) Options for new alternatives for development control regulation and justification for increasing FSI Mumbai. [Online]. Available: [http://alainbertaud.com/wp-content/uploads/2013/07/AB\\_FSI\\_Presentation\\_4\\_compr\\_200dpi.pdf](http://alainbertaud.com/wp-content/uploads/2013/07/AB_FSI_Presentation_4_compr_200dpi.pdf)