Spatial Planning Approach for supporting Climate Commitments at a local level: the case of Mumbai Metropolitan Region, India

A Thesis Submitted for the Fulfillment of PhD

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I will strive to use the skills and knowledge that I have gained and work for the society in the best possible way.

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List of Important Terms

Budgeting period - It is the span of years for which the countries are held accountable for anthropogenic emissions.

Climate target – The target defined for the purpose of governing climate change issues. It may or may not be directly related to emissions but the ultimate goal of a climate target is to reduce emissions in order to mitigate climate change.

Emission targets for MMR – The global and national climate targets scaled down for the scope of MMR.

Mitigation Pathway – Emission trajectory developed by following a mitigation rate designed to meet a predefined climate target.

Mitigation Rate – The proportion of emission reduction.

Pledges – The voluntary commitments of a country (or region) to reduce emissions in response of a climate target.

Remaining emission budget – For limiting the global rise in temperature, only a limited amount of emissions can be utilised by the world. This limited amount is known as remaining emission budget.

Executive Summary

1. Background

Climate change poses a serious threat to the development of a nation. It not only slows down the entire processes of growth but also causes damage to the well-established systems. United Nations Framework Convention on Climate Change (UNFCCC) is the primary body at international level engaged in taking actions to prevent anthropogenic climate change. And the scientific knowledge for this purpose is provided by Intergovernmental Panel on Climate Change (IPCC). Paris Agreement, a treaty that sets internationally binding reduction targets for countries aims to limit the global temperature rise to 2°C above pre-industrial levels[1]. It requires voluntary pledges from the countries in the form of Nationally Determined Contributions (NDC). With these developments, countries have become agile in taking actions to achieve climate goals in their own capacity.

In India, metropolitan regions are the biggest contributors to national emissions as these are where development is mainly concentrated. Moreover, the increasing population in these cities requires rapid urbanization which has a significant impact on carbon emissions. Hence, to achieve climate targets at national and global levels, there is a need for accelerated and focused research that improves the knowledge of cities in interpreting the meaning of climate targets at local levels. To account for this, the research focuses on determining the role of a metropolitan region in India in achieving climate targets.

The study was conducted in Mumbai Metropolitan Region (MMR), situated on the western coast of India. MMR's priorities, limitations and resources were identified and research was done to incorporate climate change priorities in MMR's current regional planning.

2. Research Outline

The study aims to find how climate-conscious planning can be integrated with the current planning priorities of MMR.

Objectives of the Study:

i. To analyse the Regional Plans of MMR for climate change adaptation and mitigation protocols.
ii. To estimate MMR's GHG emissions.
iii. To find the role of MMR in meeting the Paris Agreement's climate target and India's NDC target.
iv. To identify and prioritize planning components that can affect the emissions of MMR.
v. To recommend a planning framework for MMR strategically outlined to meet the climate targets, without altering the current priorities of the region.

Research Methodology

The research is partly qualitative; and partly quantitative. It involves field work, interviews and discussion with stakeholders, MMR's regional plans as primary data; while Government

[1] The period starting from 1850-1900 is considered the Pre-industrial period.

reports, policy documents, census data, spatial plans and literature studies as secondary data. Planning related discussions were held with officials in local and regional planning authorities in MMR and emission related discussions were held with officials of the Ministry of Environment, Forest and Climate Change.

Mumbai Metropolitan Region

MMR is a metropolitan region with an area of 4,311.75 sq.km built around Mumbai city at the core and is the sixth largest urban agglomeration in the world. Mumbai city and MMR contribute 5% and 11% to the national GDP respectively. Being a coastal region, MMR is highly prone to the climate change related disasters.

3. Structure of Dissertation

This dissertation consists of three main parts. The first part contains chapter 1 and 2 and introduces the overall research and the study area. The main work done in the study is explained from Chapters 3 to 7. Chapter 8 is the conclusion chapter which summarises the work done, enlists general observations made during the research process and highlights perspectives on future research.

3.1. Climate Change Protocols In MMR's Planning- Development of A New Planning Index

The first step in this research was to determine how prepared is MMR for climate change. MMR's planning documents were analysed to find their strength (or weakness) in climate change mitigation and adaptation. Till date, two plans for MMR have already been sanctioned, namely, the Regional Plan for Bombay Metropolitan Region 1970–1991 (Regional Plan I) and Regional Plan for Mumbai Metropolitan Region 1996–2011 (Regional Plan II). The third Regional Plan, which was to be implemented from the year 2016 to 2036, is yet to be sanctioned by the Government[2].

A new tool named Climate Change Planning Index (CCPI) was designed for analysis. The purpose was to find the relation between MMR's plans and climate priorities. The index was basically designed to translate this qualitative relation into quantitative scores. Mitigation and adaptation CCPI were found which indicated the mitigation (emission reduction strategies) and adaptation (ability to reduce vulnerability) strength of the plans. With '0' being the minimum and '10' being the maximum possible score, the higher score would suggest a more climate conscious regional plan. The results of analysis of Regional Plan I and II are presented in Table 1 and are graphically represented in Figure 1.

Table 1 CCPI of Regional Plans of MMR

Components of Regional Plan I	Mitigation CCPI	Adaptation CCPI	Components of Regional Plan II	Mitigation CCPI	Adaptation CCPI
Industrial Location Policy	0.00	0.00	Regional Development Strategy	1.00	1.00
Transport and Communication	0.00	0.00	Industrial Growth Policy	1.70	1.70
Housing	0.00	0.00	Office Location Policy	5.00	1.70
Utilities and Services	0.00	0.00	Shelter Needs and Strategies	0.00	0.00

[2] MMRDA Website last accessed on May 12; 2019

Recreation	6.67	0.00	Urban Land Policy	0.00	0.00
Planning of Rural Areas	3.36	1.67	Water Resource Development	3.00	2.00
Social Planning	0.00	0.00	Transportation	7.50	1.25
Development Control Rules	8.00	0.00	Environmental Management	3.37	5.77
			Revised Land Use Plan	2.50	5.00
			Development Control	2.50	1.00
CCPI of Regional Plan I	**2.25**	**0.21**	**CCPI of Regional Plan II**	**2.65**	**1.94**

For Regional Plan I, the mitigation and adaptation score was 2.25 and 0.21 (out of 10) respectively and that for Regional Plan II was 2.65 and 1.94 respectively. The adaptation score significantly increased from Regional plan I, depicting that climate change preparedness was moderately rooted in the new plans. However, Regional Plan I was sanctioned with the prime aim of development more than 15 years before climate change was accepted as a global concern while Regional Plan II was sanctioned in 1992 when environmental protection and climate change concerns were well established. Hence in order to avoid the conflict in broader goal of this research, only the results of Regional Plan II were used in the further research.

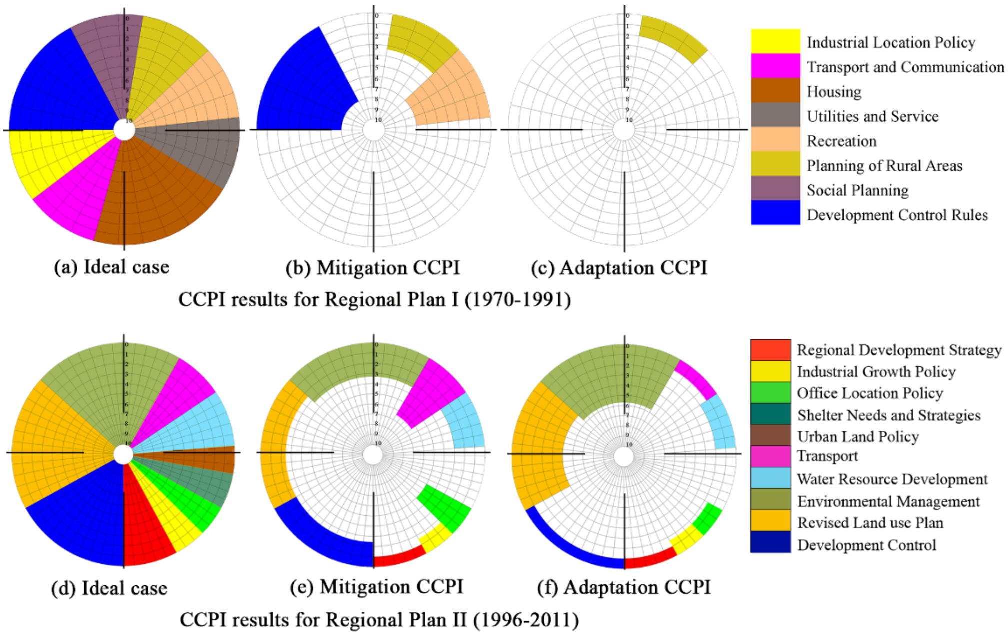

Figure 1 Results of analysis of Regional Plans of MMR

3.2. Greenhouse Gas Estimates in MMR

MMR's overall CO_2 emissions were estimated using the top down approach and road transportation, electricity consumption and fugitive emissions were calculated using the bottom up approach. Per capita emissions of MMR were compared with India's per capita emissions. 1970 was chosen as the start year because this was the first year of implementation of Regional Plan I of MMR.

The results showed that MMR has a high share in the national emission inventory. The share of MMR's emissions ranges from 2.24% (minimum) to 4.19% (maximum) of the national emissions. In other sectors (road transportation, fugitive emissions, electricity consumption) also, MMR's per capita emissions were found to be higher than India's.

3.3. MMR's Role In Climate Targets

MMR's current position in achieving the global and national climate targets was determined. Paris Agreement's 2°C target as global target and India's Intended Nationally Determined Contribution (INDC) target as national targets were studied for the purpose.

Paris Agreement aims to limit the global warming to 2°C above pre-industrial levels. In October 2018, IPCC published a special report in which the remaining emission budgets consistent with 2 degrees warming limit were estimated. Four different sharing principles (Inertia, equity, blended and inclusion) were applied to this budget to determine the emission allocation for MMR.

India's INDC aims a 33% to 35% reduction in GHG intensity of GDP of 2005 levels by 2030. This aim was translated into India's emissions and MMR's share in this budget was determined.

These budgets (estimated from Paris Agreement's target and India's INDC target) were compared with MMR's forecasted emissions. It was found that a 16.8% reduction in emissions in the year 2030 was required to meet India's INDC target while an approximately 40% to 46% reduction was required to meet the Paris Agreement's target. Figure 2 shows the emission reduction requirements estimated for both the climate targets. The mitigation rates required to meet the Paris Agreement's target were also calculated. Following are the results:

- Inertia sharing – 1.695
- Equity sharing – 1.967
- Blended sharing – 1.821
- Inclusion sharing – 2.268

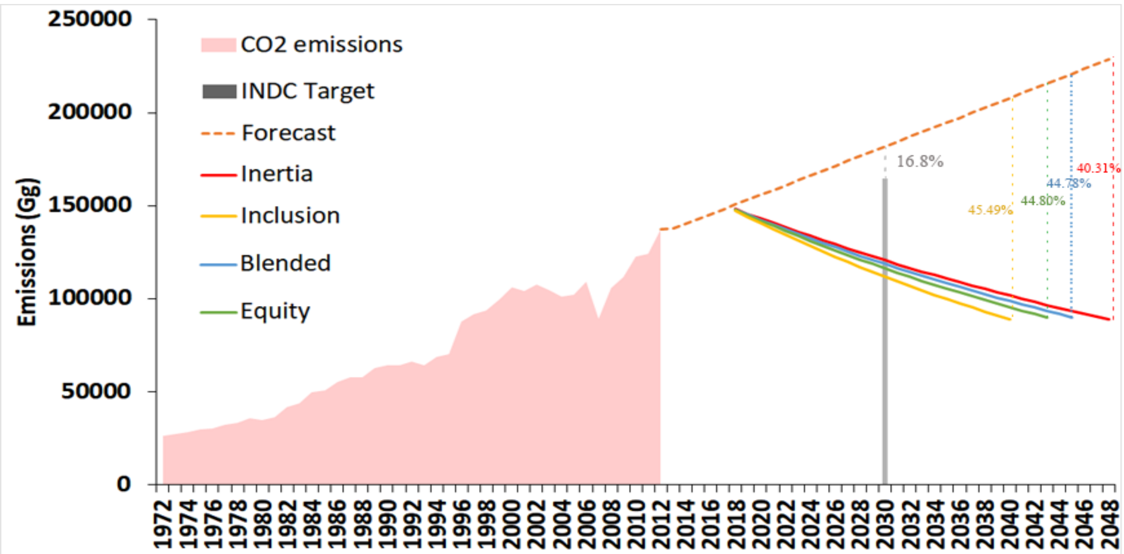

Figure 2 Past emissions and emission reduction required by MMR to meet the climate targets

3.4. MMR's Regional Planning And Greenhouse Gas Emissions

In this part, desk research was done to find the planning components present in MMR's Regional Plans which should be prioritised to reduce region's emissions.

The first step was to determine all the factors which can affect a city's emissions (geography, planning, transportation pattern etc.). In the second step, the factors which can be affected with planning procedures were filtered out of the factors found in the first step (for example planning and transportation etc.). These were called 'Intervention Categories'. These categories were then divided into planning parameters. The next step was to discover which of the components of MMR's Regional Plan contain those parameters. Finally, Analytical Hierarchy Process was used to find out which component of MMR's Regional Plans contain most of these parameters. Pairwise comparison was done using Saaty scale. Following results were drawn:

i. Transportation Strategies, Regional Development Strategy and Development Control have the highest priorities for the purpose of governing climate change.
ii. The parameters that should be focused most are travel mode, travel activity, mixed landuse, population density, energy efficiency and urban functions.
iii. The parameters energy intensity, fuel quality, energy choice, appliance use, waste volume and waste disposal were found to be missing from the regional plan.

3.5. Climate Targets And MMR's Regional Plans: Recommendations And Expected Results

This part presents the final results of the study. Based on different emission reduction goals, three scenarios were proposed.

Scenario 1: Baseline scenario

In this scenario, MMR's regional plan goes with 'business as usual' set-up. It assumes that there are absolutely no new climate policies added to the regional plan.

Scenario 2: Weak Pledges

This scenario is aimed to prepare MMR for India's INDC target.

Target Year: 2030

Target reduction: 16.8% reduction is absolute emissions from current trajectory

Scenario 3: Strong Pledges

This scenario is aimed to prepare MMR for the Paris Agreement's 2 degree target with 67% probability.

Research based recommendations were made for 'Weak Pledges' and 'Strong Pledges' scenarios. To provide empirical support to the recommendations, prospective outcomes of these proposals were also drafted. With incorporation of recommendations in the Regional Plan, CCPI was also expected to change. New mitigation and adaptation CCPIs for both the scenarios was calculated. 4.36 and 4.67 was the new score for mitigation and adaptation CCPI respectively for the weak pledges scenario and 8.04 and 8.06 for mitigation and adaptation respectively for the strong pledges scenario (Figure 3).

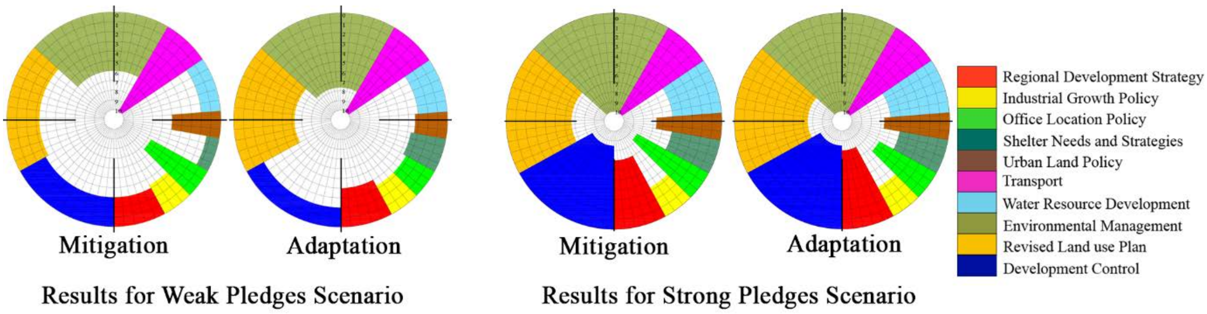

Figure 3 CCPI results for Strong Pledge Scenario

The robust proposals made for the strong pledge scenario were speculated to affect regions' economy. Hence, it was recommended to make use of the 'Clean Development Mechanism' and 'Emission Trading' scheme meant to aid developing countries in governing climate change.

4. Final Conclusion

Planning for Climate Change can have multiple approaches. There are advantages and disadvantages of all the approaches and with context, the impact also changes. Some approaches may condense each other and some may even show potential conflicts. And, when it is about a developing and rapidly urbanizing country, the issues are different and dire. MMR has many priorities including providing facilities to its people, eradicating poverty and ensuring an average standard lifestyle. In such a situation, it is impossible to avoid conflicts between regional priorities and climate change priorities for a long time. The current study has tried to integrate climate change planning into MMR's current planning. Many approaches were applied to reduce emissions and to make the region more resilient. It was observed that some methods are subtle and easy to adopt, while some need a huge change in the planning systems. Some mitigation measures oppose the adaptation measures and vice versa. Also, some ideas are already present in the plans but are weak or are overshadowed by other priorities. That is why, scoring a CCPI 10 is challenging for MMR. However, changes are difficult but not impossible to make. A balance between region's development priorities and climate change priorities can be brought with a strategic shift to mitigation measures and adaptation actions. MMR's planning has a huge scope for adopting climate conscious practices. This study highlights the same in two different scenarios. Results proved that with strong efforts and mitigation actions, MMR can achieve both the climate targets. The recommendations made for both the scenarios were able to score well for mitigation and adaptation CCPI which assures the finding.

The study benefits MMR by providing a base for climate responsive planning in future. It establishes the linkage between climate change protocols and planning policies of MMR and therefore can ensure the adherence of climate priorities in the planning process. It can be used by policymakers and planning professionals in formulating climate change related strategies for the region.

5. Perspective on Future Study

(i) The CCPI score calculated in this study was the author's individual work. However, by involving more experts, a more wholesome research can be done at this level. Also, Regional Plan III needs to be analysed when available.

(ii) In the emission calculation part, only a few sectors were accounted for. For future studies, emissions from other sources can be included in the assessment.

(iii) The scope of recommendations was limited by the 'economic development' aspect which is an explicit collateral damage in governing climate change. If this aspect is governed and guaranteed by other means of policies, new doors will open for climate change research in the region.

CHAPTER 1 INTRODUCTION

1.1 Background

Climate change has become the gravest concern of the developing world. Effects of climate change like changed patterns of temperature and precipitation, unprecedented loss of water bodies, increased incidences of floods and droughts, depreciating public health etc. are frequently encountered. Climate change poses a serious danger to the development process of a nation. The changing climate is at the forefront and is the result of both natural and anthropogenic activities going on since decades. The discovery of anthropogenic activities as one of the reasons for climate change appeared in the late 19th century when Arrhenius, (1889) first discovered the impact of carbon dioxide (CO_2) accumulation on the temperature of Earth. In 1970s this theory started emerging as a concern in the scientific community and in November 1988, World Meteorological Organisation (WMO) and United Nations Environmental Program (UNEP) jointly established Intergovernmental Panel on Climate Change (IPCC) for climate change related research. In June 1992 United Nations Framework Convention on Climate Change (UNFCCC) was formed with an aim to prevent unrestrained human interference with climate system. Currently UNFCCC is the primary body engaged in taking actions for climate change and the scientific knowledge for this purpose is provided by IPCC.

Kyoto Protocol was the first treaty adopted for operating the aim of UNFCCC in 1997. It aimed to set up internationally binding reduction targets for the member countries of UNFCCC (called Parties to the Convention) and came into force in 2005 (UN, 1998). Kyoto Protocol was the result of third Conference of Parties (COP). Two commitment periods were agreed under it; first was 2008-2012 and second was 2013-2020. Post this, Paris Agreement was adopted in December 2015 and it is to come into effect in the year 2020. Paris Agreement is aimed to limit the global temperature rise to 2 °C above pre-industrial levels[3] (UN, 2015a). It differs with Kyoto Protocol in many ways, the most important of which is that Paris Agreement is a bottom up approach to reduce emissions. It requires voluntary pledges from the countries in the form of Nationally Determined Contributions (NDC). As a response to this, countries have to submit their NDCs to UNFCCC specifying the voluntary emission reduction goals and need to communicate their emissions to UNFCCC. With these developments, countries have become agile in taking actions to achieve climate goals in their own capacity. As a result, climate change research has gained attention from every field, and efforts are being taken in every direction to reduce emissions. In the present study, spatial planning was used as a tool to govern climate change issues.

Planning has the capacity to transform the city, region or even the country as a whole. The potential of spatial planning to govern climate change has been explored worldwide (Davoudi, et al., 2009; Davoudi, et al., 2012; Füssel, 2007; Measham, et al., 2011; UN Habitat, 2014). It

[3] The period starting from 1850-1900 is considered the Pre-industrial period.

has emerged as promising directive which involves planners, policy makers and Governments. For the developed countries, the process is easier pertaining to the availability of finances and better technology. However, less developed countries face multiple challenges (UN-Habitat, 2014; World Bank, 2010). Moreover, urbanization, which is a catalyst for the climate related problems (Dodman et al., 2012; Satterthwaite, 2009) is increasing exponentially in developing countries. In 2018, out of the 10 most populated megacities[4], (UN, 2018), 8 were located in the developing countries (Table 1-1) and nine more cities located in the developing countries are projected to become megacities between the year 2018 to 2030 (UN Department of Economic and Social Affairs, 2018). In the developing countries, the already inadequate infrastructure resources are burdened by the ever increasing urban population. Beside this, migration from rural to urban areas is out of control. In such a situation, rapid economic development is required to cater to the growing population of the city, but development happening at the cost of climate change is another major concern for the government.

Table 1-1 List of the world's 10 most populated megacities (in 2018 and 2030)

City, Country	Population ranking in 2018	Population in 2018 (thousands)	Population ranking in 2030	Population in 2030 (thousands)
Tokyo, Japan	1	37,468	1	38,939
Delhi, India	2	28,512	2	36,574
Shanghai, China	3	25,582	3	32,869
Sao Paulo, Brazil	4	21,650	9	28,076
Mexico City, Mexico	5	21,581	8	25,517
Cairo, Egypt	6	20,076	5	24,572
Mumbai, India	7	19,980	6	24,282
Beijing, China	8	19,618	7	24,111
Dhaka, Bangladesh	9	19,578	4	23,824
Kinki MMA (Osaka), Japan	10	19,281		
Source: United Nations, 2018				

The metropolitan regions[5] have emerged as the biggest source of Greenhouse Gas (GHG) emissions (Kamal-Chaoui and Robert, 2009). The Clinton Foundation claims that large cities occupy just 2% of Earth's land, but contribute to 75% of GHG concentration in the atmosphere (Clinton Foundation, n.d.). The unplanned and unregulated expansion of the city boundaries forces rapid inadequate infrastructure, making governing climate change even more difficult. The World Bank (2010) also discusses cities' contribution to climate change.

Many international organizations such as Local Government for Sustainability (ICLEI's), Energy Cities, and C40 are currently promoting the introduction of climate priorities in the planning of a city and are supporting local governments in this direction. The World Bank (2011) recognises the impact that local planning governments have on emissions from the different planning sectors like land use planning, transportation etc. Developed countries have

[4] Megacity: City with a population of more than 10 million people
[5] Metropolitan region: area consisting of one or more densely populated urban core and it's less populated rural surroundings

portrayed a better example in this direction by adopting climate conscious planning practices. For example, London' has achieved a huge reduction in the emission levels; currently approximating to the 1990 level (The World Bank, 2010; Greater London Authority, 2011); New York is seeing a significant drop in GHG emissions (New York City, Mayor's Office of Sustainability, 2017). London, Ontario (City of London, 2017) has achieved a reduction as low as 8% below the 1990 level. However, planning codes and procedures differ depending on regional contexts. Therefore, it is impossible for climatologists and planners to reach one global solution favourable to the governments of different regions (EPA, 2016). The less developed countries face severe challenges because the code and conduct of planning is mitigated by several factors such as poverty, dependence on climate-based resources, and low climate adaptive capacity (Parliamentary Office of Science and Technology: UK, 2006).

In the list of world's most populated megacities, two Indian cities lie on the second and eighth platform in 2018 while there are three more in the most populated 33 megacities (UN, 2018). In 2030, this number is expected to increase to seven. India is projected to add 404 million urban dwellers by 2050 to the world urban population (UN, 2016). Also, many Indian cities especially the ones situated in the coastal regions have started to experience unexpected rain and flooding events. Six Indian cities are in the list of top 100 cities vulnerable to climate change (Broto and Bulkeley, 2012). This raises the need to address climate change issues in the large cities of India.

Mumbai Metropolitan Region (MMR), situated on the western coast of India is the sixth most populous agglomerations in the world. Mumbai, the core city of MMR, lies on eighth platform in the world's most populated megacities (UN, 2018), and is in the list of cities most 'at risk' due to climate related disasters (OECD, 2014). The region is highly significant for the country as it contributes highest to the nation's economy. Mumbai city contributes 5% to the national GDP (Bhagat and Jones, 2013) and MMR contributes 11% to the national GDP (Bahl et al., 2013). Being a coastal region, MMR is highly prone to the risks of climate change. Gupta, 2007; Stecko and Barber (2007) discuss the vulnerabilities of Mumbai's planning system when the city was exposed to floods in the year 2005. Another flooding event occurred in 2017 and similar consequences were seen. On account of this, and other reasons explained in Chapter 2, MMR was taken up as the study area for this research. MMR's priorities, limitations and resources were identified and research was done to incorporate climate change priorities in MMR's current regional planning[6]. The notion is that significant actions at local level will eventually aid in achieving the bigger targets.

1.2 Research Question, Goal and Objectives

In developing countries, the increasing population, migration and a constant need of augmenting infrastructure boils down all the climate mitigation and adaptation actions of the Government to bare ground. MMR is a rapidly urbanizing region in a developing country (India). Owing to the multitudes of social, economic and institutional disadvantages, climate

[6] MMR consists of a number of cities and villages and hence is defined as a 'Region' in India. Hence, regional planning of MMR means 'Spatial planning of the Region MMR' for the context of this dissertation.

change is definitely *not* the top priority of the region. Hence, the study aims to find **how climate-conscious planning can be integrated with the current planning priorities of MMR.**

To find an answer to this question, the present study proposed to examine the existing planning strategies of MMR with respect to climate change priorities. The aim is to suggest a research based planning framework to meet the climate targets by improvising the current plans.

Objectives of the study:

i. To analyse the Regional Plans of MMR for climate change adaptation and mitigation protocols.
ii. To estimate MMR's GHG emissions.
iii. To find the role of MMR in meeting the Paris Agreement's climate target and India's NDC target.
iv. To identify and prioritize planning components that can affect the emissions of MMR.
v. To recommend a planning framework for MMR strategically outlined to meet the climate targets, without altering the current priorities of the region.

1.3 Scope and Limitations

The present study deals with climate aspects which come under the capacity of spatial planning. Institutional Planning or administrative planning is not the scope of this research. While it is known that the boundary between them is sometimes too blur to be distinguished, care was taken in picking the limits in order to be precise with the research outcomes. The results are in the form of planning recommendations with empirical support to the outcomes of the study.

1.4 Research Methodology

The research is partly qualitative; and partly quantitative. It involves field work, interviews and discussion with stakeholders, MMR's regional plans as primary data; while Government reports, policy documents, census data, spatial plans and literature studies as secondary data.

Questionnaire survey and interviews were conducted in the field visits for data collection and making communication with key persons. Planning related discussions were held with officials in local and regional planning authorities in MMR and emission related discussions were held with officials of the Ministry of Environment, Forest and Climate Change. This served in designing the research background. The main work done was the analysis part. MMR's planning and climate change aspects were analysed first. For planning aspect, MMR's regional Planning was studied and for the climate aspects, MMR's emissions were calculated and global and national climate targets were studied. Ahead of this, the study was done to understand that how the climate aspects can be integrated in MMR's planning. With each step in the process, field visits were conducted to ensure that the research progresses in the right direction. Finally, research based recommendations were made for MMR.

Recommendations were divided into two part, each of which aimed for one climate target for MMR. Figure 1-1 shows the work-flow of the research process.

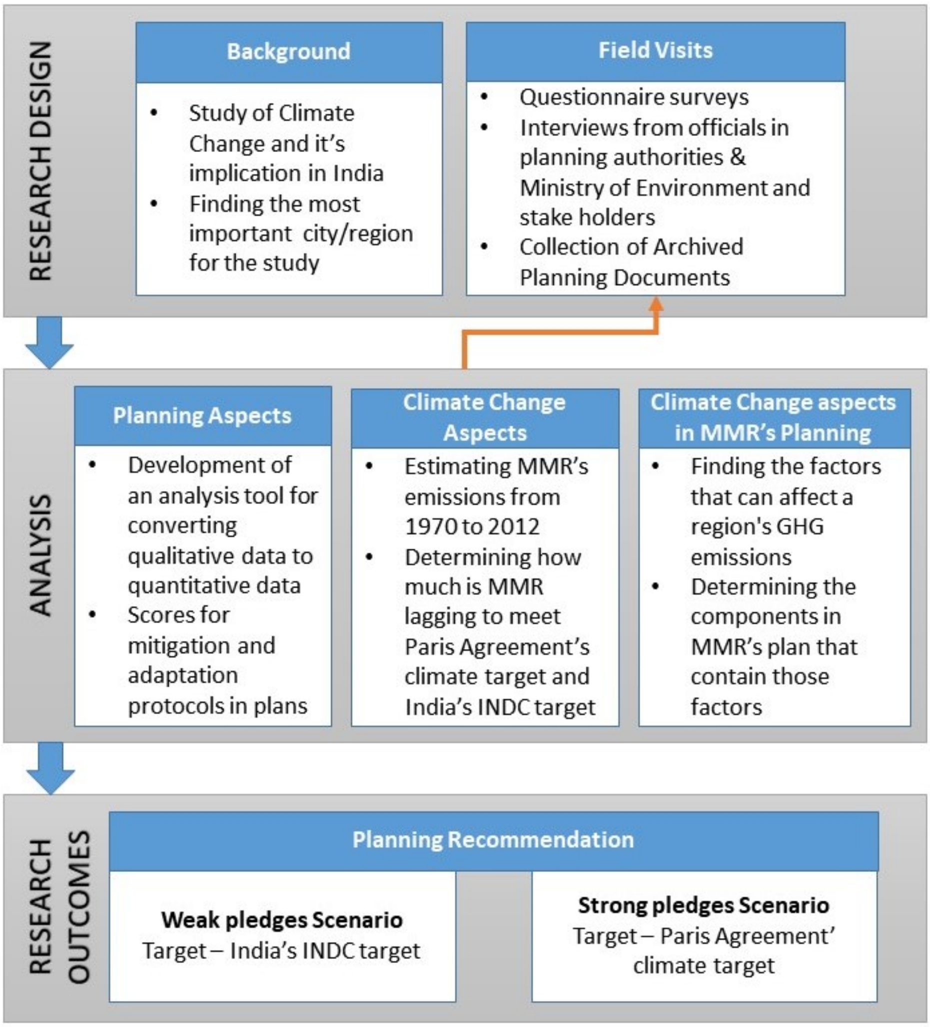

Figure 1-1 Conceptual workflow of the study

1.5 Structure of Dissertation

This dissertation consists of three main parts (Figure 1-2). The first part contains chapter 1 and 2 and introduces the overall research and the study area. Chapter 1 consists of background, research question and objectives of the study. Chapter 2 provides details of the study area and provides state of the art knowledge about climate change and planning in the study area.

Second part consists of chapter 3 to 6 and presents description of analysis done for the study. The first section in this part includes Chapter 3, 4 and 5 where, Chapter 3 presents the analysis of MMR's current planning with respect to climate change priorities. A new tool called Climate Change Planning Index has been developed to analyse the Regional Plans. Next, Chapter 4 provides estimation of GHG emissions in MMR. Emissions from different sectors are determined and comparison with national emissions is presented. Chapter 5 presents the analysis of MMR's role in global and national climate targets. MMR's emission forecast was compared with climate targets and research was done to find that how much reduction in emissions is required to meet the targets. These chapters provide a descriptive analysis of current situation of MMR from planning and climate change perspective. The second section (Chapter 6) in this part presents the analysis of potential of MMR's Regional Plan to deal with climate change issues in future. In this section, planning parameters that can affect a region's emission were found and then their presence in MMR's regional plan was investigated.

The third section consists of Chapter 7 which provides planning recommendations to meet the climate targets. Strategies to make the Regional Plans climate efficient; aiming to meet the global and national climate targets are presented separately. This section uses outcomes of all the previous chapters and provides the final result of the study.

Further on, Chapter 8 is the final chapter that summarises the study. It presents brief of each chapter and key issues in MMR's planning observed in the process. Final conclusions and perspective for future study are also presented in this chapter.

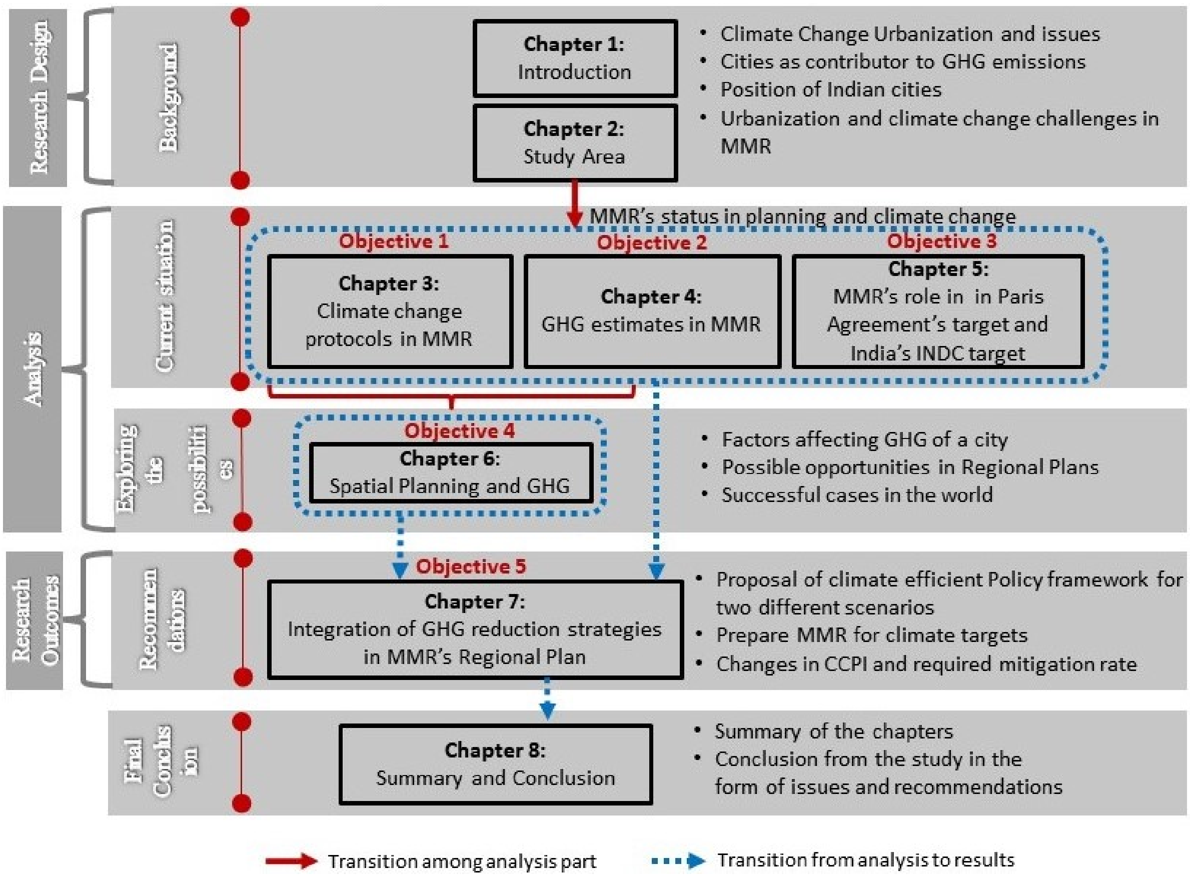

Figure 1-2 Structure of dissertation

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CHAPTER 2 DESCRIPTION OF THE STUDY AREA

2.1 Addressing Climate Change: National Circumstances

India with 3.28 million sq. km. of land has diverse geographical features. It contains great mountains (Himalayas), Plains, Peninsular plateau, coastal plains and islands. In 2.4% of the world's land area, it covers 16.2 percent of the world's population (MOEF, 2004). Figure 2-1 shows the location of the ten most populated cities in India and Table 2-1 shows the population of these cities in the year 2000, 2018 and the projected population in 2030. It also shows the annual rate of change of population and their proportion with the country's total and urban population in 2018 (United Nations, 2018). These ten cities of India occupy 0.1% of the land area of the country and contain 8% of the country's population. And with this, they are expected to produce 15% of the national GDP in total (IIHS, 2011). Table 2-1 also shows the contribution of these ten cities in the national GDP for the year 2011. The table shows that Delhi was the most populated city in 2018 and 2030, but the rate of change in population after 2018 is expected to decline. On the other hand, Mumbai is expected to continue growing in population which will result in making Mumbai the most populated city of the country in recent future. Mumbai is also the commercial and financial capital contributing the highest percentage of country's economy (Table 2-1).

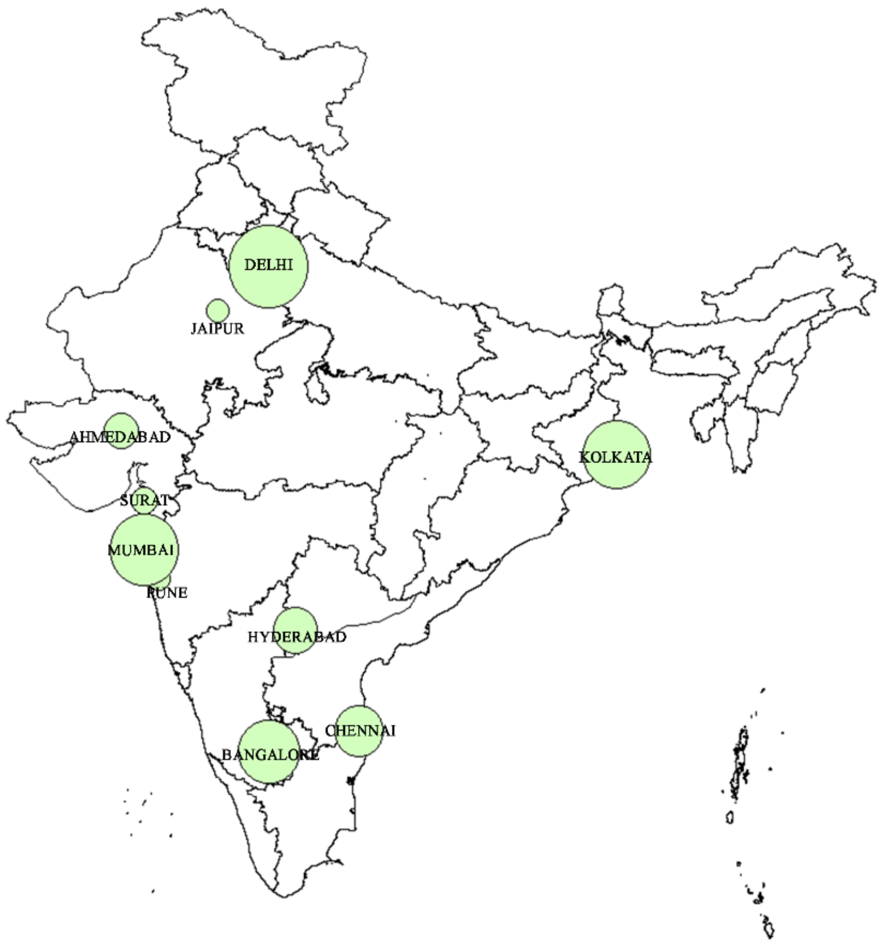

Figure 2-1 Location of 10 most populated cities in India

Table 2-1 List of the India's 10 most populated cities and their GDP

City	City Population in thousands			Avg. Annual rate of Change		City Population as % of country's total or urban population in 2018		2011 #GDP (PPP) in million USD
	2000	2018	2030	2000-2018	2018-2030	Total Population	Urban Population	
Delhi	15,692	28,514	38,939	3.3	2.6	2.1	6.2	167
Mumbai	16,147	19,980	24,572	1.2	1.7	1.5	4.3	209
Kolkata	13,097	14,681	17,584	0.6	1.5	1.1	3.2	150
Bangalore	5,581	11,440	16,227	4.0	2.9	0.8	2.5	83
Chennai	6,593	10,456	13,814	2.6	2.3	0.8	2.3	66
Hyderabad	5,650	9,482	12,714	2.9	2.4	0.7	2.1	74
Ahmedabad	4,815	7,681	10,148	2.6	2.3	0.6	1.7	64
Surat	2,706	6,564	9,711	4.9	3.3	0.5	1.4	40
Pune	3,667	6,276	8,442	3.0	2.5	0.5	1.4	48
Jaipur	2,258	3,717	4,943	2.8	2.4	0.3	0.8	

Source: United Nations, 2016. The World's Cities in 2018
Source: Maps of India, 2015

In the last century, these ten cities have seen major changes in the urbanization pattern. A few cities which were least populated and were seeing a decrement in the population in 1900s have now made it to the list of most populated cities of the country (Census of India, 2011). The change in urbanization pattern is due to a number of factors. Figure 2-2 shows the graph with X axis showing the change in pattern from the year 2001 to 2011 and Y-axis showing the change in the year 1901 to 1911. The graph shows that Surat and Jaipur were showing a negative trend of population in the 1900s. But a century later, the two cities are on the eighth and tenth platform in population respectively. A total of 2 million of population was added to the cities in a span of 100 years, which has contributed to this remarkable change. In the 1900s, while Pune and Chennai were urbanizing very slowly, Kolkata was the fastest in urbanization, followed closely by Mumbai. But in the last decade, Delhi has seen the fastest rate of urbanization. Bangalore is the second in the rate of change in pattern; however it lies fourth in population ranking.

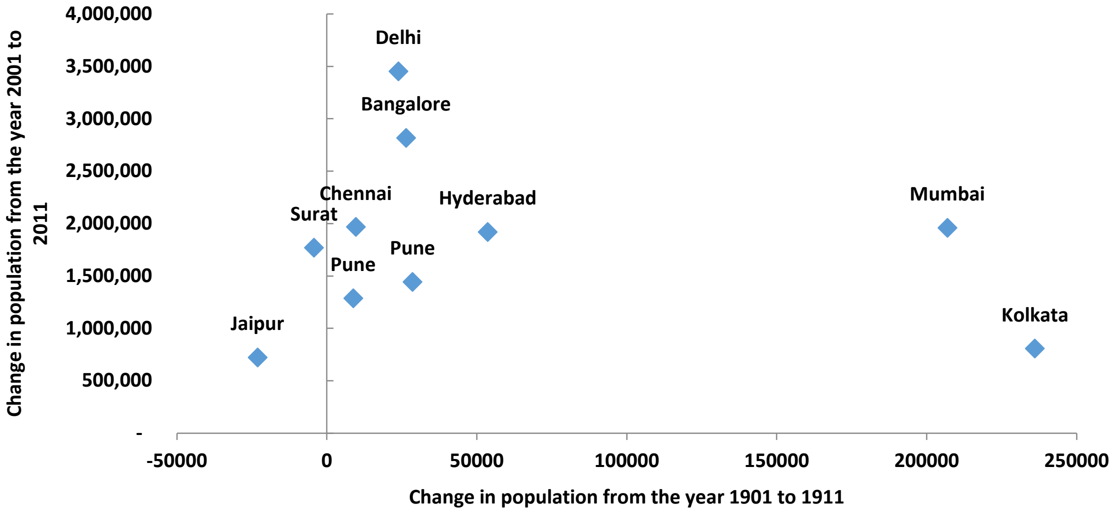

Figure 2-2 Change in population pattern from 1901 – 1911 to 2001-2011

Figure 2-3 shows the share of population (left) and number of occurrences of climate change related disasters (right) in these ten cities from 2012 to 2016. Floods, hail storms, heat waves, droughts and wild fires are the most common type of climate related disasters witnessed in these cities. The list of climate change related disasters in India was taken from EM-DAT, The International Disaster Database, Centre for Research on the Epidemiology of Disasters (EM-DAT, n.d). It can be seen that Delhi and Surat, the two cities suffered from no major climate related disaster in these years while the other cities have suffered from at least one major incident of such disasters (Recent natural Disasters, 2016). The graph shows that Mumbai has the highest frequency of such disasters with flash floods and continues heavy rains being the most recurrent ones. Hyderabad suffers most from heat strokes while Chennai and Kolkata are the worst sufferers of heavy showers. Moreover, World Bank (2010) alleges that large cities, especially the coastal cities of the world, will be the most affected by climate change.

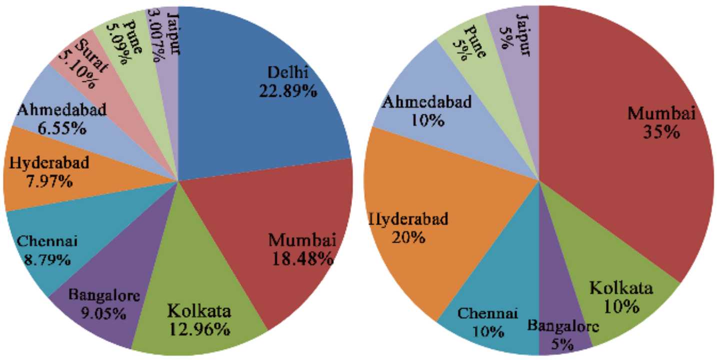

Figure 2-3 Share of population (left) and number of occurrences of climate change related major disasters (right)

2.1.1 United Nations Framework Convention on Climate Change (UNFCCC) and India

UNFCCC secretariat was established in 1992 when countries adopted an international environment treaty to stabilize the Greenhouse gas proportions in the atmosphere to prevent interference with the Earth's climate system (UNFCCC, About the Secretariat. n.d.). All the countries which are parties to UNFCCC are required to communicate their greenhouse gas inventory to the secretariat. India signed UNFCCC on 10 June, 1992 and henceforth is a party to UNFCCC (UNFCCC, India. n.d.). Ministry of Environment, Forest and Climate Change (MOEFCC) [7], Government of India, is the apex body of the central government, which is responsible to develop, periodically update, publish and report India's Greenhouse Gas (GHG) emissions to UNFCCC (MOEFCC, 2015a). The Indian Network for Climate Change Assessment (INCCA), which was launched in 2009, is an organization under MOEFCC, comprising research institutions, scientists, and government bodies that monitor and report emission records of the country (MOEFCC, 2010). These emissions inventories are communicated to UNFCCC by MOEFCC in the form of National Communication Reports (MOEF, 2004; 2012), Emission

[7] The Ministry of Environment, Forest and Climate Change (MOEFCC) was formerly known as Ministry of Environment and Forest (MOEF) or Ministry of Environment. The documents published by the MOEFCC might include the MOEFCC, MOEF, or Ministry of Environment as authors. Regardless of the different names, the author is the Ministry of Environment, Forest and Climate Change (MOEFCC) because as of 12 May, 2019, it known by this name.

Reports, Biennial Update Reports (MOEFCC, 2015b; 2018), and Intended Nationally Determined Contribution (INDC) (MOEF, 2004; 2010; MOEFCC, 2015c). Table 2-2 lists these communications with brief information about each document.

Table 2-2 Timeline of India's communication to UNFCCC with brief information

Date	Name of the Report	Description	Methodology Employed	Key Results	
16-Jun-2004	India's Initial National Communication to the UNFCCC Source: MOEF 2004	Information on National Circumstances, Greenhouse Gas emissions for the year **1994,** Vulnerability Assessment and Adaptation and National Infrastructural for combating Climate Change; to be submitted by all Non Annex-1 parties as a fulfilment of commitment to UNFCCC	IPCC 1996 guidelines -Tier 1, 2, 3 approaches	Net emissions = 1228540 Gg Per capita emissions = 0.87 t-CO2 (4% of US, 23% of Global Average)	
				CO2-793490 Gg (65%) CH4-18,083 Gg (31%) N2O-178 Gg (4%)	Energy-743820Gg (61%) IPPU[1]- 102710Gg (8%) Agriculture-344485Gg (28%) LULUCF[#]-14292Gg (1%) Waste-23233 Gg (2%)
Aug-2008	India's Second National Communication to the UNFCCC – Work Programme Source: MOEF 2010	Information on work program on India's Second National Communication to UNFCCC; national GHG inventory of year **2000** Summary of Initial National Communication	IPCC 1996 and IPCC 2006		
May-2010	India: Greenhouse Gas Emissions 2007 Source: MOEF 2010	Report on India's GHG emissions for the year **2007** Prepared by INCCA (Indian Network on Climate Change Assessment) Identified 17 key categories (sectors responsible for maximum GHG emissions)	Revised IPCC guidelines for National GHG inventory; IPCC good practice guidance & Uncertainty Management in national GHG Inventory; IPCC Good Practice Guideline for LULUCF[#]	Net emissions = 1727706.10 Gg (1.5 tons/capita)	
				CO2-1221760 Gg CH4-20560Gg N2O-240Gg	Energy-1100056.89Gg (58%) IPPU[1]- 412546.53Gg (22%) Agriculture-334405.50Gg (17%) LULUCF[#]-177028Gg (sink) Waste-57725.18Gg (3%)

12-Apr-2012	India's Second National Communication to UNFCCC Source: MOEFCC 2012	Information on National Circumstances, Greenhouse Gas emissions for the year **2000,** Vulnerability Assessment and Adaptation Climate Change Projections, Impact Assessments, Programs related to Sustainable Development; to be submitted by all Non Annex-1 parties as a fulfilment of commitment to UNFCCC	The PRECIS* regional climate modelling system is used to analyse climate scenarios for the period 1961-1990 (baseline) and three time slices: 2020 (2011-2040), 2050 (2041-2070), 2080 (2071-2098) Revised IPCC guidelines 1996, IPCC good practice guidance 2000, 2003; IPCC Good Practice Guideline for Land Use, Land use Change and Forestry 2003 Some default emission factors from IPCC 2006; Tier 1, 2 and 3 approaches used depending on data availability	Net emissions = 1027015.54 Gg CO_2 eq. Climate Change predictions: No significant decrease in rainfall except parts of southern peninsula rise in monsoon rainfall towards the end of the century All-round warming of the Indian subcontinent Annual mean surface temperature rise from 3.5 to 4.3 degrees CO2-1024772.84 Gg (67.25%) CH4-19944.68Gg (26.73%) N2O-264.16 Gg (5.24%) HFC-0.220 (0.34%); CF4-0.870 and C2F6-0.087 (0.42%); SF6-0.013 (0.02%) Energy-1,027,015.54Gg (67.4%) IPPU[1]-88,608.07 Gg (5.8%) Agriculture-355,600.19 Gg (23.3%) LULUCF#-222,567.43 Gg (net sink) Waste-52552.29 Gg (3.4 %)
Oct-2015	India's Intended Nationally Determined Contribution Source: MOEFCC 2015c	Report on India's contribution for GHG reduction; to be submitted to UNFCCC by all the countries who are parties to UNFCCC First contribution of a country towards reduction of GHG emissions after acceptance, approval of the Paris Agreement		Detailed explanation of all the policies and strategies on national and state level for combating climate change Mitigation strategies; Adaptation strategies; Financial Infrastructure and their means of Implementation
22-Jan-2016	India's First Biennial Update	Reports to be submitted by all Non-Annex 1 parties for reporting the low	Revised IPCC guidelines for National GHG inventory; IPCC	Net emissions = 1884309.46 Gg List and explanation of National policies and National and state level strategies

	Report to the UNFCCC Source: MOEFCC 2016	carbon developments of the country to UNFCCC Contains information on GHG inventory for **2010,** mitigation actions, National Infrastructure and Financial, technological or capacity building support needed as well as received	good practice guidance & Uncertainty Management in national GHG Inventory; IPCC Good Practice Guideline for Land Use, Land use Change and Forestry	CO_2-1,574,362 Gg (74%) CH_4-412,086 Gg (19%) N_2O-114,365 Gg (5%) Halogenated gases-36,026 Gg (2%)	Energy-1510120.76Gg (%) IPPU[1]-171502.87 Gg (%) Agriculture-390165.14 Gg (%) LULUCF[#]-252531.78 Gg (net sink) Waste-65052.47 Gg (%)
31-Dec-2018	Second Biennial Update Report to UNFCCC Source: MOEFCC 2018	An update to the national GHG inventory for **2014** by sectors	IPCC guidelines (Revised 1996 and 2006) provide estimation methodology. Tiers of estimates range between Tier 1 and Tier 3. Both default and country-specific emission factors have been employed.	India emitted 2,607,488.12 Gg of CO_2e LULUCF[#] was a sink 3,01,192.69 Gg of CO_2 e net emissions were 2,306,295.43 Gg of CO_2e	
				CO_2-20,15,107.88 Gg CO_2 removal-3,19,860.23 Gg CH_4-20,005.35 Gg N_2O-475.29 Gg HFC 23 -1.59 Gg CF_4- 0.71 Gg C_2F_6- 0.004 Gg SF_6-0.004 Gg	Energy-19,09,765.74Gg (73%) IPPU[1]-202,277.69 Gg (%) Agriculture-417,217.54 Gg (%) LULUCF[#]-3,01,192.69 Gg (net sink) Waste-78,227.15 Gg

IPPU[1] - Industrial processes and product use
LULUCF[#] - Land Use, Land Use Change and Forestry
PRECIS[*] - Providing Regional Climates for Impact Studies

2.2 Mumbai Metropolitan Region (MMR)

MMR is a metropolitan region with an area 4,311.75 sq.km built around Mumbai city at the core and is sixth largest urban agglomerations in the world. The population of MMR is 22,804,355 (MMRDA, 2017). It is located on the western coast of India in the state of Maharashtra (Figure 2-4 (a)). It comprises of five districts of the state (Figure 2-4 (b, c)), of which two districts are fully contained in MMR's boundaries, while only a part of other three districts is contained in MMR's boundaries (Figure 2-4 (d)). MMR includes 8 Municipal

Corporations, 9 Municipal Councils, and more than 1,000 villages (Directorate of Economics and Statistics, 2016). The boundary of MMR has been modified several times in the past.

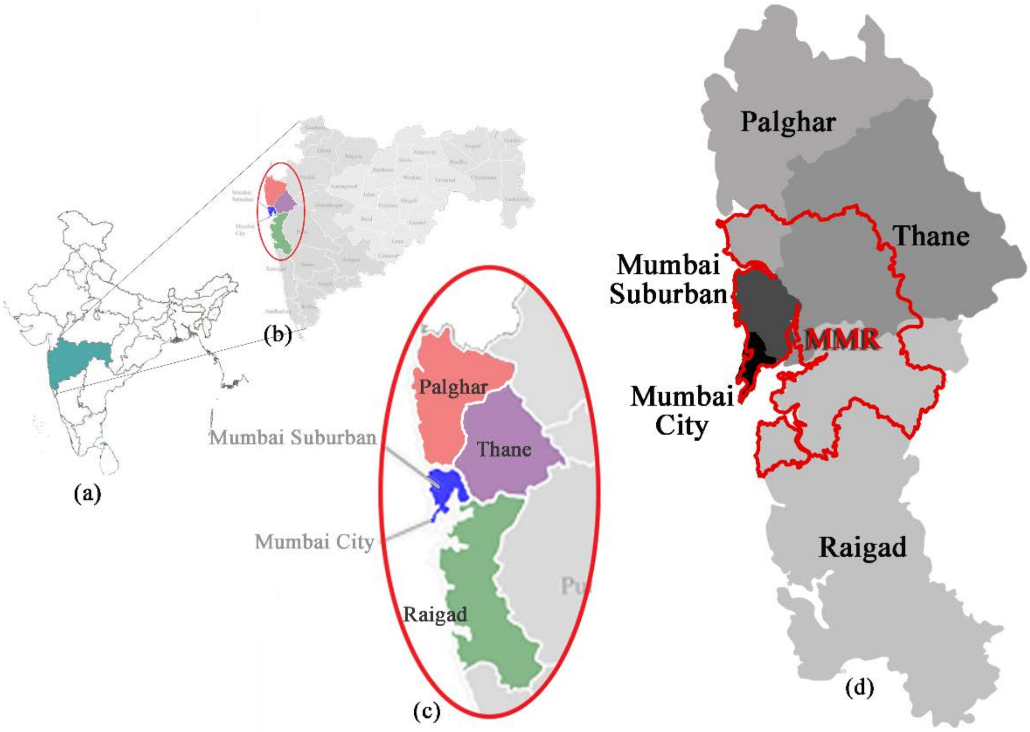

Figure 2-4 (a) Location of the state of Maharashtra; (b) location of the five districts comprising MMR in Maharashtra; (c) zoomed in image of the five districts; (d) MMR's boundaries

The present boundary of the region consists of districts subdivided into tehsils[8] and villages. Following is a list of the current major units of MMR (MMRDA, 1996a; MMRDA, 2016):

1. Mumbai City District
2. Mumbai Suburban District
3. Parts of Thane District
   (a) Thane, Kalyan, Bhiwandi, and Ulhasnagar Tehsil
   (b) Vasai Tehsil
4. Part of Raigad District
   (a) Uran Tehsil
   (b) Panvel, Karjat, Khalalpur, Pen, and Alibagh Tehsil
5. Part of Palghar District

The region has a long coastline of 840 km, which makes it highly prone to the events of floods and sea level rise. Kumar et al., (2008) deduced the development of construction zones in the floodplains and coastal areas as the reason. The pie charts in Figure 2-3 depicts that Mumbai city with 18.48% share of the national population in 2011 has the highest share of climate related disasters. As a coastal city, Mumbai is also prone to sea level rise, as heavy rains are a

[8] Tehsil: An administrative sub-division of districts as per Government of India

routine during monsoons. The Mumbai floods of July 2005 are an irrefutable example of insufficient planning standards. Unabated illegal construction in coastal areas and clogging of drains for various reasons were identified as the reasons for the catastrophe. The British daily newspaper, The Guardian (2014), predicts a similar flood occurrence in Mumbai before 2080, and remarks that the city is still not ready to face the challenge.

2.2.1 Urbanization in MMR

Population growth in MMR has been remarkable. Greater Mumbai which is the core city of MMR, is a hub of commerce and trade. This contributed towards the rapid urbanization of MMR. Figure 2-5 shows the location of different Urban Agglomerations (UAs) in MMR and Table 2-3 shows their population from 1901 to 2011 (Census of India, 2011). Greater Mumbai (Mumbai city) has always been more populated than the other UAs (Figure 2-6). It can be seen that until 2001, the population of greater Mumbai has been at a constant rise; however, after this, a downward slope is evident. In addition, the population of other cities demonstrates an upward slope from 1960s (Figure 2-6).

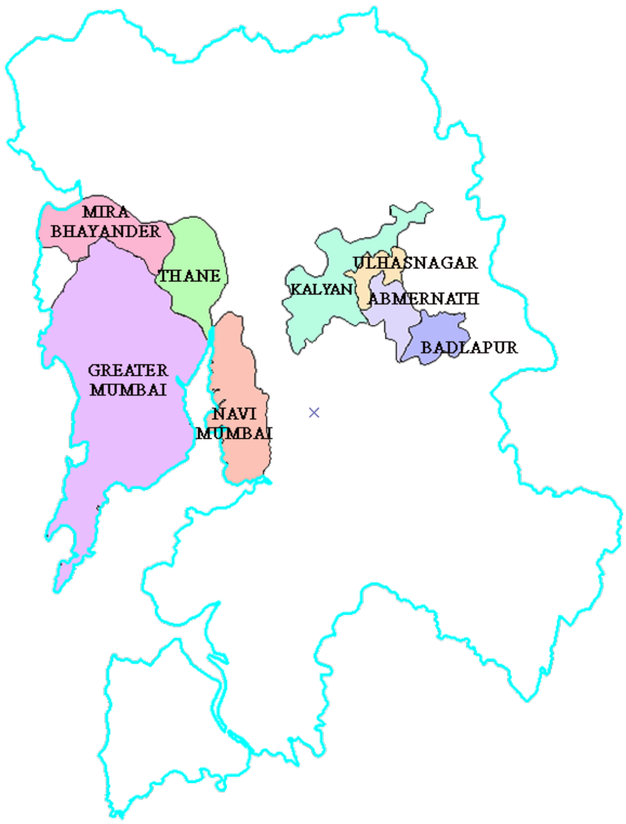

Figure 2-5 Location of Urban Agglomerations of MMR

Table 2-3 Population of UAs of MMR from 1901 to 2011

City	Greater Mumbai UA	Greater Mumbai	Mira Bhayandar	Thane	Navi Mumbai	Kalyan-Dombivali	Ulhasnagar	Ambarnath	Badlapur
1901	839,672	812,912		16,011		10,749			839,672
1911	1,046,579	1,018,388		15,591		12,600			1,046,579
1921	1,285,402	1,244,934		22,639		17,829			1,285,402
1931	1,316,413	1,268,306		21,816		26,291			1,316,413
1941	1,747,234	1,686,127		29,751		31,356			1,747,234
1951	3,216,904	2,966,902	6,327	74,310		67,006	80,861	21,498	3,216,904
1961	4,515,495	4,152,056	6,974	109,215		104,981	107,760	34,509	4,515,495
1971	6,596,370	5,970,575	10,598	207,352		178,404	168,462	56,276	6,596,370
1981	9,421,962	8,243,405	25,646	431,667	8,062	343,167	273,668	96,347	9,421,962
1991	12,596,243	9,925,891	175,605	803,389	307,724	1,014,557	369,077		
2001	16,434,386	11,978,450	520,388	1,262,551	704,002	1,193,512	473,731	203,804	97,948
2011	18,394,912	12,442,373	809,378	1,841,488	1,120,547	1,247,327	506,098	253,475	174,226

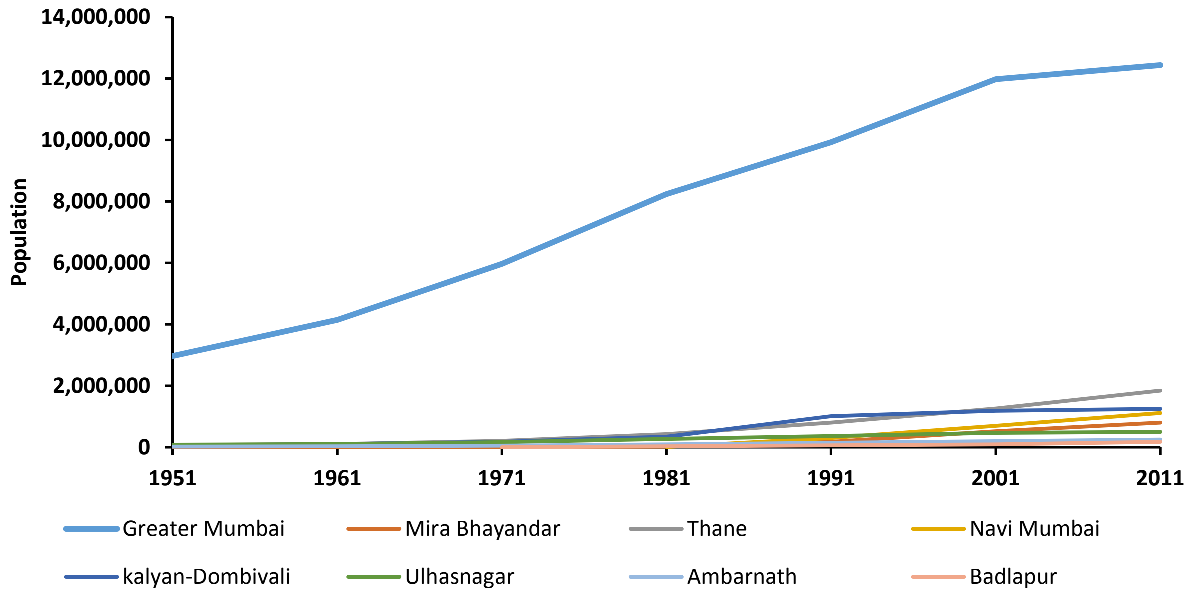

Figure 2-6 Population trend in UAs of MMR

Increasing urbanization in MMR was studied with the help of the GIS-generated land use maps shown in Figure 2-7. LANDSAT imageries downloaded from earth Explorer were employed for the years 1989 (December), 1998 (February), 2008 (October), and 2016 (December). In particular, the imagery with no external intervention was selected for each year to prevent error in the analysis. After pre-processing, maximum likelihood classification was performed to determine the land cover.

It can be observed that in the past, Greater Mumbai was the centre of urban land cover. However, as it started showing signs of saturation, the urban land cover began spreading to the surrounding region, mainly concentrated in Thane and Kalyan, also extending to the New Mumbai and Panvel. Figure 2-8 graphically shows the increasing proportion of urban cover in MMR. The trend line in the figure provides evidence of the exponential increase in the share of urban over other land uses. It is to note however that the landuse map of the year 2008 shows highest percentage of forest (Figure 2-7) compared to others. The reason for this anomaly is the seasonal variation in the region. The rainy season in MMR starts from June and ends in the month of September which is speculated to be the reason for higher share of forest cover detected in the analysis.

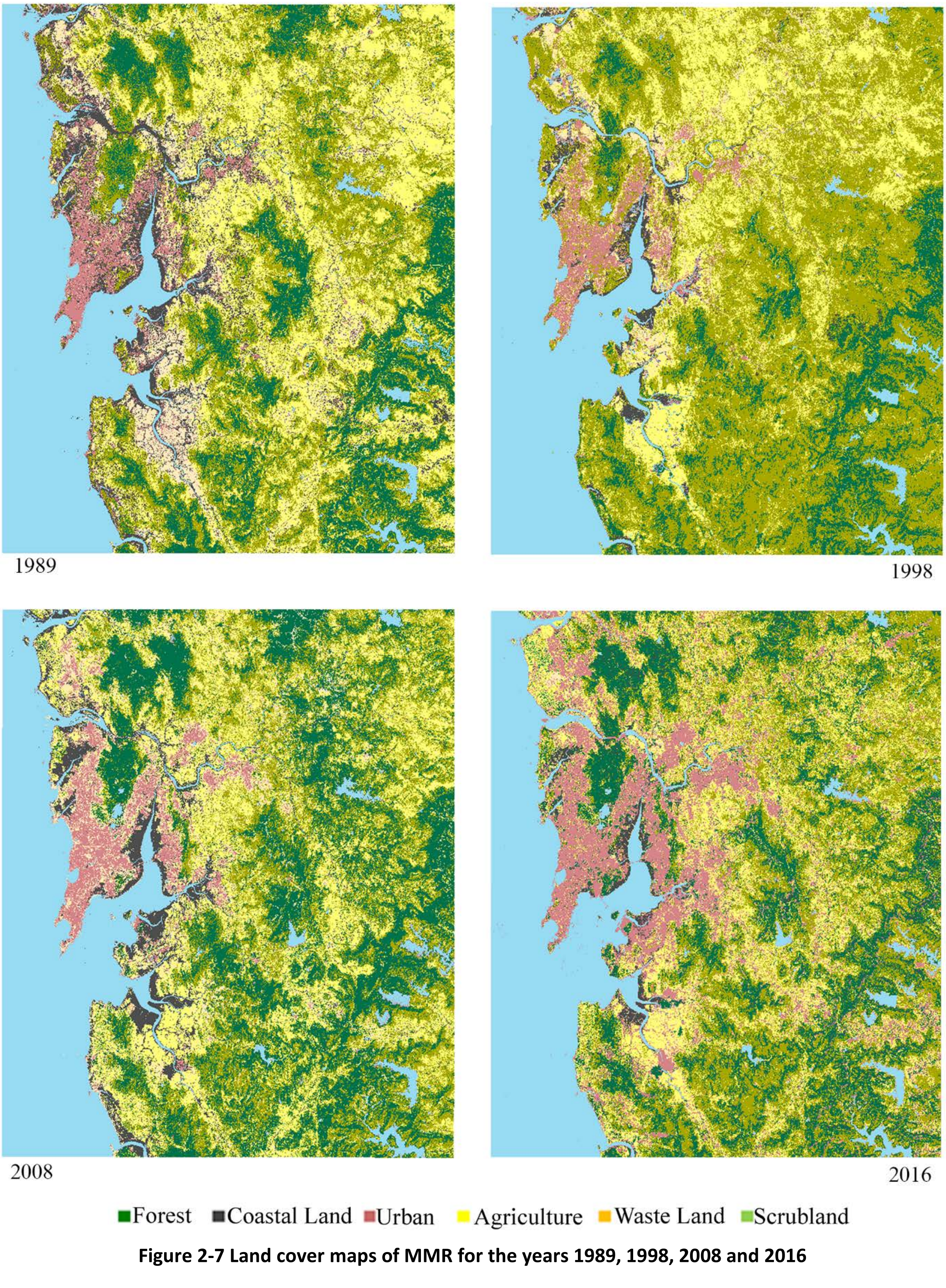

Figure 2-7 Land cover maps of MMR for the years 1989, 1998, 2008 and 2016

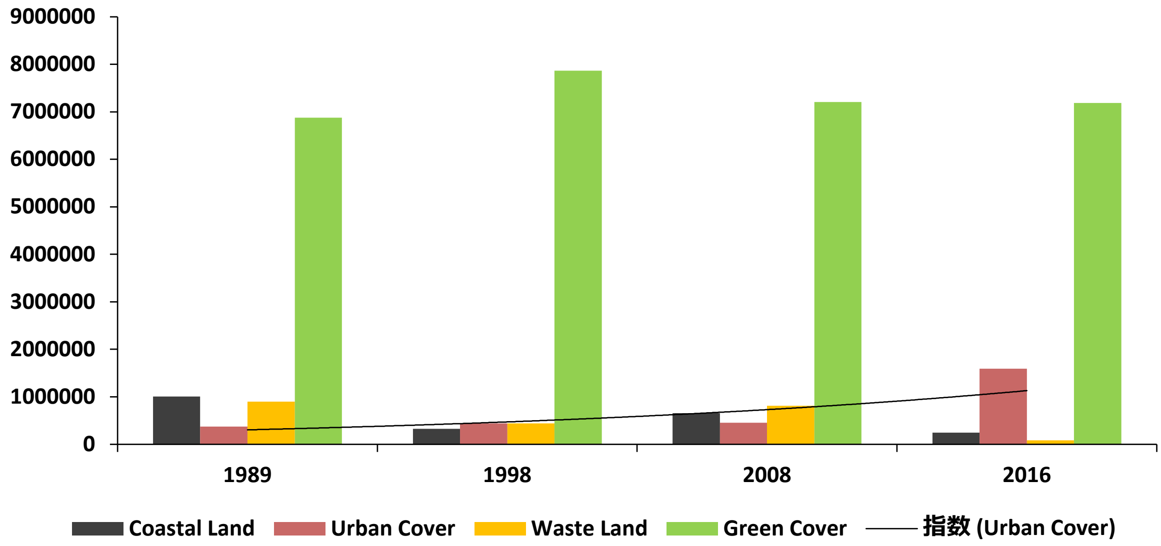

Figure 2-8 Land cover share by different land types

2.2.2 Urbanization Challenges

Currently, MMR is facing multitude of urbanization disadvantages like urban poverty, growing informal sector, electricity shortage, and poor sanitation. The never-ending land requirements are being addressed through the conversion of green zones, flood plains, saltpans, watersheds, and coastal areas into construction zones, which has become common practice. The increasing energy requirement for infrastructure (transport, water supply, electricity, sanitation) is mainly fulfilled by burning fossil fuels. The overall average consumption of fossil fuels worldwide is decreasing; however, that for India is continuously increasing (The World Bank Data, 2017). Quarrying is a major means to obtain the raw material needed for construction (Bombay Metropolitan Regional Planning Board, 1973; MMRDA, 1996b; MMRDA, 2016). Furthermore, the solid waste management system is not regularly updated to cater to these increased demands (Kumar et al., 2009) and the insufficient drainage system adds to the problems of residents (Patil and Shekdar, 2001). The already deficient storm water drains are further blocked by the solid waste produced by the increasing population. The combined effect is a damaged environmental system, the consequence of which is seen in the form of floods and other extreme unexpected weather systems.

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CHAPTER 3 CLIMATE CHANGE PROTOCOLS IN MMR's PLANNING-DEVELOPMENT OF A NEW PLANNING INDEX

3.1 Introduction

While planning is acknowledged as a solution to uncontrolled urbanization (Wahlgren et al., 2010; Taylor, 2012); studies confirm the significant role of spatial planning in shaping the strengths and weaknesses of a region's future with respect to climate change (Antonson et al., 2016; Baettig et al., 2007; Biesbroek et al., 2009; Biesbroek, et al., 2010; Davoudi et al., 2009; Hamin and Gurran, 2009; Wilson and Piper, 2010). Roggema (2016) talked about the issues of urban regions due to climate uncertainities. Chang et al., (2014) proposed a Climate Change Index which indicated the degree of susceptibility of a region to climatic extremes. Boswell, et al., (2012) established how embedding climate action plans in local plans has proven to be beneficial in US. In many researches, climate change planning has received attention (Baynham and Stevans, 2012; Hurlimann and March, 2012; Kamal-Chaoui and Robert, 2009) but even then, a universal tool that fits all contexts has not been discovered. Wilson (2007) emphasized the lack of cooperation between planning and climate change professionals as the reason for inadequate climate adaptation actions at local level. Hence, this study tries to bring the two fields together. In this chapter, MMR's planning was analysed with climate change criteria. The aim was to find that how responsive the Regional Plans are with respect to climate priorities of the region. It was an attempt to examine and discuss the following questions;

i. How important are climate change issues in MMR's local planning?
ii. How do the local plans try to cater to climate priorities?
iii. With the growing need of economic development, how MMR's balances the climate related priorities?

To find an answer to these questions, MMR's planning strategies were examined by analysing the Regional Plans. A new tool, namely the Climate Change Planning Index (CCPI) was designed to evaluate planning documents for mitigation and adaptation protocols. The purpose was to find the relation between MMR's plans and climate priorities. The index was basically designed to translate this qualitative relation into quantitative scores. A series of steps was followed to reach the final result, which was in the form of a mitigation score and an adaptation score. These scores depict the strength (or weakness) of mitigation measures and adaptation measures in the planning documents. The results were expressed as sunburst graphs, which made the results easy to interpret.

Note: The definition of planning and related terms vary with different countries and contexts. In India, Ministry of Home affairs, Government of India defines most of the terminologies. Definition of certain terms to be used in this study is given below:

- In India, a place with a municipality, corporation, cantonment board or notified town area committee; or a place with population of 5000 or more, at least 75% males engaged in non-agricultural occupations, a population density of at least 400 persons per sq.km. is known as an urban area (Census of India, 2011 a).

- A place which is not urban is known as a rural area (Census of India, 2011 b).
- According to Hall and Tewdwr-Jones (2011) 'spatial planning' is refers to planning of a space with a spatial or geographical component in which the general objective is to provide a spatial structure of activities (also known as physical planning). It may take place on a local, regional, national or inter-national scale.

Also, as defined in section 2.2, MMR consists of urban as well as rural areas and hence, for this study, Regional Planning of MMR means spatial planning at a regional scale involving disciplines like land use, urban renewal, regional, transportation and community planning.

3.1.1 MMR and Climate Change Governance

At the state level, The Government of Maharashtra possesses a State Adaptation Action Plan prepared by The Environmental Research Institute (TERI) (2014a). As per the Maharashtra Municipal Corporation Act 1949 (Government of Maharashtra, 1949), it is mandatory for all Urban Local Bodies (ULBs) to submit an annual Environment Status Report (ESR). Thereafter, MMR, possesses an ESR, developed by TERI (TERI, 2014b) which is a statement of MMR's environmental indicators like water resources, air quality, climate variability, and land resources. The report provides general recommendations and stresses the need of integrating climate related policies in the planning process.

3.2 History of Regional Planning in MMR

By the mid-19th century, the explosion of the population and industries followed by land scarcity crowded Greater Mumbai (formerly known as Greater Bombay[9]) and ended up in making the system unmanageable. This resulted in rapid growth of the city's informal sector. In 1958, Government starting considering solving the planning problems in Bombay. A Development Plan for Greater Bombay was prepared in 1964 which came into effect in 1967. However, it was being increasingly realised by the Government that only a city development plan may not be enough for surpassing this situation. Hence, in March 1965, the Government set up a committee headed by Dr. D.R Gadgil, (who served as Deputy Chairman of Planning Commission of India) for the purpose. This committee known as the Gadgil Committee suggested preparing Regional Plans for different regions (Bombay, Poona, and Nagpur) in Maharashtra. Almost simultaneously Government started drafting legislation for Maharashtra Regional and Town planning act 1966 which came into force in 1967. This enabled the concept of 'Regional planning' in the state and authorised the constitution of Regional Planning Boards, land acquisition and other relevant objectives for the development of the state (Government of Maharashtra, 1966).

Hereafter, Bombay Metropolitan Region was notified by the Government and a Bombay Metropolitan Regional Planning Board (BMRPB) was established in June 1967 (BMRPB, 1973)

[9] Bombay was the English name of the city by British East India Company. In the regional language (i.e. Marathi) the city was always called 'Mumbai' after Mumbadevi, the stone goddess of the deep sea fisherman who originally lived on the islands. In 1995, the name of Bombay was officially changed to Mumbai. Greater Bombay is hence Greater Mumbai.

by the State Government. BMRPB formulated draft perspective plans for the region which were published for public comments and suggestions on 27th January 1970. A Regional Planning Committee constituted by BMRPB for the purpose of scrutinising the plans was formed under section 16 of the Maharashtra Regional and Town Planning Act 1966 (Government of Maharashtra, 1966). After scrutiny, the plan was finalised by BMRPB on 5th October 1970 and submitted to the Government for sanction.

Meanwhile, with the idea of Greater Bombay Development Plan, the idea of planning a twin town towards the east of the city (across the harbour) emerged. This idea finally materialized in 1970 serving as one of the major strategy of the first Regional Plan. The City and Industrial Development Corporation (CIDCO) was established for the task (Jain, 2011). The new city named New Mumbai, was planned to accommodate a population of about 2.1 million. Land acquisition for 22000 hectares of land from 86 different villages was also notified (BMRPB, 1973). This city was to function as the counter magnet to Greater Mumbai. Further on, the focus was also laid on planning of various other smaller business centers on the transport link connecting the peninsular island with the eastern mainland, the main areas being Thane, Ulhasnagar, Bhiwandi, Khopoli, Kalyan, and Dombiwali (Figure 3-1). The aim was to draw urbanization to the eastern mainland to dissipate the pressure on Greater Mumbai (CIDCO, 1973).

Figure 3-1 Geographical location of proposed business centres

For the smooth planning of the entire region, Mumbai Metropolitan Region Development Authority Act (MMRDA Act) was established in 1974 establishing MMRDA as a body responsible for the development of the region on March 1, 1975 and extending the southern boundaries of the region. Since then, this authority is responsible for planning, coordinating, and supervising the development of the region and executing related plans and projects (MMRDA Act, 1975). It works for the development of growth centres aimed at improving sectors such as transport, water supply, housing, and environment in MMR. For this purpose, MMRDA publishes Regional Plans for MMR. These plans span over a period of approximately 20 years, after which they are revised and newly sanctioned for the next 20 years. Table 3-1 below presents timeline of the three Regional Plans of MMR.

Table 3-1 Time line of Regional Plans of MMR

S.No.	**Name of the Document**	**Planning Authority**	**Duration of Implementation**	**Sanction Year**
I	Regional Plan for Bombay Metropolitan Region	BMRPB	1970 to 1991	1973
II	Second Regional Plan of MMR	MMRDA	1996 to 2011	1992
III	Third Regional Plan of MMR	MMRDA	2016 to 2036	-

To date, two plans for MMR have already been sanctioned, namely, the Regional Plan for Bombay Metropolitan Region 1970–1991 and Regional Plan for Mumbai Metropolitan Region 1996–2011. The third Regional Plan, which was to be implemented from the year 2016 to 2036, is yet to be sanctioned by the Government[10]. The draft of this plan is available but it is a short document which only briefly describes the aims of all the components in a single chapter (MMRDA, 2016).

3.3 Evaluation of Regional Plans

The monitoring and evaluation of planning strategies has been a common research subject in the western countries from last few decades but in the Asian context, it is a relatively new field. Conroy and Berke (2004) used content analysis for evaluating community plans in US. Baynham and Stevens (2013), and Stevens (2013) used content analysis as the basic technique, to evaluate the quality of the official Community Plans in British Columbia by analysing specific factors designed in the previous studies. Raparthi (2014) used the technique for evaluating master plans of Indian cities. Norton (2008) discussed the advantages and disadvantages of using content analysis for plan evaluation by evaluating plans of Central Michigan and concluded with explaining the proper use of the technique for the same. Tang et al., (2011; 2013) used this method in the coastal states in US for evaluating the plans for extreme weather events. For different contexts, different modifications have been done to the basic technique. Finally, the technique used by Raparthi (2014) (with modifications to address shortcomings) formed the basis of the method developed in the present study. The study employed a rigorous methodology and exhaustive process of analysis described as follows:

[10] MMRDA Website last accessed on May 12; 2019

i. Multiple field surveys were conducted in MMR with an aim to understand the planning system; local and regional planning authorities were interviewed to understand their views on the climate change strategy
ii. Regional planning documents which are not available online were collected from MMRDA.
iii. Communications were held with planning and climate related research institutes, NGOs and academic institutions to understand their view on the issue.
iv. MMR's potentials and requirements were studied and then a detailed examination of each planning document was done.

3.3.1 Data

As discussed by Young (2016), the planning documents (Regional Plans) of an area are result of the region's cognition of planning for the present and future for climate change, taking into account all the aspects; strengths, weaknesses; needs and requirements of the area. The present study also presumed that MMR's Regional Plans reflect the present strength and future perspective of the mitigation and adaptation strategies to be implemented in the region. In anticipation of this, following information present in the regional plan was derived and studied for the analysis:

(i) Each chapter in Regional Plan which talks about planning policies and their implementation guidelines was termed as a 'component' of that Regional Plan. For example, 'Transportation' which is one of the chapters of each Regional Plan was one of the component.
(ii) Sub-sections of each chapter which demonstrate planning policies related to the chapter's theme was referred to as its sub-components. For example, 'Investment Strategy' is one of the sub-component of 'Transportation' component.

Thereafter, each components and sub-component was analysed for its relation with climate priorities.

Regional Plan I (1970-1991)

The first Regional Plan for the metropolitan region (1970-1991) was developed by BMRPB (1973). Population projection, distribution, regional economy and migration were the main factors that were considered. The main aim of this plan was development and economic growth of the region, meant to improve the living condition of the large population.

The regional Plan I is divided into two parts. The first part presents the results of regional survey, issues, aims and objectives of the region, while the second part details the proposals and recommendations followed by implementation strategies. The data for this study mainly came from part two of the Regional Plan. Table 3-2 lists the components, their objectives in brief, number of sub-components and number of pages under each component.

Table 3-2 Data from Regional Plan I

Components of Regional Plan 1970–1991	Objective	No. of Sub-components	No. of Pages
Industrial Location Policy	Industrial decentralization from Bombay	3	5
Transport and Communication	Augmenting transport infrastructure across the nearby regions, in the region and in Bombay to cater to the increasing flow of people, goods	3	9
Housing	To cater to housing demand of all categories projected up to 1981	6	7
Utilities and Services	To meet the growing needs of domestic and industrial consumption	3	1
Recreation	Planning for recreational activities such as open spaces, greenery and playgrounds in a view to offset any future demand of those locations for residential or other building uses	3	3
Planning of Rural Areas	Development of rural areas to avoid polarization between urban and rural population and ensure that the urban prosperity can easily flow to the village population	3	8
Social Planning	Urban Planning for ensuring healthy living and working conditions of the people	3	6
Development Control Rules	To control the development of the region	5	10

Regional Plan II (1996- 2011)

Members of MMRDA, a huge executive committee and an extendedly large group of planners were involved in the formulation of this Regional Plan. Support from other institutes, NGOs and academic institutions was taken. Regional Plan II which was sanctioned in 1992 consists of 3 parts further divided into 17 chapters. Part I talks about the general characteristics and regional strategy of Regional Plan. Part II mainly discusses the proposed policies regarding industrial growth, office location, shelter needs and strategies, urban land policy, water resources, transportation and environment. Part III demonstrate the legal binding of these policies and discusses about the controls and regulations under which these laws are to be abided. Table 3-3 lists the different components of the regional plan, their objectives in brief, number of sub-components and number of pages in the chapter.

Table 3-3 Data from Regional Plan II

Components of Regional Plan 1996–2011	Objective	No. of Sub-components	No. of Pages
Regional Development Strategy	Establishing links with national plans, allocating power and resources, planning investments and budgets	5	4
Industrial Growth Policy	Regulating the location of industrial development, relocating them to prospective areas identified for future development	3	38
Office Location Policy	Regulating the location of tertiary activities, i.e., sectors other than agriculture, manufacturing, trade, and commerce	3	25
Shelter Needs and Strategies	Strategy relating to shelter increment, slum improvement, and maintaining existing housing stock	4	52
Urban Land Policy	Ensuring efficient regulation of land ownership, prices, usage, and flexibility in a growing city	3	27
Water Resource Development	Regulation of water source development, conveyance, treatment, and distribution	5	25
Transportation	Catering to the transportation needs of a growing population, maintaining the present infrastructure, traffic management strategies	4	31
Environmental Management	Maintaining ecological balance, preserving places of environmental importance, speculating on the “expanse of development”	13	32
Revised Land Use Plan	Dividing zones and allocating land use according to projection and distribution of population and employment	12	31
Development Control	Controlling specific types of development that may affect overall development of the region by providing a legal framework	4	16

Draft Regional Plan III (2016-2036)

The available draft document (as of April 12, 2019) is divided into six chapters, of which the first four are explaining the status and issues of the region followed by population projections. The proposals of the regional plan are briefly explained in the fifth chapter which is summed up merely in 30 pages. Compared to the Regional Plan II, this is a very short document providing only the summary of the actual regional plan which is still awaited. The present document does not contain elaborate details of plan proposals. The proposal chapter contains headings that may be taken as components but, there is a very high probability that this incomplete set of data may lead to inappropriate results. Proper data which is worth labelling as ‘component’ of Regional Plan III cannot be extracted out of it. Moreover, there are no sub-components available. Hence the present draft document was not used for this study considering it not ready for analysis. Hence, Regional Plan I and II were analysed for the study.

3.3.2 Methodology

Raparthi (2014) analysed 64 master plans for climate change mitigation issues by employing the content analysis method. The plans were evaluated against a set of indicators, which were the same for all the 64 master plans. The integral policies/strategies/plans of the master plans were not evaluated per se. Because of this the variation, the context of development of master plan was neglected. And irrespective of the contextual diversities, all plans were scored against a pre-decided set of indicators called the 'mitigation evaluation protocol'. The indicators were as follows: land use, urban design, physical planning, building specifications, transportation, environment, incentive, education and attainment tools, and physical infrastructure. While it is understood that the planning documents may correspond differently to various aspects of climate change evaluation, this method was highly subjective, resulting in a probability of error. Hence, to overcome this drawback, in the present study, plans were not evaluated for a set of indicators. Instead, each policy/strategy proposed by the plans was individually analysed for their coherency with climate change mitigation or adaptation or environmental consciousness.

The aim of CCPI was to calculate the strength (or weakness) of each component of Regional Plan[11] of MMR. It is important to note here that in this process, no new set of parameters were used; rather, the inherent policies of the regional plan were analysed to calculate CCPI which marks the advantage of this method and makes the study unique. Steps were designed in a way to keep it simple yet useful, so that the technique is applicable to planning documents of any kind. For mitigation index, the sub-components were evaluated in terms of 'emission reduction strategies; while for Adaptation Index, sub-components were evaluated to 'check region's preparedness, ability to reduce vulnerability and resilience building capacity'. The regional plans were thoroughly studied and deductions were made based on author's understanding of climate change adaptation and mitigation; which is the foundation of the analysis.

Scores ranging from 0 to 2 were assigned to each sub-component proposed in the regional plans as follows:

- A score 0 was assigned to a sub-component if there is no consideration of climate change.
- A score 1 was assigned to a sub-component if it addresses environment or climate change as an objective directly/indirectly.
- A score 2 was assigned when the sub-component has climate change or environment protection as a mandatory objective.

This was performed for each component and sub-component of the Regional Plan for mitigation and adaptation separately. Using these scores, a Climate Change Mitigation Index and Climate Change Adaptation Index was formulated, which in its combined form is termed

[11] MMR is 'region' with a combination of multiple districts, cities and villages, hence, MMR's panning documents are addressed as 'Regional Plans'. The aim of MMR's Regional Plans is to guide the growth and development pattern of the region as a whole.

as Climate Change Planning Index-CCPI. The steps taken to calculate the Climate Change Mitigation Index are explained below.

Steps to calculate the Climate Change Mitigation Index

Step 1: Assign scores to each component on a scale of 0 to 2

Step 2: Calculate fractional score for each component: divide the assigned score by the maximum possible score of all components together

Step 3: Add all fractional scores for each policy/strategy

Step 4: Standardize the fractional score by multiplying it by 10. This is the index score for each strategy proposed in the plan.

Step 5: Calculate the Climate Change Policy Score of the Regional Plan by calculating the average of all the above.

Next to this, the weightage of each of the component was determined by means of survey questionnaires. The respondents were planners from MMRDA and other city level planning authorities in MMR. The other respondents were planners who are the members of NGO based in Mumbai; working in the field of climate change and researchers from planning institutes. Personal interviews were held as well as online surveys were conducted. To ensure an un-bias result, equal number of respondents were selected among the government and the non-government employees for the interviews. These steps were repeated for the Climate Change Adaptation Index. Following these steps for all the components, CCPI for the Regional Plans were derived.

This method is fully based on the analyst's perspective, which in a way can be noted as a disadvantage of the proposed method. However, the authors' have tried to overcome this drawback by using the weightage scores obtained through surveys and having a critical discussion over CCPI with the key persons in MMR. During the development process of this method, various field surveys were conducted and a series of discussions were held directly with the stake holders. The whole idea of CCPI- procedure, methodology as well as results have been through a strict critical analysis, only after which, it has evolved into an explicit tool.

3.4 Results – CCPI of Regional Plans

Summarizing up the scores of sub-components, the overall score of the component as a whole was determined. With '0' being the minimum and '10' being the maximum possible score, the higher score would suggest a more climate conscious regional plan. The following sections present the results from both the regional plans analysed for this study.

3.4.1 Regional Plan I (1970-1991)

Table 3-4 presents the CCPI results for Regional Plan I. Through the analysis, it was found that most of the components have no consideration for climate change. Only three components scored for mitigation while only one scored for adaptation. The overall CCPI for this regional plan was found to be 2.25 and 0.21 for mitigation and adaptation respectively. These scores indicate the low level of consideration of climate change mitigation and adaptation in the regional plans.

Table 3-4 CCPI for Regional Plan I (1970-1991)

Components of Regional Plan 1970–1991	Number of sub-components	Climate Change Mitigation Score	Climate Change Adaptation Score
Industrial Location Policy	3	0.00	0.00
Transport and Communication	3	0.00	0.00
Housing	6	0.00	0.00
Utilities and Services	3	0.00	0.00
Recreation	3	6.67	0.00
Planning of Rural Areas	3	3.36	1.67
Social Planning	3	0.00	0.00
Development Control Rules	5	8.00	0.00
CCPI of Regional Plan 1970-1991		**2.25**	**0.21**

To ease understanding and ensure that the results are visually legible, the ideal score and calculated scores for mitigation and adaptation were mapped as sunburst charts. The explanation of charts is given in Figure 3-2 and Figure 3-3 presents the result of analysis. Figure 3-2 shows a wedge which is a cut-out of a bigger circle. One wedge represents one component of the Regional Plan. In Figure 3-2 (i) is length of the arc where number of units represent the number of sub-components it comprises. For example, Figure 3-2 (i) has 4 units in arc length, implying that this components contains four sub components; (ii) shows the number of concentric arcs covered in pink. It represents the resultant score of each component. For example, in Figure 3-2 (ii) the resultant score for this component is 6.5. Higher the number of concentric circles covered the better is the response towards climate priorities. In Figure 3-2 (iii) is the length of each unit in the arc. This length is the measure of relative weightage that the component has scored through the interview surveys. As a whole, the figures represent the strength of the Regional Plan in terms of the climate change priorities. The larger the wedge, the stronger is the climate change mandate in the component.

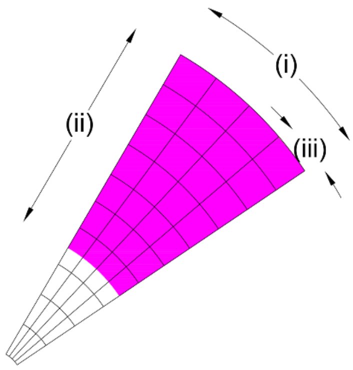

Figure 3-2 Explanation of CCPI graphs where; (i) indicates number of sub-components; (ii) shows the CCPI that component has scored; (iii) represents the weightage of each components

Finally, Figure 3-3 shows the result of analysis of Regional Plan I, where Figure 3-3 (a) shows the ideal case for a regional plan document, (b) and (c) show mitigation and adaptation CCPI respectively. As explained above, in each figure, one wedge represents one component of the regional plan. In the figures, the difference between the current CCPI and ideal CCPI is clearly visible. Observing the results it can be said that Regional Plan I is not responsive to climate change. As it was already known, the objectives of this Regional Plan were development and economic growth of the region. Since, this regional plan is not observed to be in any proximity with climate change priorities, weightage of components of this Regional Plan were not found through survey methods. Each component was weighted equal and hence the length of each unit in the arc (refer (iii) in Figure 3-2) was assumed to be same for all components.

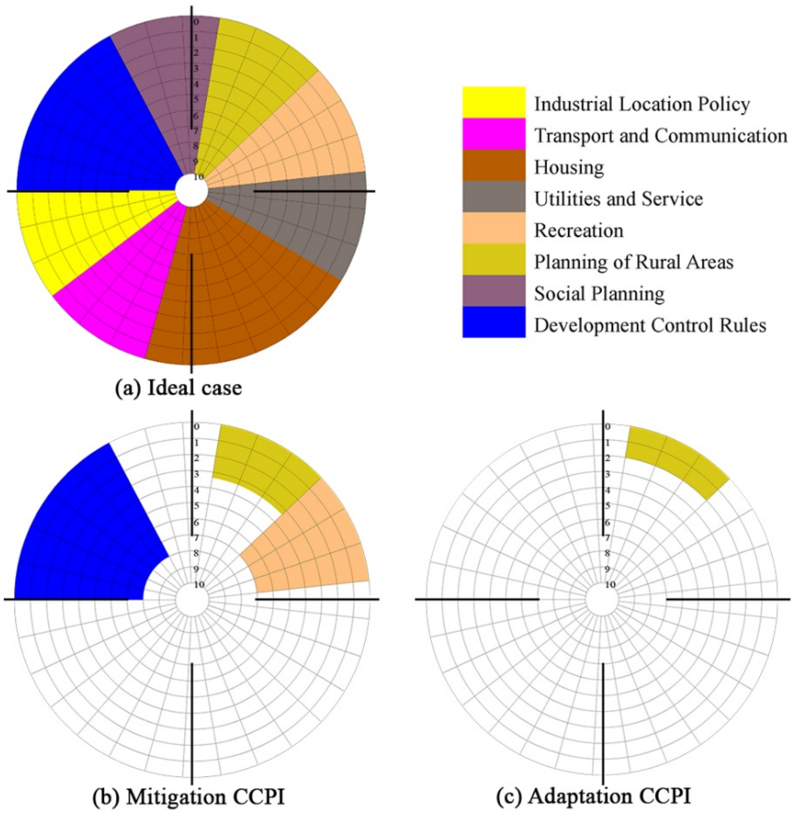

Figure 3-3 CCPI results for Regional Plan I (1970-1991); (a) Ideal case CCPI (b) Mitigation CCPI, (c) Adaptation CCPI

3.4.2 Regional Plan II (1996- 2011)

This Regional Plan was found to be more responsive for climate change priorities. Most of the components showed consideration for environment which relates to climate priorities directly or indirectly. Table 3-5 provides the results of the CCPI calculated for RP 1996–2016 of MMR. Survey was conducted to find the weightage of components. From the weightage scores it was found that ‘transportation’ component scored the highest weightage suggesting that in MMR, transportation planning in MMR is most climate conscious (compared to other planning components).

Table 3-5 CCPI for Regional Plan II (1996-2011)

Components of Regional Plan 1996–2011	Number of Sub-components	Weightage	Climate Change Mitigation Score	Climate Change Adaptation Score
Regional Development Strategy	5	3.38	1.00	1.00
Industrial Growth Policy	3	3.31	1.70	1.70
Office Location Policy	3	3.19	5.00	1.70
Shelter Needs and Strategies	4	2.75	0.00	0.00
Urban Land Policy	3	2.88	0.00	0.00
Water Resource Development	5	3.50	3.00	2.00
Transportation	4	3.81	7.50	1.25
Environmental Management	13	3.56	3.37	5.77
Revised Land Use Plan	12	3.50	2.50	5.00
Development Control	4	3.63	2.50	1.00
CCPI of Regional Plan 1996–2016			**2.65**	**1.94**

It was found that out of 10, the overall Mitigation CCPI for this regional plan was 2.65, while Adaptation CCPI was 1.94. The score is higher than Regional Plan I but still quite low considering the climate change issues in the region. In Table 3-5, it can be observed that none of the components scored 100%. The highest score was 7.5 for the mitigation of transportation, while the second highest was much lower (5.77) for adaptation for environmental management. Only a few components have scores greater than or equal to 5, while more than two thirds scored below 5. Two components scored 0 symbolizing absolutely nil connection with climate priorities. Figure 3-4, shows CCPI results; where (a) shows the case of an ideal regional plan which is 100% responsive to climate priorities; where each sub-component has a score of 2 and each component has a score of 10 (maximum score); thereby, the overall index is 10, while Figure (b) and (c) show mitigation and adaptation CCPI of the Regional plan II (1996-2011) of MMR respectively. The difference in the ideal case and the current CCPI graphs make it evident that how well (or unwell) the RP 1996–2011 considers climate priorities as mandate.

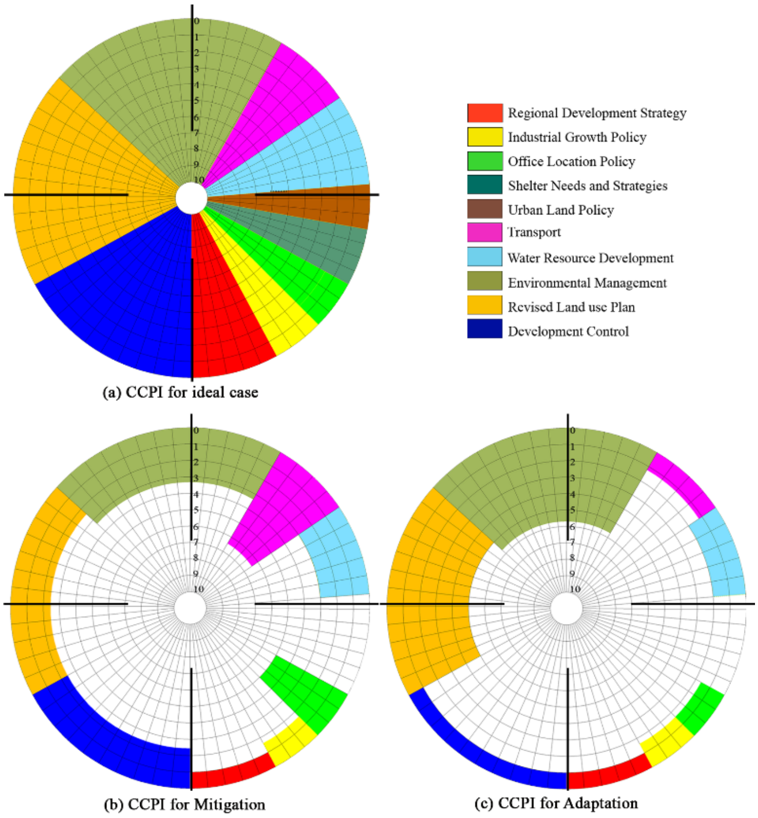

Figure 3-4 CCPI results for Regional Plan II (1996-2011); (a) Ideal case CCPI (b) Mitigation CCPI, (c) Adaptation CCPI

3.5 Discussion

From the results, it is evident that Regional Plan 1 had almost no consideration of the climate change priorities while Regional Plan II displays better connection to climate change issues. In Regional Plan I, the adaptation score was 0.21. This small magnitude shows that there was no concern regarding preparing the region for climate change. The comparatively high score for mitigation (2.25) was due to the strong control in development in specific regions. But the aim here was to distribute the development activities. Climate change priorities were not the mandate.

The results of Regional Plan II showed better results than Regional Plan II. The scores were 2.65 and 1.94 for mitigation and adaptation respectively. The adaptation score significantly increased from the previous Regional plan, depicting that climate change preparedness was moderately rooted in the plans.

With this huge difference in CCPI, there emerged a need of speculating the timeline of both the plans and matching it with the climate change awareness in the World. It should be noted that climate change issues became a global concern after the establishment of IPCC in November 1988 and adoption of UNFCCC in May 1992. Hence, it was not until 1990s that the whole world took consensus of this science. Moreover, Kyoto Protocol which is the only binding agreement for emission reduction was adopted first in 1997 and entered into force only in 2005. Comparing this time line with the timeline of regional planning in MMR shows that Regional Plan I was sanctioned more than 15 years before climate change was accepted as a global concern. The year of sanction was 1973, when climate change science did not even gain recognition in the world. Also, the prime aim of Regional Plan I was to establish infrastructure in the region to serve the multiplying population. Hence, climate change was not a perspective for the then planning authorities. Thereafter, including the CCPI of Regional Plan I for examining climate change priorities in MMR's planning agenda today is altogether unjustifiable. It was apprehended that including these results can lead the conclusion to a completely wrong direction. On the other hand, Regional Plan II was sanctioned in 1992 and the implementation period was 1996 to 2016. In this period, environmental protection and climate change concerns were well established. Kirton and Kokotsis (2016) wrote about climate change governance since the inception of this idea. Moreover, by this time, the region started to face environmental problems which were also addressed in the objectives of Regional Plan II. In addition to this, the third Regional Plan has yet not been sanctioned (refer section 3.2) hence, Regional Plan II (1996 to 2011) continues to be in force in MMR having the longest duration of implementation. Hence in order to avoid the conflict in broader goal of this research, only the CCPI of Regional Plan II were used in the further research.

As explained, CCPI is the analysis of planning documents of MMR. To understand the practical implementation of Regional Plan, a survey was conducted in which questions regarding satisfaction level of performance of each component (of Regional Plan II) were asked. The purpose was to determine that after implementation (i.e. from 1996), how well the component is serving its environmental objectives. Including officials in local planning authorities (other than MMRDA) and planners in related research organizations, there were 14 officials who responded to the survey questionnaire. Special care was taken to ensure that the planners involved in developing the Regional Plan are not chosen for responding to this survey. Figure 3-5 shows the results. Transportation components was found to be the most satisfactory. Environmental Management, Shelter Needs and Strategies got score in the level of satisfaction (mostly unsatisfactory). Overlapping the results of CCPI with these results briefly directs towards a connection between mitigation CCPI and Regional Plan's satisfaction level. The mitigation CCPI of Transportation component is high while Mitigation CCPI of Environmental Management, Shelter Needs and Strategies components is very low. This depicts that components with higher CCPI are observed to perform better during implementation.

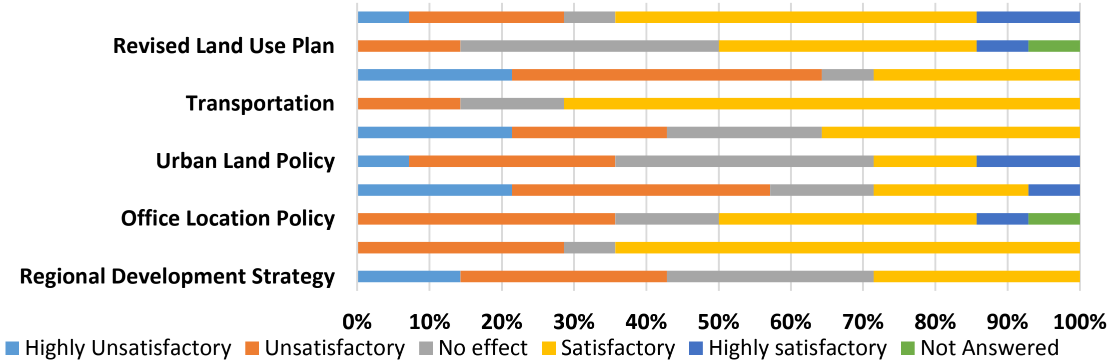

Figure 3-5 Satisfaction with implementation of Regional plan for environmental efficiency

The following sections describe the implication of each component's result separately.

The Regional Development Policy, with a score of 1 for both mitigation and adaptation, demonstrated a weak link between the regional plan and the National Climate Action Plans. The total number of sub-components were 5, and the goal of the strategy was to mobilize resources in a way beneficial to the public. However, the results suggested that this goal is not directed towards reducing emissions or achieving a resilient environment. Climate change as a threat to society was not considered, and resources were not distributed considering this aspect.

The score of the Industrial Growth Policy (number of sub-components = 3) was also low. The score 1.7 portrayed a weak industry location scheme, suggesting that the location of new industries does not really consider environmental aspects. The main objective of this strategy was to decentralize Mumbai city and distribute future growth to the surrounding areas. But, during this, climate change and environmental issues were either ignored or not prioritized. However, for the same reason, the component scored high for mitigation (mitigation CCPI = 5). This strategy was related to regulating tertiary activities in the region, which has the highest share in the type of occupation. With three sub-components, the aim was to reduce the floating population, which was appropriate considering the mandate of decentralization. However, the adaptation score was 1.7, suggesting that for the already existing tertiary activities in the region, only a few regulations aim to reduce vulnerability or increase resilience to the risk of climate change.

The next two objectives of the regional plan are Shelter Needs and Strategy and Urban Land Policy with four and three sub-components respectively. These two policies were found to be the weakest. The reason can be attributed to the large volume of people migrating into the region, who settle in unregistered, informal shelters. As early as 1977, MMRDA realized the enormous demand of housing in Mumbai. It was found that in total, 60,000 houses per annum were required, but the supply per annum was only 20,000 (Dutt et al., 1994). After 40 years, the scenario was the same. However, a new angle was added to the issue. Times of India (2012; 2017) reported a large percentage of vacant houses in the MMR. But the housing demand still did not decrease. Imbalance in ownership and severe lack of homogeneity in the city- characteristic of the region has been cited as the reason (Daily News and Analysis, 2009). The next objective of the regional plan, Water Resource Development with five sub-components, was responsible for regulating the sources of water and supply. The Climate Change Score estimated for mitigation was 3, while that for adaptation was 2 for this objective. In MMR, water recycling is aimed for, but the immense population and informal settlements make it difficult to maintain, which was the reason for the low scores.

Transportation system in MMR was found to score well. Trains and buses are used for 75% of motorized trips, and only 2.6% of households own cars in MMR (Cropper and Bhattacharya, 2012). As a result, emissions due to road transportation in Mumbai are much lower than in other large cities in India (Das and Parikh, 2004; Ramachandra and Shwetmala, 2009;

Ramachandra, Sreejith and Bharath, 2014). This is reflected in the mitigation score of 7.5. However, the adaptation score is low at 1.25, which indicates that improvements can be made for this aspect in the transportation sector.

The environmental issues emerging in MMR were identified during Regional Plan I. Hence Regional Plan II had some policies focused on protecting the environment. This is the reason for the comparatively high adaptation score estimated for the environmental management component of the regional plan II (adaptation score = 5.77). However, there are also constituents in this component that need improvement. There are gaps present in the regional plan where the regulations are loose and are prone to alterations. For example, different regulations impose different type of rules on the coastal areas. Also, informal and unregistered construction activities are undergoing in the no development zones and there is no strict law to prevent that. Environment component of the regional plan comprises of 13 sub-components; the highest number in the regional plan. Despite this, the low score for mitigation (3.37) reflects that there is need for stronger climate related policies.

The aim of the Revised Land Use Plan, which has 12 sub-components, was to divide zones and allocate land use according to the population and employment projection. The mitigation score was 2.5, which is low, and the adaptation score was 5, which is an average score. In MMR, as discussed earlier, the continuous flow of population has resulted in planning several business districts in the region. This ended up with increased urban land cover. While this strategy has helped in some aspects, considering climate change issues, it has brought about damages too. However, these damages are not due to the relocation policy, but due to the increasing population. Because of the unpredictable increase in population, the plans was not fully able to handle the issue, which is the reason for the low scores.

The last component of the regional plan is 'Development Control' which has four sub-components. It aimed to provide a legal framework to control development in different parts of the region to benefit overall development. It defines laws and regulations to ensure Government's control of development in MMR. The scores for mitigation and adaptation are 2.5 and 1 respectively. As explained for the environmental management component, the laws are not able to provide rigorous protection of the natural environment; several shortcomings are evident. Thus, even though MMR has laws pertaining to environmental issues, these are not strict enough. Moreover, the development plans of cities sometimes conflict with the regional plans. Due to the inconsistent institutional arrangement, there exists no agreement to ensure coherence in the city development plans and regional plans.

3.6 Conclusion

MMR is facing a series of urbanization issues, which are responsible for the increased threat of climate-related disasters. Even then, regional plans of MMR were observed to be unable to incorporate strict climate change mitigation or adaptation strategies. The results of Regional Plan II obtained in the analysis indicate that environmental issues are briefly considered in the planning agenda which indirectly incline to climate change priorities. No direct anticipation of climate change priorities was found in the plans. For each component, there can be different methods for taking action against increasing GHG emissions. However, approaches were weak and inefficient. The uncontrolled increase in urbanization demanding continuous economic growth can be the reason. The limited resource availability adds to the disadvantage. In a phase where the city is failing to provide basic structure to its residents and is vulnerable to climate change risks, prioritizing climate change can be difficult. In such a situation, planning authorities need to intricately carve their way towards a safe present and sustainable future.

Waldner (2004) analysed plan evaluation methods and found that monitoring and evaluation of plans is not well materialised into practicality. Lack of economic benefits, initial cost and input, political/legal requiremnts, cultural norms etc were identified as the reasons. The new tool developed in this study can be a response to fill this gap. CCPI is a simplified and comprehensive set of rules for plan evaluation. It provides an immediate understanding of the status of climate change protocols in the current plans. Moreover, this method enables finding the weakest component or sub-component to be targeted in planning strategies. This provides a clear direction to the planners, policymakers, and key persons involved in planning/policy making. Furthermore, for the layperson, the results drawn as sunburst diagrams are a convenient tool to examine the capacity of current regional plan in the perspective of climate change. It is important to note that this analysis is not a criticism to the current plans of MMR, instead it can be used for enhancement and enrichment of the planning documents as these documents are expected to shape the future of the region.

It is notable that, the new tool 'Climate Change Planning Index' is a flexible design which takes into account the planning textbooks of the city/region itself. Hence, by modifying the decision parameters as per the context, this tool can be applied to any region which has an established planning system.

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CHAPTER 4 GREENHOUSE GAS ESTIMATES IN MMR

4.1 Introduction

Development activities are to be taken up dealing with climate change issues on one hand and poverty eradication on the other (EDF, 2018). All economic activities require the consumption of energy (Deutch, 2017), which is mainly produced by the burning of fossil fuel in India (International Energy Agency, 2015; Varadhan, 2017). The consumption of fossil fuels causes elevated carbon emissions. Today, India is among the top GHG emitting countries in the world (Climate Data Explorer, 2017).

The economic development in India is mainly concentrated in metropolitan areas. According to MMRDA, urbanization in India means 'metropolitanisation' (MMRDA, 2016). To seek a better job, people from rural areas tend to move to urban areas. Cities with a high population rate have a high energy demand resulting in higher emissions. This eventually has a significant impact on national and global carbon emissions (Dodman, 2009; Sanchez-Rodriguez, 2002). Aye and Edoja (2017) studied the impact of economic growth on emissions. The executive director of the United Nations Human Settlements Programme (UN-HABITAT) stated that cities are responsible for 75% of the global energy consumption and 80% of greenhouse gas emissions (GHG) (UN-HABITAT, 2007). It is therefore important to evaluate emissions of metropolitan regions in the India. Determining the share of a city's emissions in the national emissions will be an aid in making strategies for meeting the climate targets for the nation. This chapter aimed to estimate GHG emissions of different sectors in MMR.

IPCC divides the emission sources into four broad categories (IPCC, 2006): 'Energy'; 'Industrial Process, and Product Use (IPPU)'; 'Agriculture, Forestry, and Other Land Use (AFOULU)'; and 'Waste'. Out of these four, 'energy sector' is the focus of this study. The GHG Inventory Tree (Penman et al., 2006), provides the structure of emission reporting for each sector. It sub-divides 'Energy' sector into 'fuel combustion activities'; 'fugitive emissions from fuels'; and 'carbon dioxide transport and storage' (Figure 4-1). In this study, road transportation, electricity and fugitive CO_2 equivalent (eq.) emissions in MMR were calculated. Furthermore, overall CO_2 emissions were calculated and compared with national emissions. Emissions were calculated starting from the year 1970 because this was the first year of implementation of the first Regional Plan of MMR (1970-1991). The last year of calculation depended on the availability of data which varies for different sectors and data sources. Emissions from civil aviation, railways, and water-borne navigation were not calculated for the study. This is because, for these sectors, the data collection program is conducted on a national scale and not on a local scale. Hence, the exact data for MMR was not available. Therefore, MMR's total emissions from the energy sector cannot be summed up accurately. However, the second Biennial Update Report (BUR) of India's communication to UNFCCC prepared by MoEFCC stated that road transportation in India in 2010 accounted for 90% of the emissions from transportation sector (MoEFCC, 2018). Hence, it was assumed that, with the available data for road transportation, electricity and fugitive emissions, the approximate estimation of Energy sector emissions in MMR is possible.

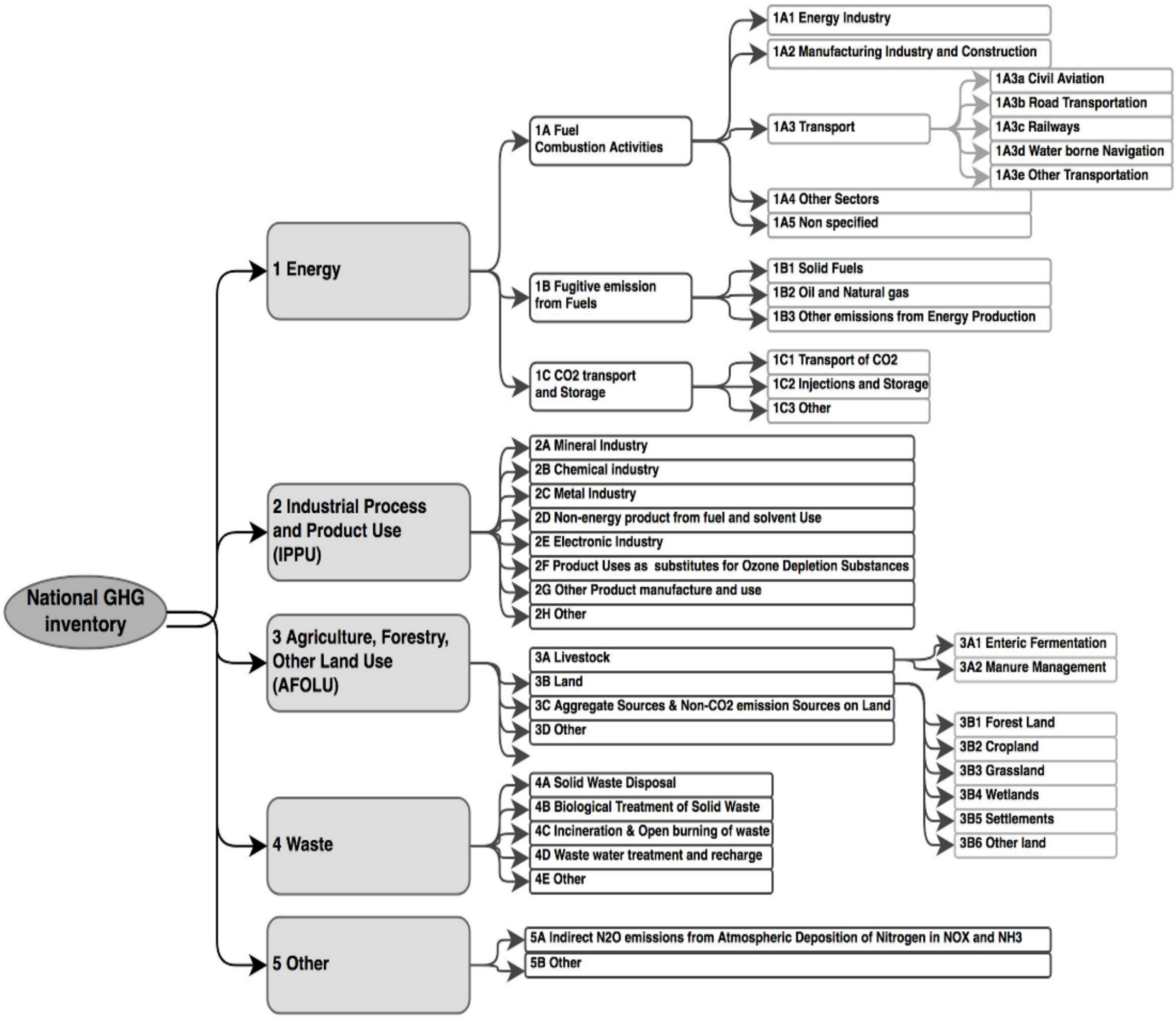

Figure 4-1 Emissions inventory tree (Source: Penman et al., 2006)

4.2 Background on Emission Data in India

As explained in section 2.1.1, India is a party to UNFCCC (UNFCCC, n.d.) and MOEFCC is responsible to communicate the GHG inventory of India to UNFCCC (MOEFCC, 2015). The inventory is made on a national level. The availability of emission data at the local level is poor. For the national emissions inventory, the data for different emission sources are collected for the whole country for each sector. For example, for the agriculture sector, the data from the whole country is collected all together and processed. Hence, if the national agricultural inventory is broken down to the scale of local emission sources, only the emissions for the agriculture sector can be found. Similarly, the emission data for each sector will have to be broken down to the local level, which is a task beyond possibility. Thereafter, researchers have developed specific methods according to the type of data available for emission calculation at local scales. New common practices include the use of questionnaire surveys, conducting interviews for data collection, or accumulation of data from several sources.

Bharadwaj et al., (2017), Bhoyar et al., (2014) Ramachandra and Shwetmala (2009), Ramachandra et al., (2014), and Sówka and Bezyk (2018) used such methodologies. Gaps in the data availability, different time series and formats, and differences in data definitions are the main reasons for researchers to choose distinct methods for emission calculations. Although this drives newer techniques and tools for emission calculations, the chances of ambiguity, non-uniformity of different datasets, and data not being able to be verified or used at a global platform are high.

4.3 Data

Availability of data is the biggest challenge in making emission estimation process. Especially in developing countries, researchers have to deal with scarcity of accurate data (Bader and Bleischwitz, 2009; Shan et al., 2017). The issue has been addressed by various organisations as well (Bai et al., 2018; Carlock et al., 2018; ICLEI, 2014; Staden, 2014). For the current research too, the challenge of data availability was encountered. Hence, different data sources were used for different sectors. Table 4-1 presents a list of data bases used in this research and the flowchart (Figure 4-2) describes the workflow applied for the analysis in this study. The detailed explanation of each route (marked in red in Figure 4-2) is present in section 4.4.

Table 4-1 Data source description

Source of Data	Data acquired	Emission sector	Source
Emission Database for Global Atmospheric Research (EDGAR)	Annual grid maps 1970–2012 for India and MMR	Overall CO_2 emissions of MMR and India	EDGAR, 2017
Motor Vehicle Department, Maharashtra	Number of vehicles in the districts of MMR	Road transport emissions of MMR	Motor Vehicles Department, Maharashtra, 2018
Ministry of Petroleum and Natural Gas	Refinery crude throughput for India and MMR	Fugitive emissions of MMR	Ministry of Petroleum and Natural Gas, Government of India, 2018
Directorate of Economics and Statistics	Electricity generation per capita	Emissions from electricity consumption in MMR and India	Directorate of Economics and Statistics, 2008
The World Bank	CO2 emissions from transport	Transportation emissions of India	The World Bank, 2019.
Census of India	• Population of districts of Maharashtra • Population of India		Ministry of Home Affairs, Government of India, 2018

4.3.1 Limitation of Data

As pointed above in brief, crisis of accurate data availability at smaller level is an issue in India. The limitations caused by this are discussed below.

(i) It is imperative to know that the Indian Census (Ministry of Home Affairs, Government of India, 2018), which is the single source of statistical information of the country, collects population data on a ten-year basis. This means that for the timeline analysed in this study, population data are available only for the years 1961, 1971, 1981, 1991, 2001 and 2011 (called the census years). For the calculation of per capita emissions, the population data for the non-census years was extrapolated using the available data.
(ii) The data from published documents are available for different years. Hence, for the purpose of comparison, only the data available for common timeline was used for finding results.
(iii) Data available from different sources are not fully synchronized due to differences in assumptions and calculation methods. Also, the format of data is different in different sources.

According to the available data, the emissions were calculated from the following sectors:

(i) **Overall CO_2 emissions (emissions from all sectors):** Top down approach was applied to calculate emissions from MMR and India. Annual emission grid-maps of India were downloaded from EDGAR and emissions for MMR and India were estimated.

(ii) **Road Transportation**: Bottom-up approach was applied for this sector. Emissions from different vehicles including two wheelers, cars and Jeeps; light motor vehicles (passengers and good); taxi; bus; truck and lorries; trailers and tractors and others were calculated. Emission compounds like CO2; CO; NOX; CH4; SO2; PM; HC were taken into account. For parallel comparison of emissions, the emissions from all the compounds were converted to CO_2 eq. emissions by multiplying the emissions with the compound's Global Warming Potential (GWP) for 100 years (IPCC, 1996).

(iii) **Fugitive emissions**: Bottom-up approach was applied for this sector too. Methane is the primary gas that is emitted from fugitive emissions (Grudnoff, 2012; Shreejith et al., 2012). For the purpose of comparison, the GWP of methane, which is 21 for the 100-year time series (Greenhouse Gas Protocol, 2013), was used to convert the CH_4 emissions to CO_2 eq. emissions.

(iv) **Electricity**: Using electricity consumption data of MMR and India, the per capita consumption emissions were calculated. Electricity consumption in domestic, commercial, industrial, and other sectors (which includes consumption in railways, street lights, municipal water supply, sewage treatment, etc.) was determined. This is also a bottom-up approach.

For smaller scales, the creating an inventory is a daunting task. Ramaswami et al., (2011) discussed the issues faced in emission accounting due to relatively small spatial sizes and role of factors outside the boundary of the city. For an answer to this issue, the definition of scope for city-level inventories was taken from Greenhouse Gas Protocol (2014). Table 4-2 illustrates these scopes and simultaneously describes how this study justifies the criteria:

Table 4-2 Boundary scope for a city emission inventory and justification for this study

Scope	Justification
Scope 1: Emissions from source located within city boundary	For top down approach, a new shape file for both MMR and India was created in GIS to extract emission data from grid-maps. Crude throughput data for fugitive emissions was taken only from refinery capacity installed inside the boundaries of MMR.
Scope 2: Emissions occurring as a result of activities within the city boundary	Road transportation activities and electricity consumption within the boundary were determined for emissions from transportation and electricity.
Scope 3: All emissions occurring outside the city boundary as a result of activities inside the city boundary	This part is most valid for emissions occurring from electricity. All the electricity consumed in MMR is not generated in MMR. Hence, instead of emissions from electricity generation, electricity consumption emissions were estimated.

4.4 Method

This study uses an exhaustive process, which includes three different methods to estimate national and regional emissions. The workflow is explained in the flowchart (Figure 4-2) and the details of each methods (described as Route 1 to 3) are provided in the box.

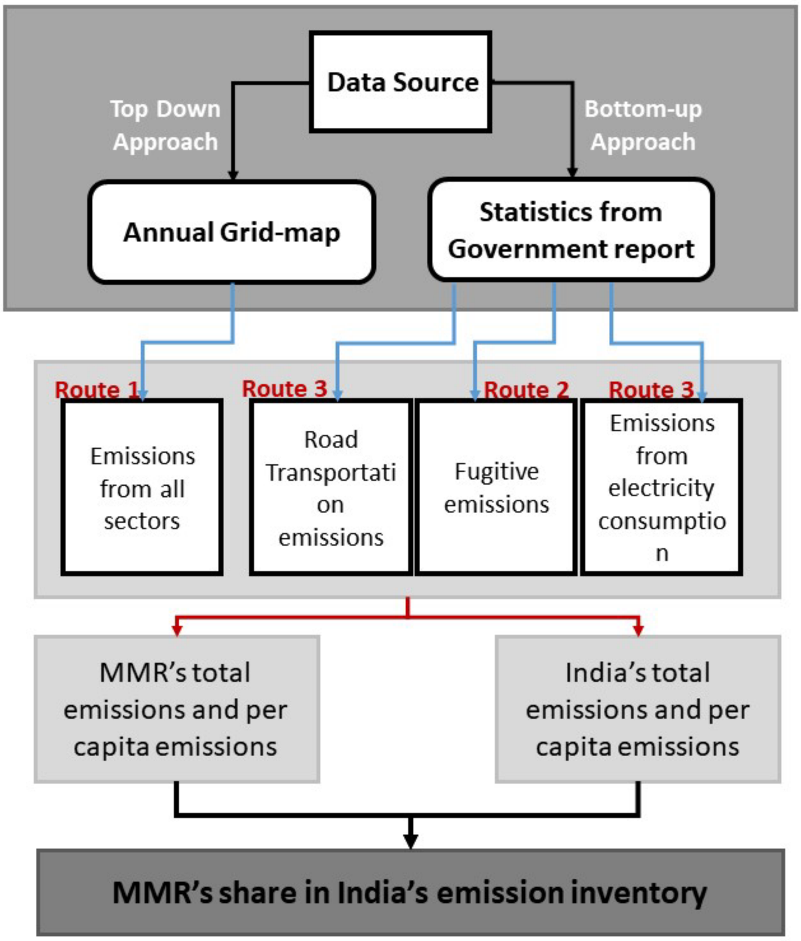

Figure 4-2: Workflow for India and MMR's emission estimation

Route 1

Annual grid maps, available from 1970 to 2012 in Emission Database for Global Atmospheric Research (EDGAR) version 4.3.2, were used in this study. The data from Edgar is available in Network Common Data Form (NetCDF) format and text formats, which was processed in R 3.5.0 to extract data on required boundary limits and convert it into Comma-separated values (CSV) files for further processing in ArcMap. ArcMap 10.4.1 was used to extract CO_2 emission data for India and MMR.

Route 2

The report on the Guidelines for the National Greenhouse Gas Inventory published by the IPCC was followed to calculate fugitive emissions from refinery crude throughput for India and MMR for the years 2001 to 2017. The following equation was used:

Equation 1:

$$CO2\ eq.\,emissions = Amount\ of\ fuel\ used\ \times Emission\ factor\ (region\ specific) \times Conversion\ factor$$

Source: IPCC, 2006

Route 3

Published reports were used to collect required data. Emissions from electricity consumption and road transport were calculated using this route.

Following equation was used for road transport emission:

Equation 2:

$$GHG\ emissions\ of\ each\ compound\ by\ each\ vehicle\ type = Emission\ coefficient\ of\ the\ compound \times Number\ of\ vehicles\ per\ type \times Distance\ traveled$$

Source: Ramachandra and Shwetmala, 2009

For emissions from electricity consumption, the following equation was used:

Equation 3:

$$GHG\ emissions\ of\ each\ compound = Amount\ of\ fuel\ used \times Net\ calorific\ value\ of\ fuel \times Emission\ factor\ (region\ specific)$$

Source: Ramachandra et al., 2014; Shreejith et al., 2012

EDGAR: This is a joint project of the European Union Joint Research Centre and the Netherlands Environmental Assessment Agency, which provides records of global anthropogenic GHG emissions. EDGAR data was used in this study because it provides a broad time series for comparison. The data format is easy to use and handle and the free subscription and availability makes it a convenient source of global information. The uncertainty estimates of EDGAR have been published for EDGAR version 2 (EDGAR, 2010) and are under review for the current version - EDGARv4.3.2 (Janssens-Maenhout et al., 2017). For this study, the uncertainty percentage for India (per gas) was also estimated.

4.5 Results

This section provides the results of MMR's emission calculations. Table 4-3 presents MMR's overall emissions (from all sectors) and Table 4-4 presents MMR's emissions from different sectors. Changing emission trend is represented in graphical form. Two type of graphs are present: first is, MMR's emissions graph, and second is MMR and India's per capita emission comparison graph. Results from different sectors are presented separately in the following sections.

Table 4-3 MMR's overall CO_2 emissions (all sectors)

Year	Total emissions (Gg)	Per capita emissions (metric ton)	Year	Total emissions (Gg)	Per capita emissions (metric ton)
1970	23,253.62	3.34	1992	65,902.61	4.74
1971	23,365.36	3.25	1993	64,265.70	4.47
1972	26,275.47	3.53	1994	68,840.90	4.64
1973	27,205.50	3.54	1995	69,939.69	4.58
1974	28,173.11	3.55	1996	87,465.55	5.56
1975	29,474.60	3.61	1997	91,832.22	5.67
1975	30,161.93	3.59	1998	93,590.46	5.62
1977	32,324.81	3.73	1999	99,643.17	5.82
1978	33,183.09	3.73	2000	106,276.83	6.05
1979	35,654.23	3.90	2001	104,301.38	5.78
1980	34,429.72	3.67	2002	107,503.07	5.85
1981	36,101.82	3.75	2003	104,401.40	5.58
1982	41,664.15	4.16	2004	101,204.40	5.32
1983	43,766.54	4.21	2005	102,328.27	5.29
1984	49,750.62	4.62	2006	109,059.06	5.54
1985	50,617.34	4.54	2007	89,087.83	4.45
1986	55,333.63	4.79	2008	105,545.07	5.19
1987	57,696.14	4.84	2009	111,731.40	5.40
1988	57,686.16	4.69	2010	122,591.26	5.84
1989	62,786.79	4.95	2011	123,992.18	5.81
1990	64,282.53	4.92	2012	137,166.44	6.33
1991	64,370.17	4.79			

Table 4-4 MMR's CO_2 eq. emissions from different sectors

Year	Transportation emissions (Gg)	Per capita transportation emissions (metric ton)	Fugitive emissions (Gg)	Per Capita fugitive emissions (g)	Electricity consumption Emissions (Gg)	Per Capita electricity emissions (metric ton)
2000	-	-	0.0202	1.15	-	-
2001	8,611.60	0.48	0.0204	1.13	-	-
2002	8,847.80	0.48	0.021	1.14	-	-
2003	9,334.72	0.50	0.0211	1.13	-	-
2004	10,144.23	0.53	0.0217	1.14	9,403.26	0.52
2005	11,602.17	0.60	0.0235	1.21	9,950.43	0.55
2006	12,722.39	0.65	0.0276	1.40	10,113.00	0.56
2007	14,007.69	0.70	0.0286	1.43	11,169.41	0.62
2008	15,292.95	0.75	0.0268	1.32	11,633.36	0.65
2009	16,273.02	0.79	0.0277	1.34	14,896.14	0.83
2010	16,772.98	0.80	0.029	1.38	17,003.99	0.94
2011	17,408.06	0.82	0.0296	1.39	20,472.17	0.96
2012	18,998.45	0.88	0.0296	1.36	18,753.07	0.88
2013	20,575.35	0.94	0.0291	1.32	22,774.56	1.07
2014	21,348.06	0.96	0.0287	1.29	23,795.06	1.12
2015	22,665.96	1.00	0.0304	1.34	-	-
2016	23,990.55	1.04	0.0313	1.36	-	-
2017	27,138.30	1.16	-	-	-	-

4.5.1 Overall CO2 Emissions (from all sectors)

Figure 4-3 shows the increasing CO_2 emissions in MMR (in Gg CO_2) from the year 1970 to 2012 (blue line) with probable uncertainties presented as an error band (area in pale blue).

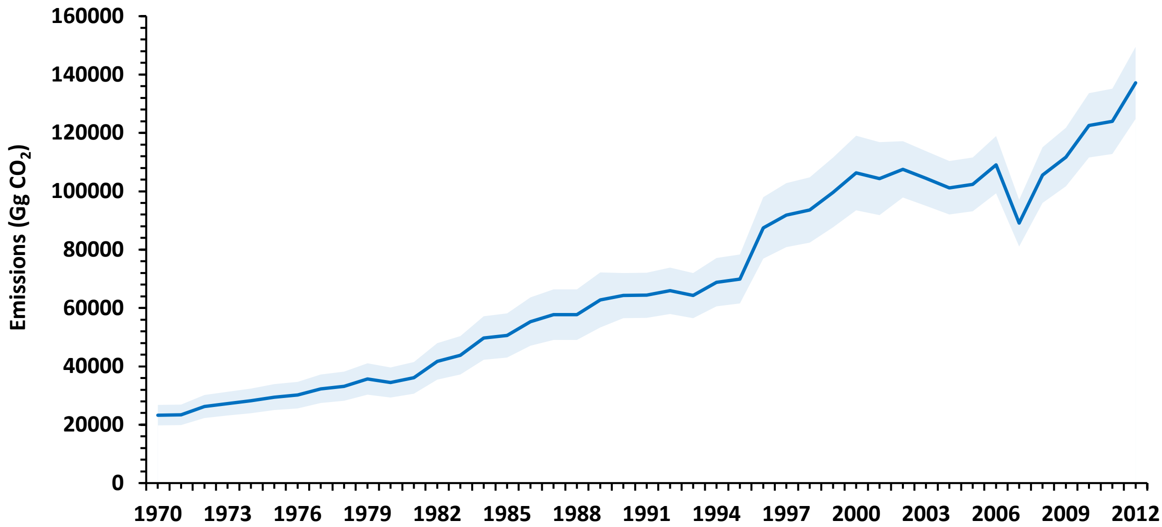

Figure 4-3 Changes in MMR's overall CO_2 emissions from 1970 to 2012

Figure 4-4 presents the comparison of per capita emissions of MMR with India and MMR's per capita emissions expressed as percentage of national per capita emissions. It shows that MMR's per capita emissions from 1970 to 2006 are much higher than per capita emissions of India. However, the difference in MMR's per capita emissions and India's per capita emissions has significantly decreased starting from the year 2007. This can also be observed through share of MMR's emissions expressed as the percentage share of India's emissions. The peak is as high as 306.75% in 1973. However, the graph shows that the per capita emissions are the lowest (127.60%) in 2007. Following this, the emissions are observed to be low; nearing the per capita emissions of the country.

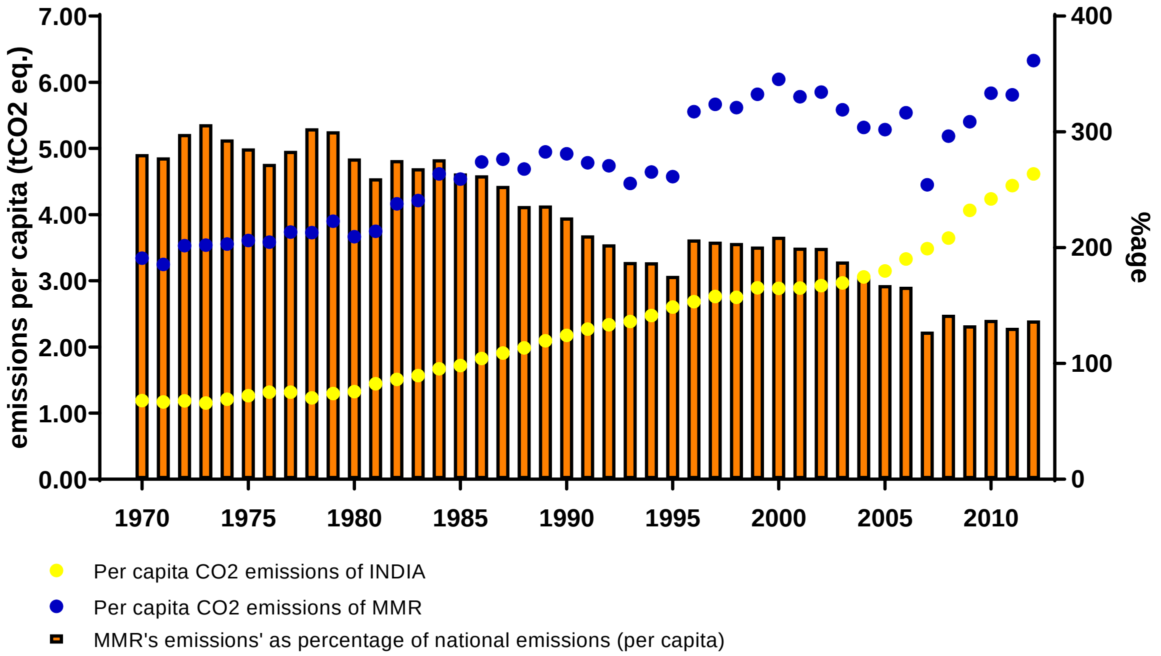

Figure 4-4: Per capita CO_2 emissions (all sectors)

4.5.2 CO2 eq. Emissions from Road Transportation

Figure 4-5 shows the emissions from road transportation sector in MMR while Figure 4-6 shows MMR's per capita emissions compared with that of India's. Because of the skewed availability of national data, the timeline for the comparison has shrunk to only seven years (2008 to 2014).

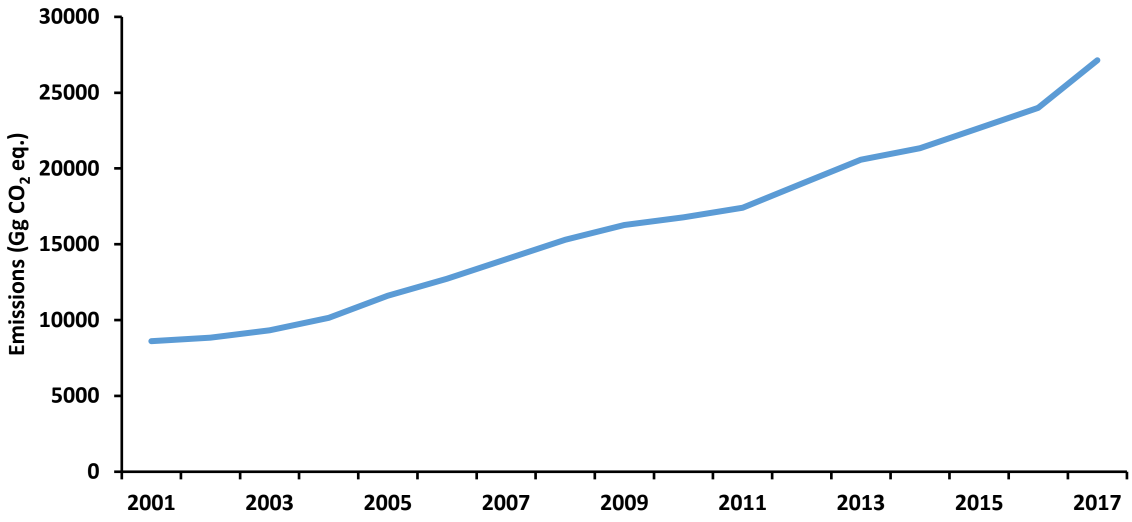

Figure 4-5: Change in road transportation emissions in MMR from 2001 to 2017

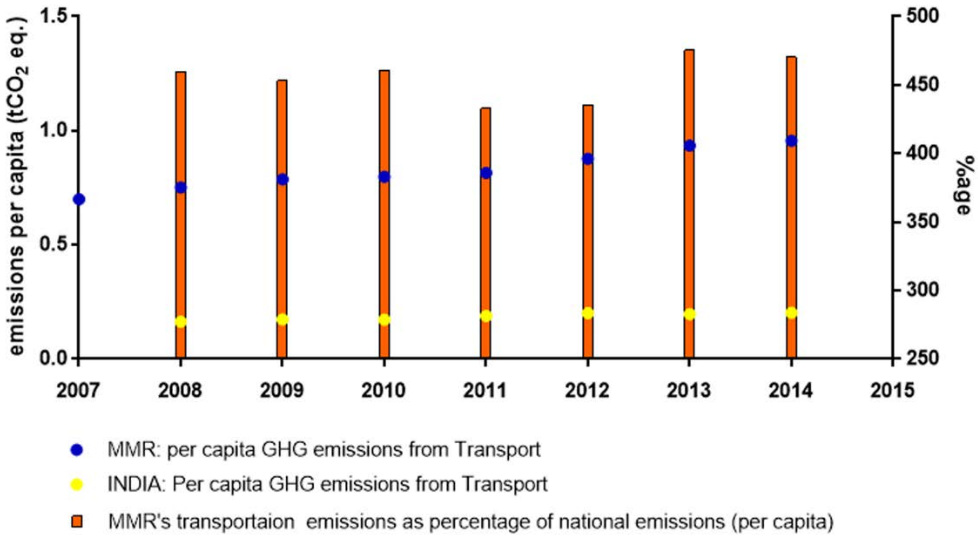

Figure 4-6: Per capita CO_2 eq. transportation emissions and MMR's share in the national emissions

Figure 4-6 shows that the per capita road transportation emissions of MMR are on an ascending trend. It was found that MMR's per capita emissions have been more than 400% higher than the national per capita emissions. Also, MMR's share in India's emissions was found to be increasing.

4.5.3 Fugitive CO2 eq. Emissions

Figure 4-7 shows fugitive emissions in MMR while Figure 4-8 shows MMR's per capita fugitive emissions compared with that of India's. The comparison was done from the year 2000 to 2016.

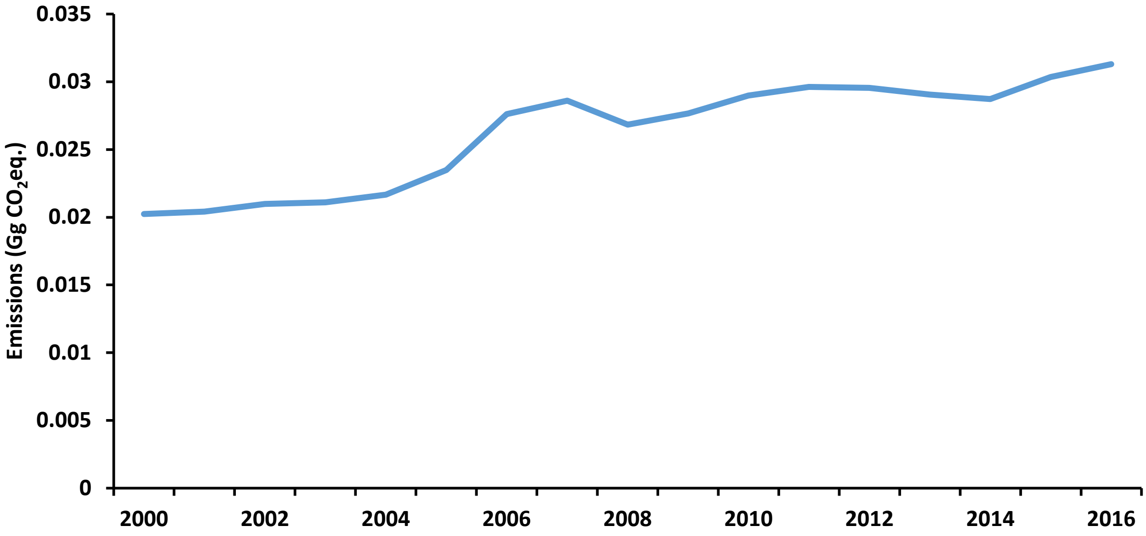

Figure 4-7: Change in fugitive emissions in MMR from 2000 to 2016

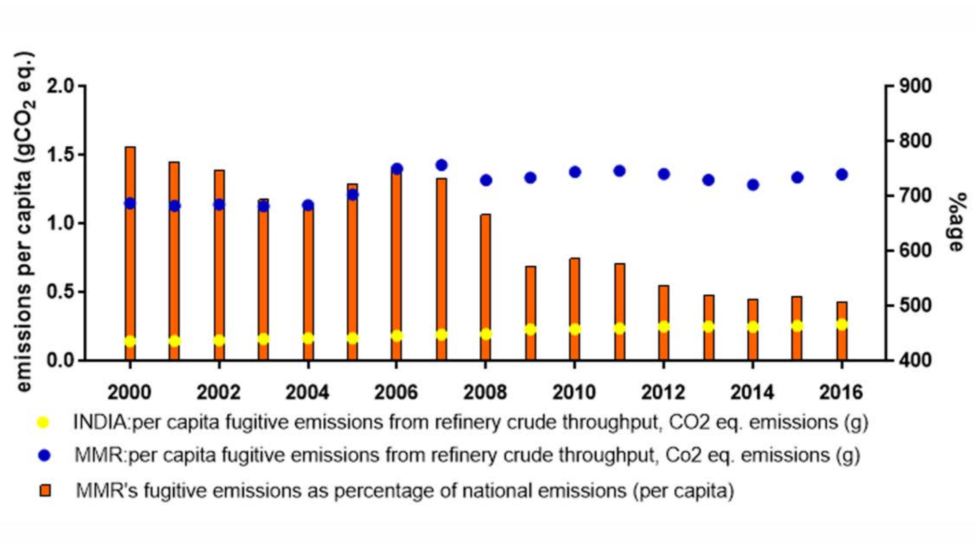

Figure 4-8: Per capita fugitive emissions and MMR's share in the national emissions

Figure 4-7 shows that MMR has a high fugitive emission record. Figure 4-8 confirms the same showing that the per capita fugitive emissions of MMR are very high compared with the per capita fugitive emissions of India. In 2000, MMR's per capita emissions are as high as 792.44% of the national per capita emissions. However, the share was observed to be decreasing slowly.

4.5.4 CO2 eq. Emissions from Electricity Consumption

Figure 4-9 shows the emissions from electricity consumption in MMR while Figure 4-10 shows MMR's per capita emissions compared with that of India's. Due to the lack of data available for electricity, only the emissions from 2009 to 2014 were compared.

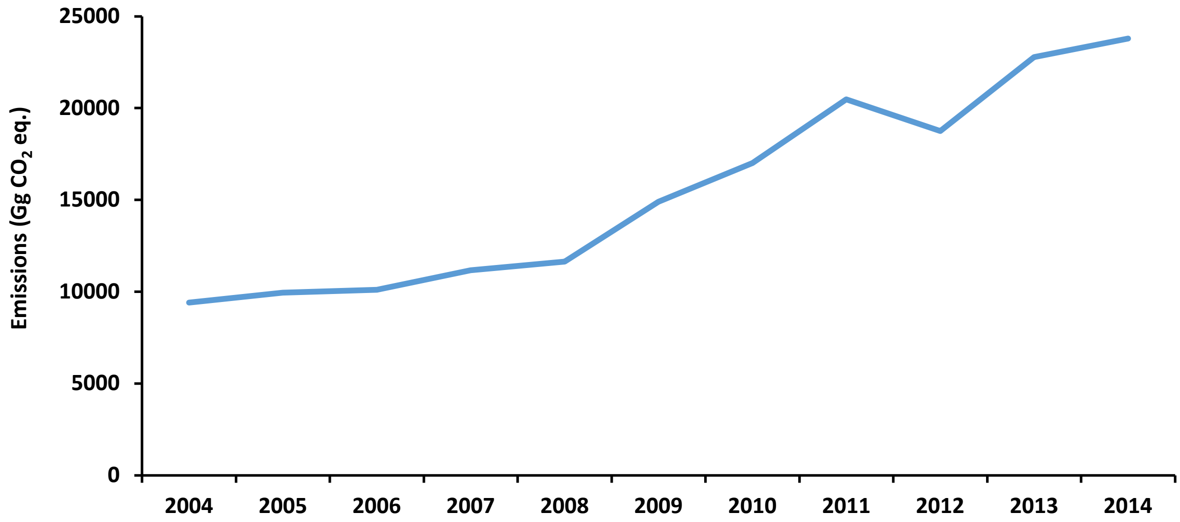

Figure 4-9: Change in emissions form electricity consumption in MMR from 2004 to 2014

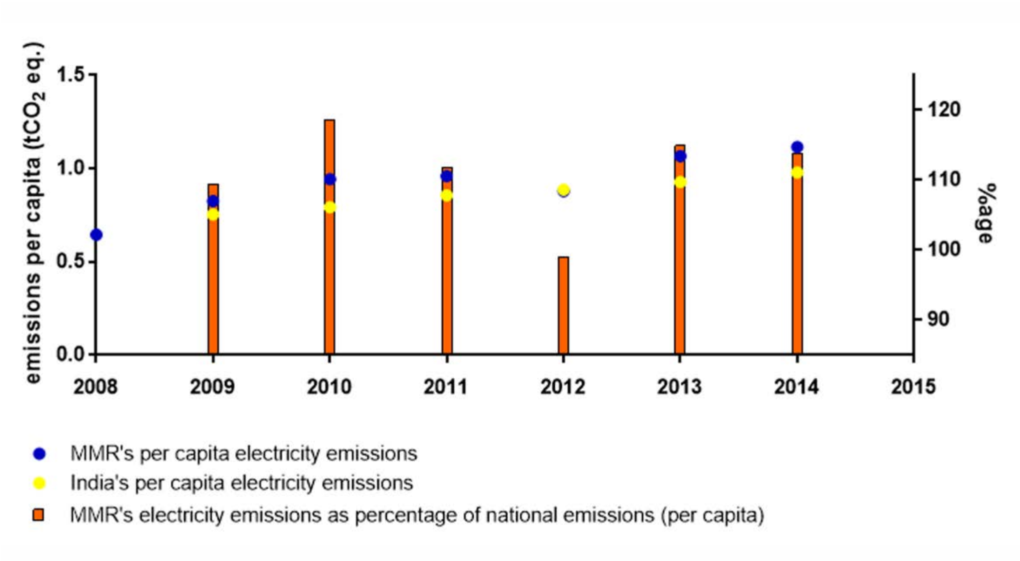

Figure 4-10: Per capita CO_2 emissions from electricity consumption and MMR's share in the national emissions

It was found that per capita emissions of MMR were constantly increasing from 0.52 t in 2004 to 1.115 t in 2014 (Figure 4-9). However, this sector shows an interesting shift from the previous trends. Unlike the other sectors, the per capita electricity consumption emissions of MMR are very close to the national per capita emissions. MMR's per capita emissions expressed as percentage of national per capita emissions shows that MMR's emissions were 118.79% of national per capita emissions in 2010 (highest) and 99.14% in 2012 (lowest).

4.6 Discussion

The graphs in the previous sections show different trends for emissions in different sectors. Table 4-5 presents MMR's share in the national emissions and MMR's per capita emissions expressed as percentage of national emissions (all sectors). Table 4-6 shows MMR's share in national emissions from road transport, fugitive and electricity sector and MMR’s per capita emissions expressed as percentage of national emissions.

Table 4-5: MMR's overall CO_2 emissions (from all sectors) expressed as percentage of national emissions

Year	Total emissions (%)	Per capita emissions (%)	Year	Total emissions (%)	Per capita emissions (%)
1970	3.65	280.77	1992	3.26	202.92
1971	3.65	278.14	1993	3.05	187.62
1972	3.95	298.17	1994	3.08	187.46
1973	4.10	306.75	1995	2.92	175.73
1974	3.95	293.63	1996	3.48	207.06
1975	3.88	285.82	1997	3.48	205.29
1975	3.72	272.44	1998	3.49	204.14
1977	3.90	283.64	1999	3.47	201.00
1978	4.20	303.17	2000	3.64	209.44
1979	4.19	300.60	2001	3.51	200.06
1980	3.88	277.05	2002	3.51	199.87
1981	3.66	259.87	2003	3.30	188.19
1982	3.94	275.59	2004	3.05	173.83
1983	3.90	268.60	2005	2.95	167.83
1984	4.07	276.52	2006	2.92	166.28
1985	3.94	264.11	2007	2.24	127.61
1986	3.96	262.62	2008	2.50	142.21
1987	3.87	253.43	2009	2.34	132.89
1988	3.64	235.93	2010	2.43	137.69
1989	3.69	236.51	2011	2.31	130.91
1990	3.56	226.27	2012	2.42	137.12
1991	3.35	210.62	-	-	-

Table 4-6 MMR's CO_2 eq. emissions from different sectors expressed as percentage of national emissions

Year	Transportation emissions (%)	Fugitive emissions (%)	Per capita transportation emissions (%)	Per Capita fugitive emissions (%)	Per Capita electricity emissions (%)
2000	-	13.78	-	792.44	-
2001	-	13.41	-	764.93	-
2002	-	13.14	-	749.01	-
2003	-	12.20	-	695.07	-
2004	-	11.97	-	681.73	-
2005	-	12.72	-	723.69	-
2006	-	13.27	-	754.76	-
2007	-	12.91	-	733.89	-
2008	8.10	11.76	460.36	668.35	-
2009	7.99	10.11	453.67	573.84	109.44
2010	8.13	10.37	461.51	588.32	118.79
2011	7.64	10.22	433.26	579.74	112.00
2012	7.69	9.50	436.05	538.65	99.14
2013	8.40	9.20	475.92	521.39	115.04
2014	8.31	9.06	470.69	513.33	113.89
2015		9.18		520.00	-
2016		8.99		508.70	-

It can be seen that MMR's per capita emissions are always higher than India's per capita emissions. For an area of 4304.48 km^2, which is just 0.13% of the total area of the country (3262011.73 km^2), the share of MMR's emissions is strikingly high. But the share is observed to be decreasing slowly (Table 4-5). Increase in India's national emissions was deduced to be the reason. The emissions from road transportation and electricity consumption look much parallel in magnitude (Table 4-4). However, comparing with national emissions, MMR's per capita road transportation are about 400% higher compared with India's per capita emissions, while per capita electricity consumption emissions are close to India's per capita emissions (Table 4-6). Fugitive emissions from MMR are very low compared to the road transportation and electricity consumption (Table 4-4). But per capita fugitive emissions of MMR are about 700% higher compared with India's per capita fugitive emissions (Table 4-6).

4.7 Conclusion

The results show that MMR has a high share in the national emission inventory. Based on the results of the CO_2 emissions from all sectors, the share of MMR's emissions ranges from 2.24% (minimum) to 4.19% (maximum) of the national emissions. In other sectors (road transportation, fugitive emissions, electricity consumption) also, MMR's per capita emissions were found to be higher than India's. The higher share of MMR can be attributed to the fact that Mumbai, the core city of MMR, plays a strong role in national and global economy. Mumbai contributes 40% of the GDP to the state of Maharashtra and 5% to the national GDP (Bhagat and Jones, 2013). MMR's contribution to the state and national GDP is approximately 70% and 11%, respectively (Bahl et al., 2013).

Emission estimation is important for improving national emission inventories. Especially for local Government bodies, it is the key step in framing emission reduction policies. Emission estimation from different sectors can be used to determine that which sector need more focus for mitigation policies. Comparison of MMR's emissions with India's emissions highlights its position in the national emission share. Moreover, India's INDC target is associated to reduction in GHG intensity by the year 2030. Linking MMR's emission share in national emission with MMR's GDP contribution in national GDP can assist in meeting India's climate goal. Hence estimation of MMR's share in India's emission is important for planning strategies to meet India's INDC target.

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CHAPTER 5 MMR's ROLE IN CLIMATE TARGETS

5.1 Introduction

Kyoto protocol was the first legally binding effort that the countries took in unison to meet the stipulated climate targets. The final commitment period of the protocol is to end in the year 2020, but the world is still far from meeting the targets (Böhringer and Finu, 2005; Kutney, 2013; Oberthür and Ott, 1999; Prins and Rayner, 2017; Rosen, 2015; Schiermeier, 2018; Victor, 2014). At this end, the Paris Agreement (United Nations, 2015) is being seen as the new roadmap to achieve these targets (Bodansky, 2016; Christoff, 2016; Höhne et al., 2017; Jacquet and Jamieson, 2016; Morgan, 2016; Savaresi, 2016). This agreement aims to limit global warming to 2 °C and pursue efforts to limit it further to 1.5 °C. The Fifth Assessment Report (AR5) of IPCC observed a close relationship between global temperature and carbon emissions (IPCC, 2013) which is being called 'the transient climate response to cumulative carbon emissions (TCRE)' (Collins et al., 2013). TCRE states that the global temperature increases with increase in the global emissions; implying that there has to be a limit on emissions to stay under a safe temperature limit. This has given way to several questions:

(i) What is the safe limit?
(ii) How much emissions can be allowed to stay under the safe limit?
(iii) What will be the basis of distribution of emission allowance?

While Paris Agreement defines 2 °C as the safe limit, many more studies are going on with a target of limiting the increase in temperature from 1.5 °C to 6 °C. In 2018, IPCC published a special report in which this 'safe limit' was translated into emission quota (Table 5-1) (Rogelj et al., 2018). This emission quota is the remaining emission budget that the World can emit in order to stay under the safe temperature limit. Several emission sharing principles and ideas have been proposed for dividing the emission quota among countries. The most common of them are inertia and equity principles. Inertia sharing (formerly known as grandfathering) is based on the theory that the countries should be allocated future emissions based on their historical emissions trajectories (Knight, 2012; Paterson, 1996; Sijm et al., 2018). Equity sharing is based on the theory that each person on Earth has an equal right over emissions and hence, future emissions should be allocated based on the population share of the countries (Yu et al., 2011). Since these two principles are seen as the two ends of justice spectrum (Elzen, 2017; Trudinger and Enting, 2017; Zhou and Wang, 2016), many more modifications were proposed in these theories, but until the 24th meeting of COP, held in December 2018, none of the sharing principles were globally accepted. Research is going on and efforts are still being taken to find a justified sharing principle that may suit the interest of all the countries to the best.

Table 5-1 Remaining carbon budget (from 1 January, 2018) with 1.5 °C and 2 °C warming limit above the pre-industrial level (in $GtCO_2$)

Warming limit	**1.5 °C**		**2 °C**	
Probability	**67%**	**50 %**	**67%**	**50 %**
	420	580	1170	1500

Source: Rogejl et al., 2018

Meanwhile, countries which are party to UNFCCC, are contributing to reducing global emissions with targets defined at global and local levels. At global level, the common target for all the countries (which are parties to UNFCCC) is the Paris Agreement's 2 °C target. Also, all the parties that ratified Paris Agreement are required to prepare national level climate targets depending on the country's potential. These are called Intended Nationally Determined Contributions (INDC) (UNFCCC, 2019). These are country's voluntary targets based on their capacities and ambitions. India has also maintained a national level climate target defined in India's INDC. The aim of the current chapter was to translate these global and national targets for the scope of MMR. Depending on the past emissions, MMR's future emissions were forecasted and compared with the climate targets to find the status of MMR in meeting the targets. The objective was to determine that how much reduction in MMR's emissions is required to meet the Paris Agreement's target and India's INDC target.

5.2 MMR's Emissions Forecast

MMR's CO2 emissions from 1970 to 2012 using EDGAR data were calculated in Chapter 4. Using results from this chapter as base data, MMR's emissions were forecasted for the duration 2013 to 2048. The duration for forecast was chosen based on the requirements of climate targets (explained in section 5.3 and 5.4). Statistical Analysis System (SAS) University Edition 3.71 (Basic Edition) software developed by SAS Institute at North Carolina State University (SAS Institute, 2018) was used for forecasting. Forecasting was done using Linear (Holt) exponential smoothing forecasting model with 95% confidence level. Table 5-2 shows the results and Figure 5-1 show the emission forecast band produced by SAS software.

Table 5-2 Emission forecast (in Gg) for MMR calculated using SAS software

Year	Emissions	Year	Emissions	Year	Emissions	Year	Emissions
2013	137,596.00	2022	161,041.60	2031	184,487.20	2040	207,932.80
2014	140,201.10	2023	163,646.70	2032	187,092.30	2041	210,537.90
2015	142,806.20	2024	166,251.80	2033	189,697.40	2042	213,143.00
2016	145,411.20	2025	168,856.80	2034	192,302.40	2043	215,748.00
2017	148,016.30	2026	171,461.90	2035	194,907.50	2044	218,353.10
2018	150,621.40	2027	174,067.00	2036	197,512.60	2045	220,958.20
2019	153,226.40	2028	176,672.00	2037	200,117.60	2046	223,563.20
2020	155,831.50	2029	179,277.10	2038	202,722.70	2047	226,168.30
2021	158,436.60	2030	181,882.20	2039	205,327.80	2048	228,773.30

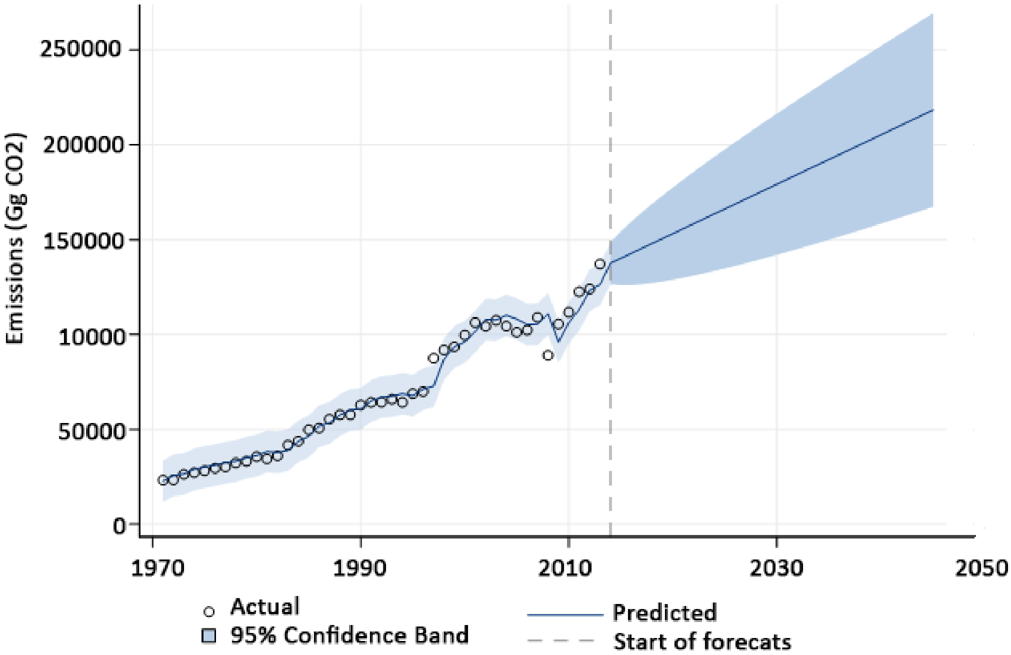

Figure 5-1 Emission Forecast Band generated by SAS software generated by SAS software

5.3 India's INDC Target

According to India's INDC, a 33 to 35% reduction in GHG intensity of GDP of 2005 levels by 2030 is aimed. This is a development oriented voluntary target by India. With the responsibility of a reasonable Human Development Index, and the economic progress of its vast population, MOEFCC defined voluntary aims as a part of communication to UNFCCC (MOEF, 2004).

5.3.1 Emission Reduction for India's INDC Target

This emission target is relative to the economy of the country. A reduction in emission intensity of GDP is aimed; a direct reduction in absolute emissions is not the aim of this target. According to World Resource Institute, GHG intensity of GDP is the level of GHG emissions per unit of economic activity measured in GDP of a country (Baumert et al., 2005). A study derived this target in terms of absolute emissions (Frank, 2016). According to this study, India's economy is expected to grow at 7% and it will reach 18 trillion USD based on 2005 prices. The study concluded that with this growth, India's emissions in 2030 will be 5.6×10^6 Gg. Assuming that MMR's share in India's national emissions in 2030 is the same as in 2005, MMR's targeted emissions in 2030 were calculated to be 164640 Gg. This target was to be compared with MMR's emission forecast based on its current emission trajectory assuming that no climate change related policy is implemented in the due course.

According to the forecast, MMR's emissions in 2030 will be 181882.20 Gg. Comparing this prediction with the targeted emissions, it can be observed that MMR needs to reduce its emissions by 17242.20 Gg in the year 2030. This is approximately 16.8% of the 2005 emission level of MMR. Hence, for meeting India's INDC target, a contribution of 16.8% reduction from 2005 level is required from MMR in 2030.

5.4 Paris Agreement's Target

Estimation of Paris Agreement's target is more complicated compared to INDC target. It requires all the countries (which are parties to UNFCCC) to come to an agreement regarding the sharing of global emission budget. Since India is a party to UNFCCC, as a part of the country, MMR is also obliged to reduce its emissions. Unlike INDC, Paris Agreement's targets are to be implemented uniformly at a global level. Hence, calculations were made specifically for MMR, considering it an exclusive region and sharing principles were applied directly to MMR. India's emissions or population were not taken for estimating this target.

Paris Agreement's target for MMR was derived using four sharing principles. Other than inertia and equity sharing (as discussed in section 5.1), the other sharing principles used in this study are: 'blended sharing' proposed by Raupach (2014), which introduces a sharing index (w) to maintain a balance between equity and inertia extremes, and 'inclusive sharing' proposed by Neumayer (2000); including the factor of historical accountability with equity sharing. The principles are briefly described below:

i. Inertia sharing–based on the past emissions of the country.
ii. Equity sharing–based on the population of the country.
iii. Blended sharing–incorporates the sharing index concept and may lie anywhere between inertia and equity sharing. However, for the purpose of analysis, blended sharing combines equal parts of inertia and equity sharing, with sharing index = 0.5 (as developed by Raupach et al., (2014) and used by Sahu and Saizen (2019)).
iv. Inclusion sharing–adds the factor of historical responsibility (in the form of compensation) to the population-based emissions sharing criteria. Compensation is the debt/credit a country owes to the world (or other countries) depending on its past emission trajectory (developed by Neumayer (2000) and used by Gignac and Matthews (2015) and Sahu and Saizen (2019)).

Messner et al., (2010) has raised the importance of four fundamentals in calculating the national emission budget: (i) period of total budgeting defined by the start year and end year; (ii) the year when the emission distribution is to start; (iii) probability of the estimations; and (iv) demographic reference year. In the present study, the budgeting period starts from 1970 which is the start year for the first Regional Plan of MMR. The budgeting period ends in the year 2012 which is the last year for which EDGAR data for emissions is available. Hence total budgeting period is 1970 to 2012. 2018 was the start year as per the budget estimates by IPCC (Rogelj at al., 2018). 2°C warming limit with 67% and 50% probabilities was considered. The demographic reference year is the year based on which the future calculations are to take place. As explained by Messner (2010), the more recent is the demographic reference year is, higher are the chance that countries with larger populations benefit through equity sharing, while countries with higher emissions benefit with inertia sharing. To neutralize this effect in the current study, the demographic reference year was superseded by the reference period as instead of choosing one year as reference year, mean of years was used. For example, the reference for emissions was the mean of emissions from 1970 to 2012 and reference population was the mean of population from 1970 to 2012. This method is meant to counterbalance the advantages for highly populated countries and high emitting countries.

5.4.1 Data

Historical emissions of MMR were calculated using EDGARv4.3.2 (section 4.4). The corresponding world's historical emission data was compiled from the Carbon Dioxide Analysis and Information Centre (CDIAC) (Boden et al., 2018). It includes emissions from fossil fuel combustion, oxidation and cement production and bunker fuels. World's remaining emission budget was taken from IPCC (Rogelj et al., 2018). Budget consistent with the 2 °C warming limit was used. The data on committed future emissions was obtained from other studies (Davis et al., 2010; Davis and Socolow, 2014). The data on global population was obtained from The World Bank (2018). MMR and India's population data was taken from Census of India (Ministry of Home Affairs, 2017). Since demographic data of India is collected on a 10-year basis, exact population data was only available for the years 1961, 1971, 1981, 1991, 2001, and 2011. The population data of the non-census years was extrapolated using available data (explained in section 4.3).

5.4.2 Methods for Estimating MMR's Remaining Budget

The following equations were employed for calculating MMR's remaining budget according to the sharing principles:

Equation 4

$$E^t_c = (E^b_c / E^b_w) \times E^t_w \qquad \text{(inertia sharing)}$$

Equation 5

$$E^t_c = (P^b_c / P^b_w) \times E^t_w \qquad \text{(equity sharing)}$$

where,
Etc (E^b_c) = Emission of region C in target year t (base year b)
E^t_W (E^b_W) = Emission of the world in target year t (base year b)
P^b_c = Population of the region C in base year b
P^b_W = Population of the world in base year b

Equation 6

$$E^t_c = [(1\text{-}w) \times (E^b_c / E^b_w) + w \times (P^b_c / P^b_w)]\, E^t_w \qquad \text{(blended sharing)}$$

Calculations based on the principle of inclusion are more elaborate (Neumayer, 2000). This principle takes into account the historical emission debt (or credit) of the region and compensation that the region deserves (or owes) to the world. Following are the equations:

Equation 7

$$HED_c = \Sigma\, [E_c - (P^b_c / P^b_w) \times E_w]$$

Equation 8

$C^n_c = (1/N) \times HED^n_c$

Equation 9

$E^t_c = [(P^b_c / P^b_w) \times E^t_w] - C^n_c$ (inclusion sharing)

where,

HED_c = Historical emission debt (or credit) of the region C

C^n_c = Compensation that the region C agreed in N years (where n = 1,…..N)

Here, the calculations were done for future cumulative emissions, hence we assume that the region is to be compensated for all the years. It numerically means that for this study, we assume that 100% of HED is to be compensated to the region. Therefore, we dissolve the factor N from our equation in order to make compensation factor (C^n_c) = Historical emission debt (HED^n_c).

Figure 5-2 presents the change in HED of MMR from 1970 to 2012

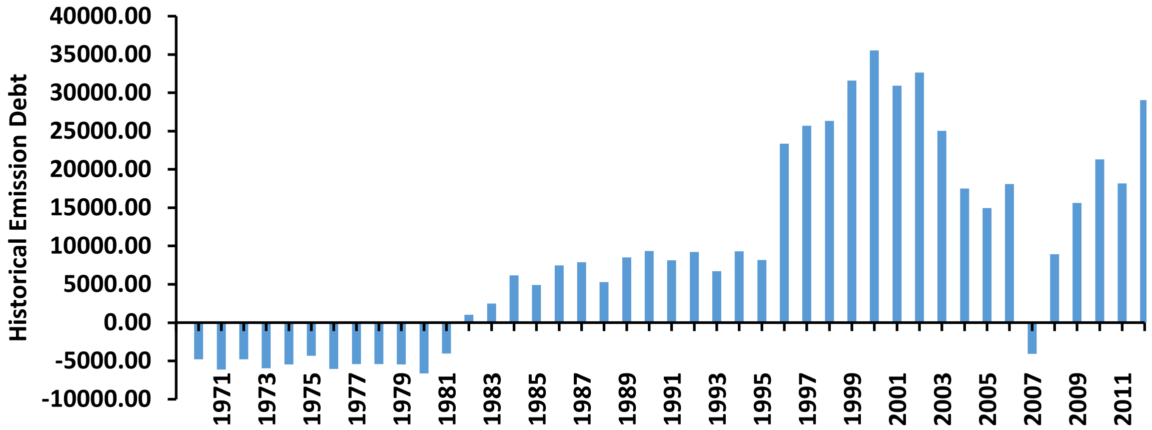

Figure 5-2 Change in Historical Emission Debt of MMR from 1970 to 2012

5.4.3 Results

Remaining carbon budget for MMR was calculated using the above equations starting from the year 2018. Table 5-3 and Figure 5-3 shows the results.

Table 5-3 Remaining carbon budget for MMR starting from 2018 for 2 °C warming limit

Warming limit	2 °C	
Probability	**67%**	**50 %**
Inertia sharing	3,510,119.700	4,500,153.462
Equity sharing	3,023,337.437	3,876,073.637
Blended sharing	3,266,728.569	4,188,113.550
Inclusion sharing	2,622,465.181	3,475,201.381

It was found that inertia sharing allocated highest emission budget to MMR, followed by blended sharing and equity sharing, while inclusion sharing allocated lowest budget to MMR.

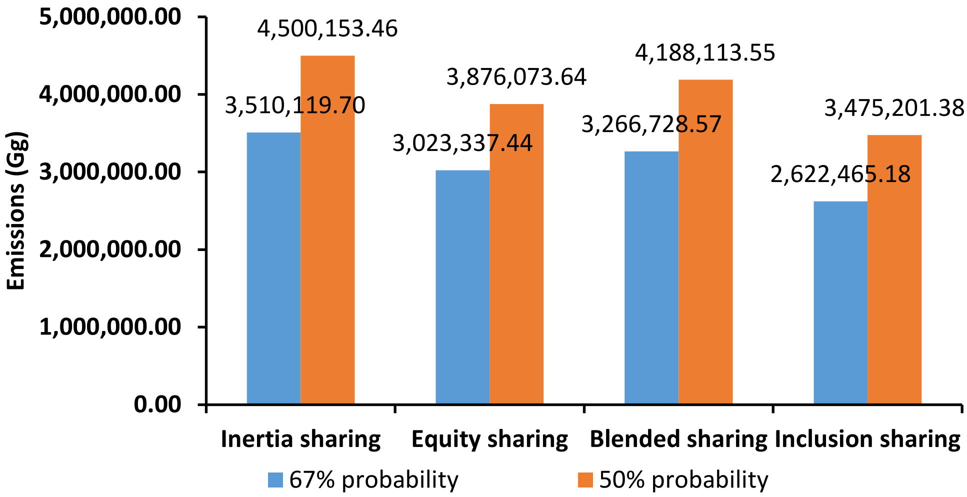

Figure 5-3 Budget allocation to MMR for 2 warming limit with different sharing principles.

5.4.4 Mitigation Rates

Mitigation rates required to meet Paris Agreement's 2 °C target with 67% probability were calculated using the methodology provided in the supplementary paper by Raupach et al., (2014).

Mitigation Rate $=\frac{1+\sqrt{1+rT}}{T}$ **Equation 10**

Where,

r = initial proportional growth rate $=1/f_0 \times \frac{df}{dt}$ **Equation 11**

T = emission time (defined by quota q) $=\frac{q}{f}$ **Equation 12**

and,

f = capped emission trajectory (and f_0 = initial cumulative emissions)

q = emission quota (in this case, emission quota is different for different sharing principles)

MMR's past emissions for 43 years (1970 to 2012) was adopted as capped emissions for future. Past cumulative emissions were found to be 2,974,226.23 Gg. Hence, for this study,

$f_0 = 2974226.23$

$r = \frac{1}{2974226.23} \times \frac{f(2012)-f(1970)}{2012-1970} = 9.119 \times 10^{-4}$

q (Inertia sharing) = 3,510,119.70

q (Equity sharing) =3,023,337.43

q (Blended sharing) =3,266,728.56

q (Inclusion sharing) =2,622,465.18

According to this, mitigations rates calculated for limiting the global temperature rise to 2 °C with 67% probability for different sharing principles were found to be:

- Inertia sharing – 1.695
- Equity sharing – 1.967
- Blended sharing – 1.821
- Inclusion sharing – 2.268

It means, if inertia sharing is followed, 1.695% mitigation in emissions will be required every year to meet the Paris Agreement's target.

In addition to the mitigation rates, the time duration, in which the remaining budget will be exhausted was also found by applying the mitigation rates to MMR's emissions. It was found that emission budget consistent with inertia sharing would be exhausted in the year 2048, budget consistent with equity sharing will be exhausted by 2043, and the budget consistent with blended and inclusion principle will be exhausted by 2045 and 2040 respectively.

5.4.5 Emission Reduction for Paris Agreement's Target

For finding required emissions reductions, the emission forecast of MMR was compared with Paris Agreement's targets. For each sharing principle, the duration of exhausting the remaining budget was different. Therefore, reduction required for different sharing principles was also different. Table 5-4 shows the results.

Table 5-4 Difference in cumulative emission compared with Paris Agreement's 2 °C target with 67% probability

Sharing principle	Remaining Budget	Difference in emissions (Gg)	Emission Reduction required (%)	Last year of exhausting emissions
Inertia sharing	3,510,119.70	2,370,498.60	40.31	2048
Equity sharing	3,023,337.44	2,453,495.60	44.80	2043
Blended sharing	3,266,728.57	2,649,415.70	44.78	2045
Inclusion sharing	2,622,465.18	2,214,938.90	45.79	2040

It was found that a 40 to 45 % reduction in emissions was required to meet the Paris Agreement's target. A 40.31% emission reduction was required to meet the inertia allocation target. Equity sharing required 44.80 % reduction while blended and inclusion sharing required 44.7 and 45.7 % reduction compared to the forecasted emissions respectively.

5.5 Conclusion

Being an economically advanced region, MMR has huge potential to lead the country in mitigating GHG emissions. In this part of the study, the climate targets were translated into emission reduction targets for MMR. Comparing MMR's stance in Paris Agreement and India's INDC targets, it is evident that MMR has higher chances of meeting India's INDC goal with less ambitious efforts, while, for meeting Paris Agreement goal, strong efforts will have to be made. On top of that, different sharing principles have different emissions budgets for MMR. Figure 5-4 showcases the past emissions, emission forecast as well as mitigation pathways required for INDC and Paris Agreement's target. The differences in targets are evident. It can be seen that INDC target is the closest to emission forecast. According to Paris Agreement's target, inclusion sharing can be observed to be forcing strongest reduction targets.

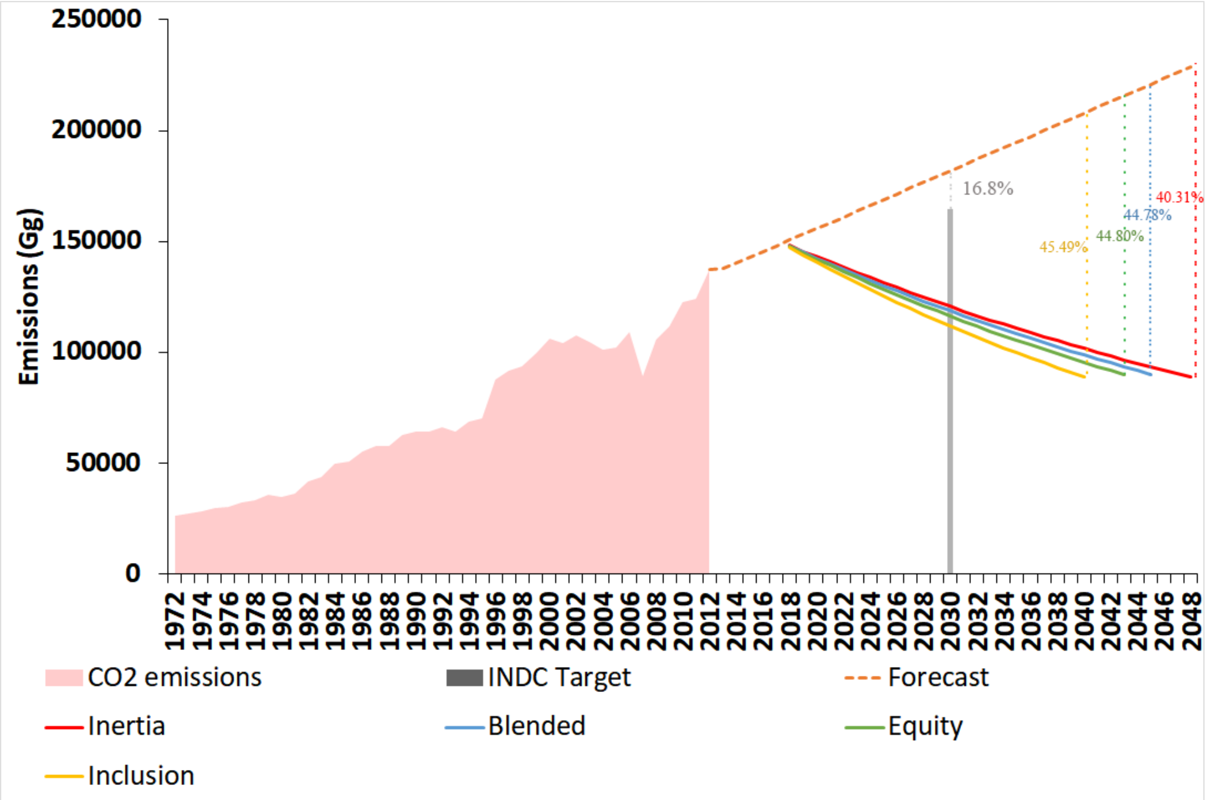

Figure 5-4 MMR's past emissions, emission forecast, and mitigation pathways

For calculating emission targets, MMR was considered an exclusive region in this study. However, as a part of the country, the targets may vary depending on national targets. Also, time period used for budgeting is an important factor that has the potential to alter the results in huge magnitudes. The time-scale considered in this study was the time scale of the regional plans of MMR as the study is mainly meant to deal with climate change issues in MMR from the planning perspective. Depending on the type of emission sharing principle accepted, MMR's goals will vary in large extents. However, MMR will be allocated highest budget through inertia sharing while inclusion sharing will allocate smallest budget to MMR.

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CHAPTER 6 MMR's REGIONAL PLANNING AND GREENHOUSE GAS EMISSIONS

6.1 Introduction

The role of a city's plan in governing climate change is important as cities have been acknowledged as a prominent source of GHG emissions (Dubeux and Rovere, 2011; Kamal-Chaoui and Robert, 2009; The World Bank, 2010). Now the discussion has moved to the point where Government needs to take mitigation and adaptation measures in the planning of the region. This has given way to various line of thoughts. Firstly, the focus on regional/ city level GHG inventory has gained priority and many metropolitan governments and researchers are taking interest in exploring ways to monitor the emissions more accurately. Secondly, focus is on finding measures to reduce emissions at every possible step. For the former field, the literature is now abundantly available. Chapter 4 of this study is about estimating MMR's GHG emissions. In the second field, not much has been achieved from the planning perspective. At planning level, the spatial parameters which are most responsible for GHG emissions greatly differ with context. Hence there is no standard approach to determine the relationship between cities and emissions in terms of planning parameters. The present chapter talks about this relation for MMR. The chapter aims to discover the parameters in MMR's Regional Plans which are most related to the region's emissions. These are the spatial parameters which can be modified with an objective to reduce emissions.

6.2 Methodology

There can be two approaches to determine the role of planning parameters in a city's emissions. First is the empirical approach as used by Zhang et al., (2018) where the city's socio-economic factors and different land use types are used as indicators and GHG emissions are apportioned for each of these indicators. This approach needs development of a detailed city emission inventory of each sector and exhaustive elaboration of the indicators. The unavailability of this data in India makes it impossible to use this approach, hence, in the present chapter, the second approach was used which is more theoretical. In this approach, the complex link between city's emissions and each planning parameters is analysed and depending on various criteria, the priority of the parameters is decided. This approach requires deep understanding of spatial planning parameters and the relation between them. The first step was a desk research conducted to gather and synthesise useful information from literature studies and research papers. In this, firstly, various research papers were used to form a list of factors that can affect a city's emissions. Secondly, planning strategies of some successful cases (cities of the World) were studied to find strategies/policies that can be regularized in a Regional Plan; keeping in mind the listed factors. Climate Action Plans, Energy Plans and Regional Plan Strategies were studied to make notes and determine the contemporary practices in the Regional plans of a metropolitan area. Planning categories that can be intervened to take part in mitigation measures were found. The second step was to discover that which component(s) of the MMR's Regional Plan contain those parameters or has the prospect to absorb one or more of those parameters. With this step, it can be determined that which component is dominant in reducing emissions (and hence more responsive to climate protocols). Analytical Hierarchy Process was used in this step to find the Regional Plan components that can affect MMR's emissions the most. The steps can be listed as follows:

Step 1: Determine all the possible factors that can affect the emissions of a city.
Step 2: Find planning categories and spatial parameters that can regulate the factors found in step 1.
Step 3: Determine the components of MMR's Regional Plans that contain parameters found in step 2.

6.2.1 Literature Study

As discussed above, desk research was conducted for this part. Literature study was done, firstly using the previous studies and secondly examining the cities of the world which have successfully reduced their emissions using planning strategies.

Research Papers: Lessons from Previous Studies

Various studies are available that talk about climate change related policy options for different cities. Most of these talk in the terms of climate change adaptation and mitigation policies theoretically explaining the elements that are the target of respective policies. Davoudi (2009) elaborates the role of planning in climate change by mapping three policy areas against three type of planning interventions. Baynham and Stevens (2013) evaluated British Columbia's city plans for action on climate change mitigation and adaptation. Marcotullio et al., (2014) outlines the interaction of urbanization pattern and energy demand resulting in increased emissions. Maenhout et al., (2013) has found the relationship between a city's transportation and household energy consumption drivers and emissions. Hoornweg (2011) and Seto et al., (2014) detailed policy instruments and tools that can be applied to a city for climate change mitigation and adaptation. Zhang et al., (2014) studied the driving factors for emissions in a city and concluded that government policies effect population growth, energy consumption, industrial and economic structure of a region. Dulal and Akbar (2013) elaborated planning strategies that can be employed to reduce GHG emission in a city. Summarizing up these studies, it was concluded that the factors that have a key impact on a city's emissions are diverse. Most of the factors are interdependent and get influenced by a range of social, economic, political activities. The geography of the city, demography, living standard, income, and behavioural aspects play an important role. Although, regional planning might indirectly affect them, but they are definitely not a factor of spatial planning of a region. However, other parameters like population dynamics; urban form; connectivity of house, work and leisure; taxation policies; incentives and subsidies; infrastructure; usage of renewable energy; transportation strategies can be directly influenced by regional planning. Along with this, the institutional capacity of the city, political will, governance mechanism and financial resources of the city play a huge role.

These studies give an elaborate description of climate change planning components. But since the planning solutions need to be modified with the changing contexts, the approaches proposed in these studies cannot be directly applied to a specific area, highlighting the importance of a dedicated research for different cities. For this, the cities which have applied specific approaches to govern climate change and have shown an effective response were studied. The new and specialized planning strategies practiced in different cities of the developed and developing countries were considered.

Climate Responsive Cities: Lessons from the World

This section elaborates the spatial planning approaches practiced in different cities aiming to adapt or mitigate climate change.

Singapore

According to the International Energy Agency (2015), Singapore is ranked 123 in the CO_2 emissions and 26th in terms of per capita emissions per dollar GDP (out of 142 countries). In the National Climate Change Strategy Report (2012) published by National Climate Change Secretariat, Singapore identifies itself as an 'alternate energy disadvantaged country'. Because of the small land area that Singapore possesses, the alternative energies like hydroelectric power, marine renewable energy, geothermal energy, wind energy, nuclear, and solar energy cannot be harnessed at a large scale. Hence, its key strategy is to improve energy efficiency.

Singapore's Climate Action Plan (2016) states that in Singapore, car ownership and car usage is strongly controlled by the Government. There is a quota system for car ownership and the ownership contract is renewed after a particular time interval. There is a strict road pricing system for private vehicles while the public transportation is being promoted using a number of government policies, initiatives and subsidies. There is a mandatory 'give way' system for public buses and advanced railways are being installed. Singapore uses natural gas as the main source of energy for electricity generation and solar power use is highly motivated. Minimum standards for energy performance for building construction, appliances, and cars have been set and these are regularly monitored by the Government. Low carbon emission cars, energy saving in industries by various schemes and grants is encouraged. Industries are required to report their emission counts and industries emitting 25000 t CO_2 or more are required to pay carbon taxes. As an approach to protect its land from floods, the minimum reclamation level for newly reclaimed land has been raised and soft coastal protection measure like using plants for coastal protections are being taken. Drainage system capacities are being enhanced and advanced modelling tools are being implemented.

Paris

The metropolis is a model for the world after the Paris Agreement. The Paris climate action plan is updated every five years. Reduction in energy consumption and GHG with increased usage of renewables is the target. Regulation of building density for adaptation of the fabric of Paris by regulation of building height, open areas, social housing scheme for creating a compact space is practiced. It allows for a collective district heating, cooling, gas, and electricity distribution facilities which has shown high reduction in the energy consumption in past. The aim is to cut the energy consumption by 25% by 2020 (Riahi, 2015). This is also being seen as an opportunity to move towards renewable and recovered energy usage. Private transport is controlled by regulating parking rules, speed limit reduction, vehicle's environmental performance checks; driver-less vehicles, car sharing schemes etc. (New Paris Climate Air and Energy Plan, 2017). The use of part of a public building is authorised for external insulation of existing buildings. An energy information advisor gives information regarding sustainable living to applicants of a building permit (Paris Climate and Energy Action Plan, 2012). Owners of small facilities are given subsidies to carry out energy audit of their buildings. Big corporations are allowed to play a direct role in the Paris Climate Action Plan. Sustainable tourism is being developed and there is promotion of sustainable consumption to reduce wastage. Tap water is cleaned and made drinkable directly to reduce the water bottle wastage. Fountains, plantation and other means are used for alleviating the effect of UHI. Another advancement is the encouragement to flexible and reversible building design through building control regulations. In this plan, the buildings are designed with reversibility and versatility, in order to accommodate several purposes (family dwellings, hostels, offices and workshops, etc.) which may change the function over time without major renovation work.

Tokyo

Tokyo is a polycentric metropolis like Singapore and Paris (also MMR). It has successfully linked its cities with advanced subway and railway system. It has innovative ideas in line like establishment of a 'Zero Emission Island' as a demonstration project in one of its islands (Tokyo Metropolitan Government, 2018). Tokyo Zero Carbon 4 days Scheme is another example where, the aim is to offset all the GHG emissions that will be generated during the Tokyo Olympics in 2020 with the cap and trade system. Planning of a 'Super Eco Town' is another example where the government is planning to create a town where all the activities are aimed to be environment friendly and renewables are the only source of energy. Also, a community space has been established for conducting experiments to coordinate with the Paris Agreement.

Other than this, promotion of the Zero Emission Vehicles including battery operated vehicles and hybrid vehicles is high. Zero energy building aim is being accomplished with green building programs, energy efficiency schemes etc. Cap and trade program for large facilities is a mandate and carbon reduction and reporting is a mandate for small facilities along with a Building Environmental Plan. A green labelling of property at the time of sale is required which displays the details of the building's environmental performance. Mitigation of Urban Heat Island (UHI) by creating cool spots, planting trees, installing mist generators etc. is a common practice. Online information about the building's suitability for solar power generators is provided by the Government. Environmental awareness is being engraved in the culture by spreading awareness in the public. Providing free information through leaflets, organising lectures for adults and sending sanitation workers to schools for spreading awareness is a common practice. A team of automobile inspectors (mainly the former police officers) are employed to check the environmental performance of private vehicles. Under the greening program, 20% of roof area and more than 20% of open space on ground is required to be green. Conservation of nearby green areas and developing eco-tourism is another scheme by the government. As a result of practicing such schemes, huge improvement in the air quality of Tokyo were witnessed compared to last 10 years, when most of the metro cities are suffering from bad air quality issues.

<u>United Kingdom</u>

In UK, market strategies are prominently used to cut down emissions. Carbon price is set by trading emission quotas instead of directly setting a carbon price. Cap and trade scheme plays a prominent role and other carbon taxes (like vehicle excise duty, hydrocarbon fuel duty etc.) are also levied. Promotion of renewable energy is done along with usage of nuclear power and carbon capture and storage programs'. There is a 'renewable obligation scheme' in UK under which the electricity end suppliers are required to purchase electricity generated from renewable resources. A similar scheme runs for road transportation too (Bowen and Rydge, 2011).

Additionally, there is a 'Green Deal 'scheme for homes where steps are being taken to reduce home emissions by architectural designs, raising energy standards of appliances, and promoting usage of renewable energy for heating. There is provision of energy grants calculator and an advisor who educates regarding benefits of an environment friendly home. There are schemes in European Union for low emission transportation. UK also runs an 'Ultra Low Carbon Vehicle Innovation Platform' under which development and demonstration of ultra-low carbon fuels and vehicles are developed.

<u>London</u>

A detailed plan including dedicated chapters for places, people, economy, climate change issues, transportation, living spaces etc. is made and implemented. For checking its climate responsiveness, the city uses architectural design and development control as tools for energy saving. District heating and cooling and combined power usage are practiced. On-site renewable energy technology is a mandate and there is an obligation to provide for the shortfall off site. Urban greening is practiced through tree planting, green roofs and walls, and muti-functional infrastructure. (Climate) Risk Management for related disasters is practiced. Buildings are designed for quick recovery in the event of a flood. Sustainable practices for water, waste and drainage systems are adopted (The London Plan, 2016).

<u>New York</u>

The first Regional Plan of New York favoured roads and highway infrastructure (and not mass transit system). As a result, suburbanization took place and people, business and jobs moved from city centre to neighbouring centres. With the second regional plans, the social and economic distance between city centre and suburbs only increased. In the third regional plan, focus was on transit and connectivity, preservation of green and open spaces in order to make up for the social loss of the region. Similar is the goal of the fourth and current regional plan which favours transit oriented development. Growth is encouraged in already developed areas in a way that consumes less area and promote mixed land use. Regional jobs are being restored and affordable suburban transit systems are being promoted. Methods for reducing highway congestion are being taken. Land and coastal conservation measures, establishing national parks and green infrastructure, cooling the communities, steps for protecting open spaces and transitioning away from areas that cannot be protected are being taken. Cap and trade variable prizing, carbon tax, vehicle prizing and similar market strategies are used in the city to reduce GHG emissions. Renewable energy sources are being scaled up for a more reliable usage (Regional Plan Association, 2018; The fourth Regional Plan, 2018). Television and media was used in New York to expand the public participation in the development of the region. Meetings, workshops with residents were held which gave insight to the major concerns of the region.

<u>Portland, Oregon</u>

Portland is among the top few cities in US which are prepared for climate change risks (McCormic, 2016). The city has used advanced technology for energy efficiency. High performance buildings, use of solar array, stretch energy code (an appendix to a mandate state-wise minimum energy code that allows municipality to adopt greater levels of energy efficiency) are the general strategies. Transportation and land use management is integrated to manage the traffic demand. Improved transit facilities, bike sharing, electric vehicle and charging networks, enhanced infrastructure is installed. Issues arising from sea level rise and flooding are specially focused. Owners of large commercial buildings are to report the building's energy performance. For family homes, disclosure of building energy information is required at sale. A financing mechanism is set up to make it easier for owners to invest in energy efficiency and renewable energy. A loan system for the building is also framed which is transferable to the next owner when the building is sold. Fossil fuel infrastructure was restricted by changing the zoning codes and regulation. Inclusionary housing is encouraged to reduce carbon footprint by designing mixed-use, walkable neighbourhood (Climate Action Plan Progress Report, 2017; Climate Action and Adaptation Plans, 2018).

'Take back', 'repair' as well 'sharing economy' is encouraged. 'Fix it' fares are planned. Specialised waste reduction programs are run in the city. Plastic usage is minimised and plastic bags are charged, plastic packaging is reduced, construction waste is reused and recycled.

<u>Hong Kong</u>

Hong Kong has been recognised as one of the top five climate leaders in the world. It aims to achieve a 20% carbon reduction by the year 2020 and 26% to 36% by the year 2030. It needs to achieve this aim by increasing the share of non-fossil fuel resources for energy generation, promoting low carbon consumption and transportation system. There are strong provisions for environmentally conscious infrastructure design. Flood management and drainage systems are integrated for flood control. Food and resource wastage is minimised by putting a charge on wastage. Water conservation techniques are strongly promoted. Slope design is mandated in the new construction for water conservation. Along with climate action plan, Hong Kong also possesses a biodiversity action plan.

<u>Cape Town</u>

Cape Town is another city in a developing country which was among the top five cities in climate leadership. The city's efforts for monitoring and communicating climate action data aiming to reduce carbon emissions and to adapt to the changing climate were the reasons behind the title.

6.3 Interventions that can be done in a Regional Plan

From the above process, certain elements that have a strong impact on a region's emissions were found. For the context of this study, these elements were termed 'factors that can affect the GHG of a city'. These factors can be summarised as follows:

(i) Geography: Climate of the city, location etc.
(ii) Economic base of a city: whether the city is industrial or service based
(iii) Political and institutional characteristics
(iv) Urban demographic characteristics: population concentration and economic activity
(v) City's urban fabric: density, location pattern etc.
(vi) Layout of its transportation system: transit based development, ownership of vehicles
(vii) Consumer behaviour: Appliance use, home insulation, energy saving awareness
(viii) Waste management system of the city: waste segregation and disposal

In this comprehensive list of factors, some may be dominant and some might have a subtle effect on GHG- which is another complex issue and may change with different contexts. For example, the geographical factor will have a strong impact on energy usage in the countries in colder region, say the Nordic countries, resulting in higher GHG emissions. However, for India, specifically for MMR, geographical factor is not as strong as that in the Nordic countries. Moreover, geography is not a factor of planning. Also, many other factors in the list may or may not be the direct consequence of the region's planning policies. For example, the economic base of a city cannot be a direct factor of spatial planning aspects of a city. Regional planning can affect emissions but, availability of natural resources and political favourability may have a stronger impact on emissions and these cannot be altered through Regional Planning. Hence, to avoid the complexities, the present study took into account only the factors which can directly be affected by spatial planning. Refining the factors and summing them up into specific categories, it was found that there can be four broad categories in which a Regional Plan can have an effect on the city's emissions. These were termed 'Intervention Categories' for the context of this study. These are the factors that can be worked upon (in the Regional Plan) to have an effect on GHG. The factors can be broadly classified in following four 'Intervention categories':

1. Planning
2. Transportation System
3. Energy Usage
4. Waste Management System

The scope of each of these categories is wide. Each category can be further sub-divided into different heads. Hence, for simplification in understanding, each category was divided into specific planning heads called 'parameters'. The common characteristic of each parameter is that they are spatial planning elements and are capable of affecting GHG emissions. The major difference is that they are chiefly governed by the broad category they are classified in.

As explained in section 3.1, the definition and scope of planning and related terms vary with context. Because of this, the scope of one category may overlap with another category. Also, parameters in each category may overlap or effect the parameters in other categories. Hence, for simplification in understanding the difference and similarities, detailed description of each of these categories and parameters is elaborated here.

1. Planning

Urbanization is the major cause of spatial expansion of a city. However, if the agricultural land is productive, the cities are found to be more spatially compact and resistant to expansion (Brueckner, 2000). If the land's economic worth is more than its agricultural worth, the city is highly prone to undergo quick urbanization. With the increasing population and urgent need of housing and infrastructure, the social benefits of open space are entirely overlooked (because these benefits cannot be mapped monetarily). Other important reasons of urban sprawl are, decrease in commuting time, variation in land prices, rising income, job opportunities etc. The present category includes such parameters which determine the pattern of land use and accessibility, defined as access to jobs, housing, services, shopping, and in general, to people and places in cities (Hansen, 1959; Ingram, 1971; Wachs and Kumagai, 1973). Infrastructure planning which accounts for provision of water, energy, connectivity, shelter, sanitation and public spaces in cities are also classified under this category. Connectivity refers to street density and design. Where street design is dense with smaller and planned blocks with mixed land-use, the use of vehicles is less, resulting in reduced emissions. By efficient planning, it is possible to avoid the frequency of vehicle use or to reduce the length of the journey. The main parameters classified under 'Planning' are:

(i) Population Density – Seto at al. (2014) discusses various definitions of density – the ratio of jobs to residents; mix of amenities and activities; proportion of leisure and housing.

(ii) Mixed Landuse- It refers to variety and mix of different land-use types, ex. Residential, commercial etc. A more diversified land use mix has been observed to emit lesser GHG emissions by improving connectivity.

(iii) Urban function – Greenery measures in infrastructure, transportation planning and adaptation systems come under this head.

2. Transportation System

Distance travelled is strongly related to accessibility to destination and street design, while walking is strongly related to land use diversity and number of destinations within walking distance (Ewing and Cervero, 2010). Use of public transit use is highly impacted by availability and distance to public transportation. Travel behaviour is affected by transportation facility and distance. The German Corporation for International Cooperation (GIZ) strongly recommends the 'Avoid-Shift-Improve' approach for sustainable Urban Transportation (GIZ, 2016), where 'Avoid' refers to reducing the trip length by land-use planning and transport demand management. 'Shift' refers to a modal shift from energy consuming mode to a more environment efficient transportation system and 'improve' refers to improving the efficiency of fuels and related technology. This approach has been used by many Climate efficiency related European organizations like 'The European Cyclists' Federation' and is said to be the backbone of climate oriented transportation system (Blondel, 2011). Considering these aspects, the main parameters classified under this category are:

(i) Travel activity – managing traffic demand by reducing number of trips and changing travel behaviour is an important parameter for reducing GHG emissions

(ii) Travel mode – encouraging efficient travel mode like car share, bicycle riding and encouraging public transport

(iii) Energy Intensity – road improvement, using advanced technology comes under this head

(iv) Fuel choice - shifting to efficient fuel alike CNG instead of diesel for private transportation. Planning more CNG gas stations, pricing and taxation on less efficient fuel can be some policy aims

3. Energy Usage

According to the National Communication Reports (MOEF, 2004; 2012), energy sector is the biggest source of GHG emissions in India. It also implies that this sector has high possibilities for GHG reduction strategies. In regional level planning, the parameters that need attention can be summarized as follows:

(i) Energy efficiency- reducing energy load, energy saving strategies and community wide energy share planning

(ii) Energy choice- Using untapped energy, unused energy and waste heat; switching to renewable energy.

(iii) Appliance use – promoting the use of energy efficient appliances

4. Waste Management System

Waste management practices may include reducing, reusing and recycling of waste, repair of goods and preventing them from going into landfills. The parameters that can contribute in a regional plan can be:

(i) Waste volume – encouraging reducing waste volume by market strategies, information and awareness

(ii) Waste disposal- practicing segregation of waste makes the entire disposal process more efficient; inducing this as a culture can be a huge step.

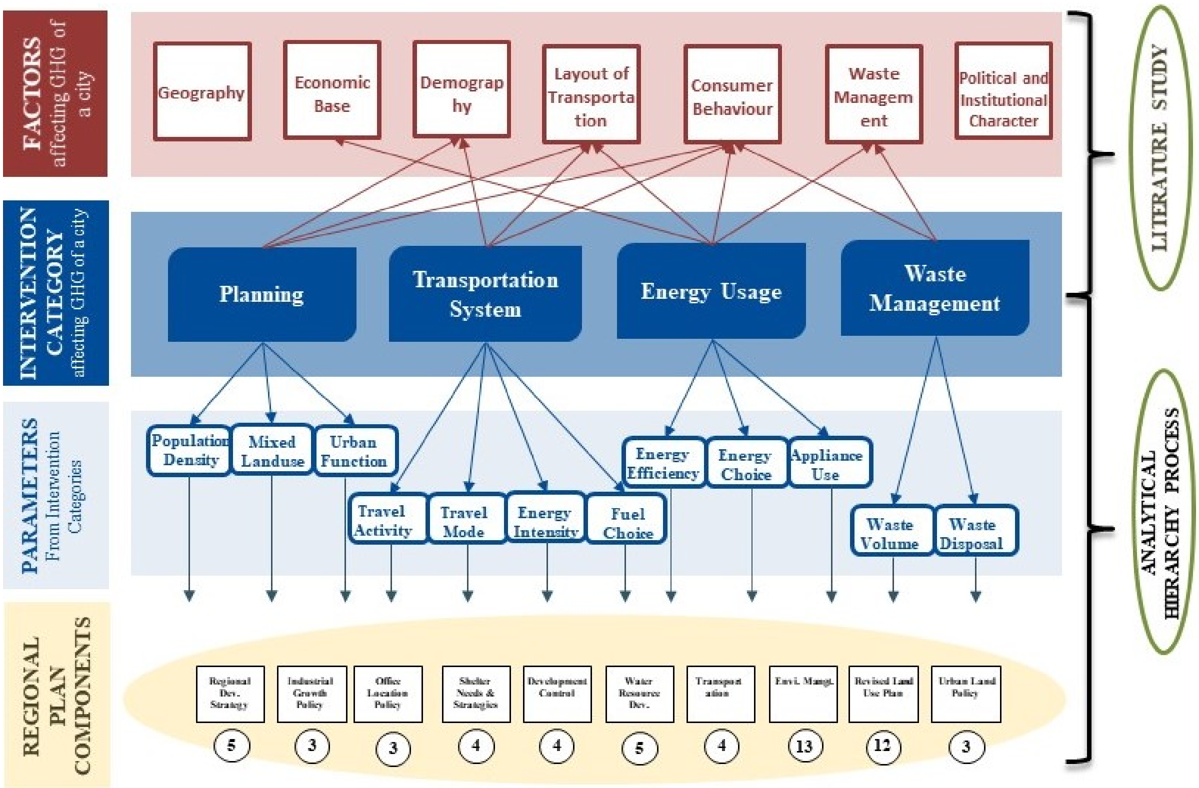

Figure 6-1 Brief demonstration of relationship between factors, intervention categories, parameters and Regional Plan Components

The 'parameters' elaborated above are from the 'Interventions' that can be done in a Regional Plan of a city. These 'intervention categories' come from the 'factors' affecting GHG of a city, and are related to regional plan components in a complex manner. Figure 6-1 briefly demonstrates the dependency of all these elements with each other. The aim of this part of the study is to figure out this interconnection for the context of MMR.

6.4 Prioritization of Regional Plan Components

In decision making, we first need to understand the problem, the need, and the purpose it is going to serve. The conditions and effect of the decision, alternative solutions need to be known. These alternatives need to be prioritised for fitting finest into the context. Only then the best solution can be found. In this section, planning alternatives were prioritised for the aim of emission reduction in MMR. The objective was to verify the presence of the planning parameters (found in section 6.3) in each components of the Regional Plan of MMR.

As explained in section 3.5, until date, the Regional Plan II is the most important Regional Plan in MMR. Hence, components of this Regional Plan were given highest importance. Components of other Regional Plans were studied and included in the components of Regional Plan II for analysis. Accordingly, prioritization was carried on. The components were prioritised based on the number of parameters they contain or have the scope of containing. Following this, the components which can hold highest number of parameters for the integration of climate change priorities were selected. However, the parameters are highly interdependent as well as the intervention categories are interdependent on each other; which might cause uncertainty in decision making. Hence, a Multi-Criteria Decision Analysis (MCDA) was done for prioritization of the components. It is a dynamic process suitable for addressing complex problems with overlapping or conflicting interests and uncertainties (Wang, 2009). Cristobal and Ramon (2012) defined the following steps to be followed in MCDA:

(i) Defining the aim, generating the alternatives and laying the criteria
(ii) Assigning rank to the criteria (depending on the importance of the criteria against the criteria with which it is being compared)
(iii) Building evaluation matrix
(iv) Selecting a method for ranking
(v) Ranking the alternatives

For the current study, the *aim* was to reduce GHG emissions; a*lternatives* were the components of Regional Plan; intervention categories were the criteria and, the parameters under intervention categories were *sub-criteria*. Analytical Hierarchy Process (AHP) was employed for ranking the alternatives. AHP is a systematic approach for MCDA, designed to provide the decision that best suits the goal (Majumder, 2015). It has been defined as a theory of measurements carried out through pairwise comparisons using the Saaty scale (Saaty, 1988). Saaty (2008) proposed following steps to generate priorities:

(i) Define the problem
(ii) Determine the decision hierarchy from the top (goal); intermediate levels (criteria) to bottom (alternatives)
(iii) Construct a set of matrix for pairwise comparison. Each element in the upper level is used to compare lower level elements with respect to it.
(iv) Use the priorities obtained from pairwise comparison of higher level to weigh lower level priorities. Continue this process of weighing until final priorities of bottom most level (alternatives) are obtained.

For this study, a three levelled hierarchy was structured. The calculations were carried out using the methods adopted by Bolaños et al., (2016). The calculations were performed in an Excel spreadsheet and the ranking work was carried out by the author using multiple research papers and literature studies, out of which the selected cases are explained above. The detailed explanation of each level of hierarchy is elaborated below.

Level 1

'Intervention categories' (criteria) were compared for the goal 'reducing GHG emissions'. Only one matrix was structured at this level (Table 6-1). Each intervention category was compared using the Satty pairwise comparison scale (refer Appendix A) (Saaty, 2008). The first comparison of the first element (in this case Planning) is with itself, for which the result is always 1. The second comparison is with the second element (in this case Transportation System). Here, according to the importance of Planning against Transportation systems for the goal of reducing GHG emissions, a ranking has to be assigned to Planning. Here, ¼ rank was given to Planning against Transportation systems. Thereafter, Transportation systems is ranked 4 (inverse of ¼) against Planning. Likewise, all the four elements were ranked against each other (Table 6-1).

Table 6-1: Level 1 - Pairwise comparison matrix of Intervention Categories

	Planning	Transportation System	Energy Usage	Waste Management System
Planning	1	1/4	1/3	7
Transportation System	4	1	2	9
Energy Usage	3	1/2	1	5
Waste Management System	1/7	1/9	1/5	1

For estimating individual priority, the above matrix was to be normalised and sum of each column was to be calculated (Table 6-2). Later, each cell was divided by the sum of its respective column (Table 6-3).

Table 6-2: Level 1 – Calculation of Normalized matrix of Intervention Categories: step 1

	Planning	Transportation System	Energy Usage	Waste Management System
Planning	1.00	0.25	0.33	7.00
Transportation System	4.00	1.00	2.00	9.00
Energy Usage	3.00	0.50	1.00	5.00
Waste Management System	0.14	0.11	0.20	1.00
SUM	8.14	1.86	3.53	22.00

Table 6-3: Level 1 – Calculation of Normalized matrix of Intervention Categories: step 2

	Planning	Transportation System	Energy Usage	Waste Management System
Planning	1.00/8.14	0.25/1.86	0.33/3.53	7.00/22.00
Transportation System	4.00/8.14	1.00/1.86	2.00/3.53	9.00/22.00
Energy Usage	3.00/8.14	0.50/1.86	1.00/3.53	5.00/22.00
Waste Management System	0.14/8.14	0.11/1.86	0.20/3.53	1.00/22.00
SUM	1	1	1	1

Next, individual priority of each element is calculated by taking the average of each row. Here, the priority of Planning is to be calculated as follows:

$$\textit{Individual Priority} = \frac{0.12+0.13+0.09+0.32}{4} = \boldsymbol{0.1674}$$

Similarly, the priority of all the elements is to be calculated. Table 6-4 shows the priority of elements of level 1 matrix.

Table 6-4: Level 1 -Normalized matrix with individual priority of Intervention Categories

	Planning	Transportation System	Energy Usage	Waste Management System	***Individual Priority***
Planning	0.12	0.13	0.09	0.32	***0.1674***
Transportation System	0.49	0.54	0.57	0.41	***0.5009***
Energy Usage	0.37	0.27	0.28	0.23	***0.2868***
Waste Management System	0.02	0.06	0.06	0.05	***0.0448***

Level 2

The parameters (sub-critera) were compared under each intervention category (elements of previous level). Since, there were four intervention categories, four matrices were structured at this level. Individual priority of each element (for level 2, element is sub-criteria) was estimated. Out of four matrices, one matrix is demonstrated here as an example in Table 6-5. It shows pairwise comparison of parameters- Populaion density, Mixed Landuse and Urban Functions under Planning. Table 6-6 shows the normalized matrix with the individual priority of these parameters.

Table 6-5: Level 2 - Pairwise comparison matrix of parameters (sub-criteria) under Planning

	Population density	Mixed Landuse	Urban Function
Population density	1	1/5	4
Mixed Landuse	5	1	7
Urban Function	1/4	1/7	1

Table 6-6: Level 2 - Normalized matrix of parameters (sub-criteria) under Planning with individual priorities

	Population density	Mixed Landuse	Urban Function	***Individual Priority***
Population density	0.25	0.20	0.43	***0.2918***
Mixed Landuse	0.74	0.60	0.43	***0.5916***
Urban Function	0.01	0.20	0.14	***0.1166***

Similarly, individual priorities of all the other parameters were estimated.

Level 3

Each component of Regional plan (alternatives) were compared under each parameter (elements of previous level). In total, there are 12 parameters in the list. Hence, 12 matrices were structured in this level. Table 6-7 presents the pairwise comparison of Regional Plan components (alternatives) under the parameter Urban Function and Table 6-8 presents the normalized matrix with individual priorities.

Table 6-7 Level 3 - Pairwise comparison matrix of Regional Plan components (alternatives) under the Urban Function

	Regional Developm ent Strategy	Industrial Growth Policy	Office Locatio n Policy	Shelter Needs and Strategies	Develop ment Control	Water Resource Dev.	Transpo rtation	Env Managem ent	Revised Land Use Plan	Urban Land Policy
Regional Dev.t Strategy	1	3	3	2	6	7	1.1	1/1.2	1/2	1/3
Industrial Growth Policy	1/3	1	1.2	1/3	4	5	1/4	1/5	1/8	1/7
Office Location Policy	1/3	1/1.2	1	1/4	4	5	1/5	1/6	1/4	1/3
Shelter Needs and Strategies	1/2	3	4	1	5	6	1/4	1/5	1/3	1/2
Development Control	1/6	1/4	1/4	1/5	1	2	1/8	1/9	1/5	1/5
Water Resource Dev.	1/7	1/5	1/5	1/6	1/2	1	1/7	1/8	1/4	1/5
Transportati on	1/1.1	4	5	4	8	7	1	1/2	4	4
Environment Management	1.2	5	6	5	9	8	2	1	4	3
Revised Land Use Plan	2	8	4	3	5	4	1/4	1/4	1	1/2
Urban Land Policy	3	7	3	2	5	5	1/4	1/3	2	1

Table 6-8: Level 3 - Normalized matrix of Regional Plan components (alternatives) under the Urban Function with individual priorities

	Regional Development Strategy	Industrial Growth Policy	Office Location Policy	Shelter Needs and Strategies	Development Control	Water Resource Dev.	Transportation	Env Management	Revised Land Use Plan	Urban Land Policy	***Individual Priority***
Regional Dev.t Strategy	0.10	0.09	0.11	0.11	0.13	0.14	0.20	0.22	0.04	0.03	***0.12***
Industrial Growth Policy	0.03	0.03	0.04	0.02	0.08	0.10	0.04	0.05	0.01	0.01	***0.04***
Office Location Policy	0.03	0.03	0.04	0.01	0.08	0.10	0.04	0.05	0.02	0.03	***0.04***
Shelter Needs and Strategies	0.05	0.09	0.14	0.05	0.11	0.12	0.04	0.05	0.03	0.05	***0.07***
Development Control	0.02	0.01	0.01	0.03	0.02	0.04	0.02	0.03	0.02	0.02	***0.02***
Water Resource Dev.	0.02	0.01	0.01	0.01	0.01	0.02	0.03	0.03	0.02	0.02	***0.02***
Transportation	0.09	0.12	0.18	0.22	0.17	0.14	0.18	0.13	0.32	0.39	***0.19***
Env Management	0.12	0.15	0.22	0.27	0.19	0.16	0.36	0.27	0.32	0.29	***0.24***
Revised Land Use Plan	0.21	0.25	0.14	0.16	0.11	0.08	0.04	0.07	0.08	0.05	***0.12***
Urban Land Policy	0.31	0.22	0.11	0.11	0.11	0.10	0.04	0.09	0.16	0.10	***0.13***

In level 1 and 2, individual priorities of each element were determined in the end. For level 3, with priorities, sensitivity analysis was also performed under which consistency ratio and consistency index of each matrix were determined. Sensitivity analysis is a tool to confirm the consistency of the judgements (comparison) made. It is considered is an advantage of AHP.

<u>Sensitivity Analysis</u>

Sensitivity analysis is to be performed separately for each of the 12 matrices. For this, consistency ratio of each element is calculated using the priorities. Following are the steps:

i. Consistency ratio of each element is calculated by multiplying the values in each column in pairwise comparison matrix present in Table 6-7 by their priority (last column in Table 6-8)
ii. Eigen vector (λ) is calculated by dividing the sum of every row by its priority.
iii. Consistency index (CI) is calculated as follows:

$$CI = \frac{\lambda \max - n}{n-1}$$ ***Equation 13***

where,
λmax is the average of all Eigen vectors obtained in the respective matrix,
n is the dimension of the matrix.

Table 6-9 presents the result of above calculations with consistency ratio of each element along with its Eigen vector (λ) and λmax.

Table 6-9: Level 3- Consistency ratio of elements with Eigen vectors

Consistency ratio	Regional Development Strategy	Industrial Growth Policy	Office Location Policy	Shelter Needs and Strategies	Development Control	Water Resource Dev.	Transportation	Env Management	Revised Land Use Plan	Urban Land Policy	Sum	Eigenvector
Regional Development Strategy	0.12	0.13	0.13	0.15	0.13	0.12	0.21	0.20	0.06	0.04	1.28	10.93
Industrial Growth Policy	0.04	0.04	0.05	0.02	0.08	0.08	0.05	0.05	0.01	0.02	0.46	10.53
Office Location Policy	0.04	0.04	0.04	0.02	0.08	0.08	0.04	0.04	0.03	0.04	0.46	10.70
Shelter Needs and Strategies	0.06	0.13	0.17	0.07	0.11	0.10	0.05	0.05	0.04	0.07	0.84	11.34
Development Control	0.02	0.01	0.01	0.04	0.02	0.03	0.02	0.03	0.02	0.03	0.23	11.15
Water Resource Dev.	0.02	0.01	0.01	0.01	0.01	0.02	0.03	0.03	0.03	0.03	0.19	11.27
Transportation	0.11	0.17	0.21	0.30	0.17	0.12	0.19	0.12	0.48	0.54	2.40	12.33
Envi.l Management	0.14	0.22	0.26	0.37	0.19	0.14	0.39	0.24	0.48	0.40	2.82	11.94
Revised Land Use Plan	0.24	0.35	0.17	0.22	0.11	0.07	0.05	0.06	0.12	0.07	1.44	12.12
Urban Land Policy	0.35	0.30	0.13	0.15	0.11	0.08	0.05	0.08	0.24	0.13	1.62	12.08
											Average (λ max)	11.44

$$CI = \frac{11.44 - 10}{10-1} = 0.15992$$

Now, consistency ratio (CR) of the matrix is calculated using the following formula:

$$CR = \frac{CI}{RI} \qquad \textbf{\textit{Equation 14}}$$

Where, RI is the random index developed by Saaty (2008) which depends on the dimension of the matrix (n). For the present matrix, n = 10 and RI = 1.49

$$CR = \frac{0.15992}{1.49} = 0.10733$$

Likewise, calculations were done for all the matrices and consistency ratios were obtained. According to Saaty (2012), a consistency ratio less than 0.1 is considered reasonably consistent. However, Ishizaka and Labib (2011) reviewed results from different studies and concluded that in some cases, a ratio slightly higher than 0.1 is also acceptable. This approximation has been used by Park and Kim (2014). For the current study, the consistency ratios for different matrices ranged from 0.08 to 0.17. Since the ratio was only slightly greater than 0.10, the judgements (comparisons) were assumed to be consistent.

At each level, priorities were calculated for each element (criteria/sub-criteria/alternatives) which were called their 'individual priority' as it was calculated amongst the group of its own category. For example, in the second level, under the head 'Planning', priorities for Population Density, Mixed Landuse and Urban Functions were calculated which are termed 'individual priorities'. In the next step, 'global priorities' of each element are calculated. Global priority is the priority of an element amongst the whole set of elements. For example, in Table 6-6, the priority of population density is 0.2918. This priority holds relevance only under Planning (i.e. amongst only 3 parameters that come under Planning); it is totally independent of the other Intervention Categories. Global priority of population density is the priority it will have amongst all the 12 parameters. In level 1, individual priority and global priority is same as the comparison is done under the four main categories. For level 2 and 3, individual and global priorities are different. Table 6-10 shows individual and global priorities among criteria (Intervention Categories), sub-criteria (parameters) and alternatives (Regional plan components).

Table 6-10: Priorities among criteria, sub-criteria and alternatives calculated through AHP

LEVEL 1: CRITERIA		*LEVEL 3: SUB CRITERIA*			*LEVEL 3: ALTERNATIVES*		
Intervention categories	**Priority**	**Parameters**	**Individual Priority**	**Global Priority**	**Regional Plan Components**	**Individual Priority**	**Global Priority**
PLANNING	0.16741	**Population density**	0.2918	0.1818	Regional Dev.t Strategy	0.227	0.007
					Industrial Growth Policy	0.032	0.001
					Office Location Policy	0.098	0.003
					Shelter Needs and Strategies	0.178	0.005
					Development Control	0.193	0.006
					Water Resource Dev.	0.000	0.000
					Transportation	0.111	0.003
					Environmental Management	0.000	0.000
					Revised Land Use Plan	0.034	0.001
					Urban Land Policy	0.083	0.003
		Mixed Landuse	0.5916	0.3687	Regional Dev.t Strategy	0.243	0.015
					Industrial Growth Policy	0.071	0.004
					Office Location Policy	0.064	0.004
					Shelter Needs and Strategies	0.159	0.010
					Development Control	0.189	0.012
					Water Resource Dev.	0.000	0.000
					Transportation	0.035	0.002

					Environmental Management	0.042	0.003
					Revised Land Use Plan	0.099	0.006
					Urban Land Policy	0.099	0.006
		Urban Function	0.1166	0.0727	Regional Dev.t Strategy	0.118	0.001
					Industrial Growth Policy	0.043	0.001
					Office Location Policy	0.043	0.001
					Shelter Needs and Strategies	0.074	0.001
					Development Control	0.021	0.000
					Water Resource Dev.	0.017	0.000
					Transportation	0.195	0.002
					Environmental Management	0.236	0.003
					Revised Land Use Plan	0.119	0.001
					Urban Land Policy	0.134	0.002
TRANSPORTATION SYSTEM	0.50091	**Travel activity**	0.2175	0.1356	Regional Dev.t Strategy	0.228	0.015
					Industrial Growth Policy	0.029	0.002
					Office Location Policy	0.037	0.002
					Shelter Needs and Strategies	0.094	0.006
					Development Control	0.096	0.007
					Water Resource Dev.	0.019	0.001
					Transportation	0.275	0.019
					Environmental Management	0.099	0.007
					Revised Land Use Plan	0.055	0.004
					Urban Land Policy	0.068	0.005
		Travel Mode	0.6030	0.3758	Regional Dev.t Strategy	0.217	0.041
					Industrial Growth Policy	0.052	0.010
					Office Location Policy	0.063	0.012
					Shelter Needs and Strategies	0.000	0.000
					Development Control	0.146	0.028
					Water Resource Dev.	0.000	0.000
					Transportation	0.322	0.061
					Environmental Management	0.141	0.026
					Revised Land Use Plan	0.025	0.005
					Urban Land Policy	0.031	0.006
		Energy Intensity	0.0577	0.000		0.000	0.000
		Fuel choice	0.1218	0.000		0.000	0.000
ENERGY USAGE	0.28684	**Energy efficiency**	0.0759	0.0473	Regional Dev.t Strategy	0.173	0.002
					Industrial Growth Policy	0.041	0.001
					Office Location Policy	0.035	0.000
					Shelter Needs and Strategies	0.025	0.000
					Development Control	0.076	0.001
					Water Resource Dev.	0.019	0.000
					Transportation	0.282	0.004
					Environmental Management	0.190	0.003
					Revised Land Use Plan	0.106	0.001
					Urban Land Policy	0.053	0.001
		Energy choice	0.7099				0.000

		Applianc e use	0.2142				0.000
Waste Management System	0.0448 2	**Waste Volume**	0.2000				0.000
		Waste disposal	0.8000				0.000

Table 6-10 is the outcome of the AHP process conducted to find the priority of different elements that reduce GHG emissions of the city. In the table, some elements have a priority 0 because these were found to be missing from the Regional Plan components. Moreover, the current Regional Plan also does not contain any component that can absorb these elements in future. Now, to find out the priority of MMR's Regional Plan components in reducing GHG emissions, prioritization among the components is to be done. This was done by summing up the weights (estimated global priorities) of each parameter for each component and then ranking the components with respect to the highest weight calculated. Table 6-11 shows the result.

The important points that this table demonstrates are: firstly, it can be found that which parameter has got the highest weight (highest priority) in reducing the GHG emissions in a city; secondly, which parameter is ingrained in which component(s) of MMR; and thirdly, how strongly, the parameters are ingrained in each components, i.e. which parameter is stronger in which component.

6.4.1 Results

It can be seen that the parameter 'Travel mode' has the highest weightage (0.1876) and it is most strongly ingrained in the 'Transportation' components, followed by 'Regional Development Strategy' and 'Development Control'. The second highest weight belongs to the parameter 'travel activity' followed by 'Mixed Landuse'. 'Travel Activity' has got highest weightage in the Transportation component followed by Regional Development Strategy, while, Mixed Landuse has got highest weightage in Regional Development Strategy followed by Development Control. Among the 12 parameters, energy intensity, fuel quality, energy choice, appliance use, waste volume and waste disposal got '0' weightage. These six parameters were found missing from the regional plan. Overall, 'Transportation was found to have obtained the highest priority (24.48%), followed by Regional Development Strategy (22.04%), and Development Control (14.12%). Figure 6-2 shows the final weight of parameters with respect to MMR's Regional plan Components and Figure 6-3 shows the final weights (prioritization) of the Regional Plan components in reducing GHG emissions of MMR.

Table 6-11: Result of prioritization of MMR's Regional Plan components against parameters

REGIONAL PLAN COMPONENTS	PARAMETERS												Total weight of each Component	
	Urban Dev Layout			Transportation Sys.			Energy Usage				Waste Mangt. Sys.			
	Population density	Mixed Land Use	Urban Function	Travel Activity	Travel mode	Energy Intensity	Fuel choice	Energy efficiency	Energy choice	Appliance use	Waste volume	waste disposal	SUM	Percentage
Regional Dev.t Strategy	0.00691	0.015027	0.00143	0.015449	0.0408	0.0000	0	0.002	0.000	0	0	0	0.08201	**22.04141**
Industrial Growth Policy	0.000986	0.004365	0.000527	0.001946	0.0099	0	0	0.001	0	0	0	0	0.018226	**4.898527**
Office Location Policy	0.002982	0.003943	0.000521	0.0025	0.0118	0	0	0.000	0	0	0	0	0.022231	**5.974832**
Shelter Needs and Strategies	0.00543	0.009795	0.000905	0.006376	0.0000	0	0	0.000	0	0	0	0	0.022852	**6.141906**
Urban Land Policy	0.002519	0.006083	0.001633	0.004622	0.0058	0	0	0.001	0	0	0	0	0.021378	**5.745602**
Water Resource Dev.	0	0	0.000206	0.001299	0.0000	0	0	0.000	0	0	0	0	0.001764	**0.474053**
Transportation	0.00337	0.002178	0.002372	0.018697	0.0607	0	0	0.004	0	0	0	0	0.091096	**24.48344**
Envi.l Management	0	0.002592	0.00287	0.006728	0.0265	0	0	0.003	0	0	0	0	0.041233	**11.08207**
Revised Land Use Plan	0.00103	0.006102	0.001448	0.003756	0.0046	0	0	0.001	0	0	0	0	0.018401	**4.945611**
Development Control	0.005871	0.011639	0.000256	0.00653	0.0276	0	0	0.001	0	0	0	0	0.052881	**14.21255**
Total weight of each parameter	**0.029098**	**0.061724**	**0.012166**	**0.067901**	**0.1876**	**0**	**0**	**0.014**	**0**	**0**	**0**	**0**	**0.372074**	

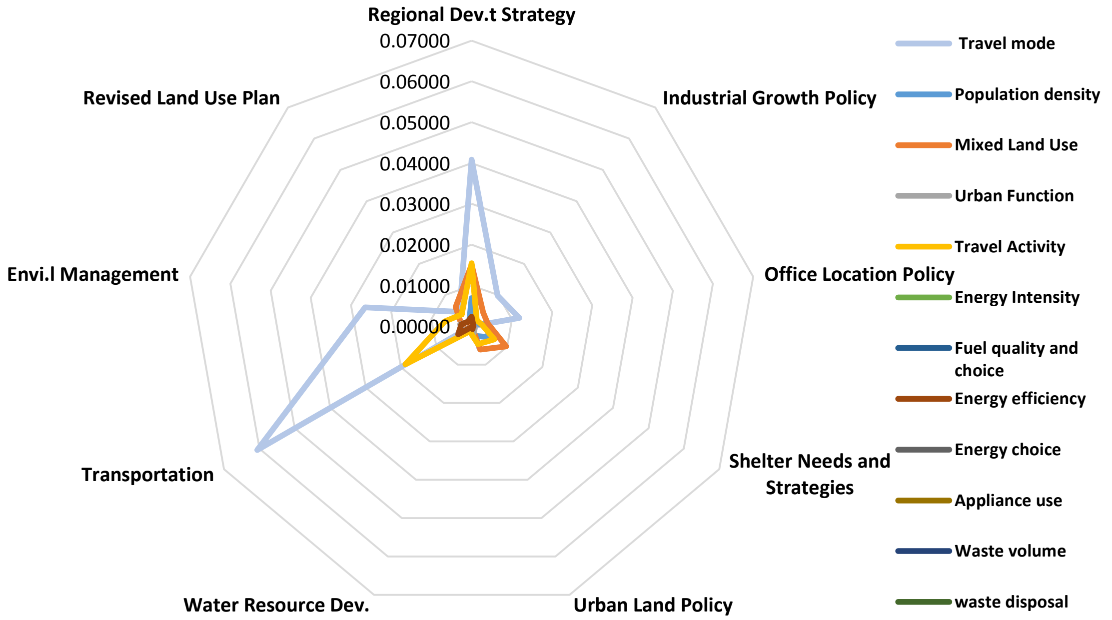

Figure 6-2 Final weight of parameters (sub-criteria) with respect to MMR's Regional Plan components

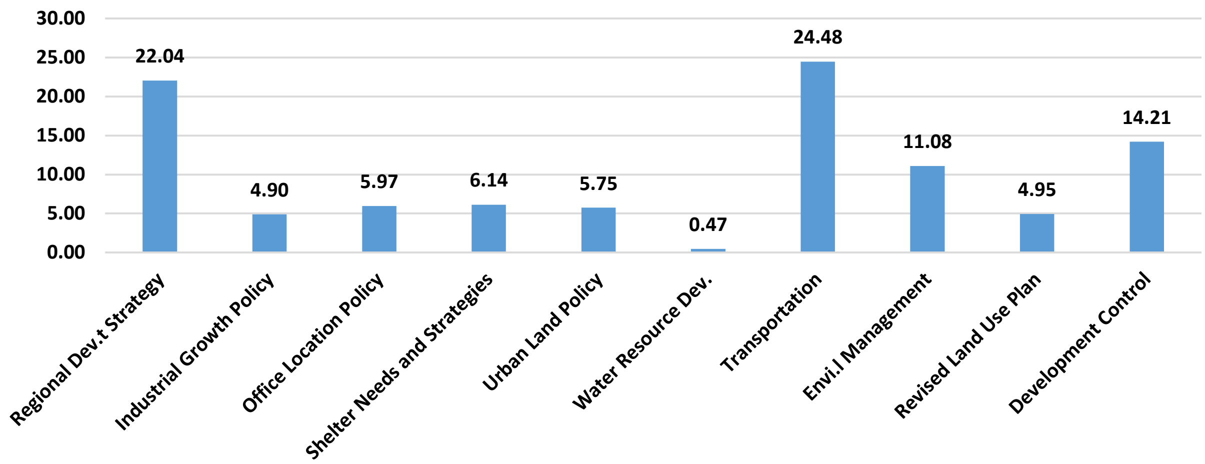

Figure 6-3 Final weights of MMR's Regional Plan Components in reducing GHG emissions of the region

6.5 Comparison of Results with Climate Change Planning Index (CCPI)

In chapter 3, section 3.4.2, CCPI of the Regional Plan 1996-2016 was calculated (Table 3-5 and Figure 3-4). Mitigation and adaptation indices were found for each component of Regional Plan. Comparing the results of current chapter with the results of CCPI produced interesting outcomes. Table 6-12 presents the mitigation and adaptation CCPI for each component ranked from highest to lowest priority.

Table 6-12: Regional Plan components listed from highest to lowest priority with respective mitigation and adaptation CCPI.

Priority ranking	Regional Plan Components	Percentage	Mitigation CCPI	Adaptation CCPI
1	Transportation	24.48	7.50	1.25
2	Regional Dev.t Strategy	22.04	1.00	1.00
3	Development Control	14.21	2.50	1.00
4	Environmental Management	11.08	3.37	5.77
5	Shelter Needs and Strategies	6.14	0.00	0.00
6	Office Location Policy	5.98	5.00	1.70
7	Urban Land Policy	5.74	0.00	0.00
8	Revised Land Use Plan	4.95	2.50	5.00
9	Industrial Growth Policy	4.90	1.70	1.70
10	Water Resource Dev.	0.47	3.00	2.00

From the table, it can be seen that the Transportation components which has got the highest priority is fairly strong from the mitigation perspective (CCPI 7.50), while in adaptation, the component is weak (CCPI 1.25). The second highest priority component, Regional Development Strategy is weak both in mitigation and adaptation strategy. The third highest priority component which is Development Control is comparatively stronger in mitigation than adaptation. But the mitigation CCPI is also very low and hence the component can be said to be performing low in both perspectives. Similarly, comparison can be made for the rest of the components. In chapter 3, (Figure 3-5) it was found that implementation of

Regional Development Strategy and Development Control Regulations has not been quite satisfactory. Verifying these results with priority of components found in this chapter further enhances the need to work upon these components of regional plan.

6.6 Conclusion

In this chapter, ranking of components of MMR's Regional Plan with the criteria of GHG reduction was done. Out of the 12 parameters that can affect the emissions of a city, six were found to be totally absent from the MMR's Regional Plan. The parameters- energy intensity, fuel quality, energy choice, appliance use, waste volume and waste disposal were neither found to be present in the components of the current Regional Plan, nor was there any planning strategy found in the Regional Plans that may be enhanced or updated to contain these parameters in future. The weightage of these parameters was found to be 0 for every component. Examining the missing parameters, it can be easily observed that four of these are closely related to the energy usage and the other two are related to the waste management system. Hence, it can be said that the Regional plan is weak from the energy and waste management perspective. The Regional plan as such does not have any component relating to the waste management in MMR; which clearly reflects the reason of the two missing parameters. As from the energy usage point of view, the Regional Plan components do contain certain strategies but those are found to be less effective and need to be sharply strengthened.

Finally, the conclusions drawn from this chapter were:

(i) It was found that the three components namely, Transportation Strategies, Regional Development Strategy and Development Control have attained highest priorities. Hence, these three components need to be worked upon for reducing the region's GHG emissions, where Transportation component mainly needs to be strengthened for the adaptation aspects while the other two components need to be enhanced for mitigation as well as adaptation.

(ii) The parameters that should be focused most are travel mode, followed by travel activity, Mixed Landuse, population density, energy efficiency and lastly urban functions. For the other six missing parameters, new strategies/ideas need to be added to the Regional Plan. The new addition may be in the form of renewal of the existing component or adding a whole new component to the Regional Plan.

(iii) Overall, the framework of the Regional Plan needs to be enhanced from the energy usage and waste management perspective. Along with reinforcing the other prioritized components, MMR's regional Plan needs to cater to these two aspects too in order to efficiently reduce GHG emissions.

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CHAPTER 7 CLIMATE TARGETS AND MMR'S REGIONAL PLANS: RECOMMENDATIONS AND EXPECTED RESULTS

7.1 Introduction

Function of Regional Plans is to frame general policies according to the needs of the region. The development Plans (made by local planning authorities) are the detailed plans for the spatial development of the specific area that comes under the local authority. The Regional Plan and Development Plans are supposed to be in close coordination with each other. MMRDA's purpose is to support the local authorities and not to supersede them. There have been conflicts in the interests of these authorities which has often become the reason for slow development (Pethe et al., 2011). There is institutional gap in the functioning of panning bodies in MMR. But institutional planning is not the scope of this study. This study aims to provide recommendations for GHG reduction through spatial planning strategies which can be integrated with the priorities of MMR.

Before making recommendations to the Regional Plan of MMR, it is important to ascertain some specific information regarding MMR that may be important for the study. It is important to know that for MMRDA, economic growth is the priority of the Regional Plan and currently, environmental benefits are only regarded as externalities (MMRDA, 2016). The population of MMR exceeded the projections made in Regional plan I (BMRPB, 1973), but increased less than the forecast made in the Regional Plan II (MMRDA, 1996). The rate of increase in projected population was highest in Navi Mumbai, followed by the North East Region (Thane, Kalyan, Ulhasnagar, Ambernath, and Bhiwandi), followed by Mira Bhayander Region, and the eastern suburbs. Public transport share declined from 88% to 78% from 1992 to 2005. Increasing population and inadequate supply in transportation system was accounted as the reason. Draft Regional Plan III reported huge differences between urban and rural MMR in terms of average household sizes, house ownership, number of trips made, basic needs and infrastructure, availability of open space etc. (MMRDA, 2016). The average these characteristics from urban and rural areas of MMR do not show the exact picture of the whole region. The issues are to be analysed with a profound analysis of specific areas and a deep knowledge of the region is required for this.

7.2 Policy Recommendations

For managing climate priorities, MMR has two climate targets to face, namely, India's INDC target and Paris Agreement's target (as discussed in chapter 5). Using the results from chapter 6, the present chapter aims to give recommendations for the integration of these climate targets into the regional plan. Considering the two different types of targets, the recommendations were also proposed with two different aims. For this purpose, MMR's climate strategy can be divided into three different scenarios. First- the current scenario (baseline scenario), second - the weak pledges scenario targeting India's INDC target and third- the strong pledges scenario targeting Paris Agreement's climate target. The description is as follows:

Scenario 1: Baseline Scenario

In this scenario, MMR's regional plan goes with business as usual set-up. It assumes that there are absolutely no new climate policies added to the regional plan. There is no regional climate target and no emission reduction goal.

Scenario 2: Weak Pledges

This scenario is aimed to prepare MMR for India's INDC target (refer section 5.3). The emission goals are less ambitious and recommendations are given aiming to bring certain reduction in the current emission trajectory of MMR.

Target Year: 2030

Target reduction: 16.8% reduction is absolute emissions from 2005 levels

Scenario 3: Strong Pledges

This scenario is aimed to prepare MMR for the Paris Agreement's 2 °C target with 67%, probability (refer section 5.4). As per the calculations, the target years start from 2018 and end at different times (2040 to 2048) depending on the sharing principles. In this scenario, the emissions goals are more ambitious and a huge reduction in cumulative emissions is aimed. Table 7-1 shows the targets.

Table 7-1 Paris Agreement's climate target for MMR

Sharing principle	Emission Reduction required (%)	Target years
Inertia sharing	40.31	2018 -2048
Equity sharing	44.80	2018 - 2043
Blended sharing	44.78	2018 - 2045
Inclusion sharing	45.79	2018 - 2040

In section 6.4, it was found that 'Transportation Strategy', Regional Development Strategy' and 'Development Control Regulations' are the three components on highest priority for GHG reduction. This chapter provides recommendations for Weak Pledges Scenario and Strong Pledges Scenario separately using the three components. The recommendations were divided in two heads: Government Regulations and Government Incentives. These heads were further sub-divided into mitigation and adaptation aspects in order to clearly distinguish between the two kinds of approaches for governing climate change. Another important point to be considered here is that for each of the components, all the four type of intervention categories (defined in section 6.3) are important in making an impact. The effect of certain parameters overlap with others. Also, some parameters in one category can partially cover up for the parameters in another category. Figure 7-1 briefly demonstrates this inter-dependency. In this situation, to avoid redundancy, in the case of strong overlap, only one of the overlapping category (with stronger impact) was chosen for giving recommendations; and in the case of weaker overlaps, both categories were chosen but for giving recommendations.

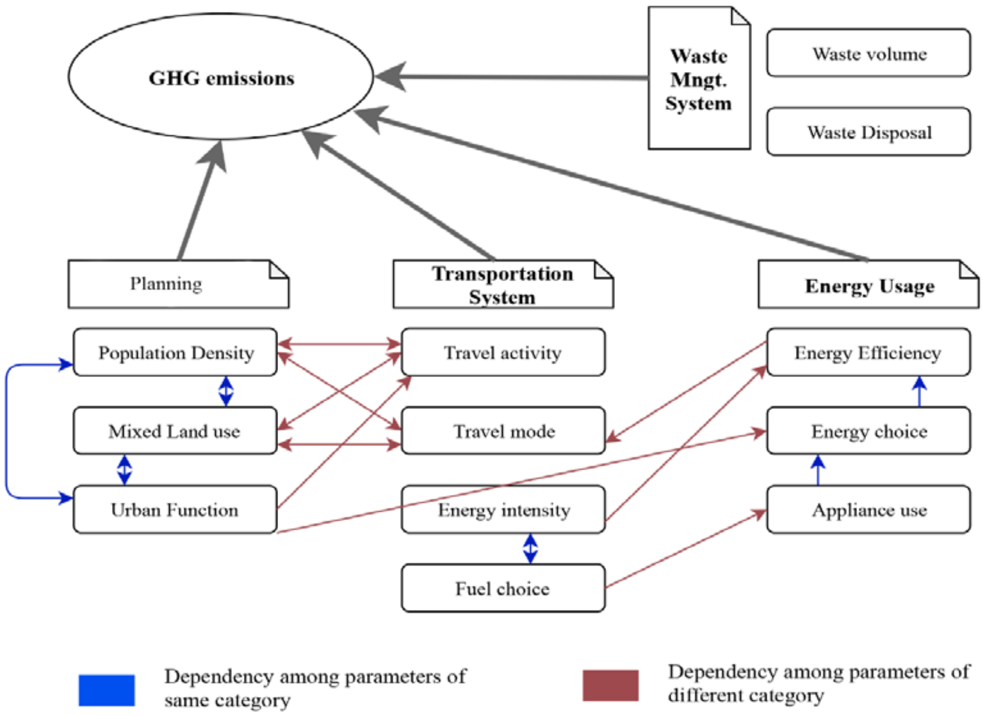

Figure 7-1 Interdependency of parameters

7.3 Weak Pledges

As stated earlier, this scenario aimed to address India's INDC target in MMR. This scenario was projected to be a part of India's voluntary pledges. Owing to the fact that economic development is the priority of the country and not climate change management, the scenario was termed 'weak pledge scenario'. Considering the role of MMR in national economy, the focus here was more on adaptation measures. Hence, recommendations were made with a view to place no serious effect on the economy of the region. Three priority components – Transportation, Regional Development Strategy and Development control were focused to make the targeted 16.8% reduction in emissions.

7.3.1 Transportation

According to a report prepared by LEA Consulting Limited (LEA, 2008) for MMRDA, a total of 13.5 million motorized journeys are made in MMR per day. Of this, 51.67% journeys are made through local trains and more than 70% are thorough public transit making MMR's transportation sector comparatively more environment friendly than other metropolitan regions of the country. But owing to the huge travel demand, there is a dire need of augmenting this network. Table 7-2 presents some climate responsive approaches recommended for transportation in brief which are detailed in the context of the region in the following section.

Table 7-2: Recommendations for Weak Pledges- Transportation

		Government Regulations		Government Incentives	
		Mitigation	**Adaptation**	**Mitigation**	**Adaptation**
Planning	**Population density**	Integrate mixed land use with location of public stations and bus stops through land use policies		Plan Integrated bus and train transport	
	Mix Land Use				
	Urban Function	Add pedestrian and cycle lanes to new road projects		Invest more on public transit instead of highways	
Transportation System	**Travel Activity**		Wider road design;	Encourage walking by provision of street furniture; transit stops; Attractive fare pricing for public transit	Telecommuting culture
	Travel mode	Modernize subways, add number of buses and trips; more coaches in trains, double decker buses			Increase in gas stations supplying efficient fuel
	Energy Intensity	Maintenance of roads; advanced signalling system; control on speed limit			
	Fuel choice	Lowering carbon content of fuel	Certification of vehicles for energy efficiency	Incentives on energy efficient cars	
Energy Usage	**Energy efficiency**	Car sharing; Prohibition of private cars in public places in peak hours			Increase street size for cycle lane, bus lane
	Energy choice				
	Appliance use	Environmental performance check of old vehicles			

The draft Regional Plan 2016-2036 recognises the need of a more environment friendly transport network in MMR but, the lack of land availability is cited as the reason for inability to provide this update (MMRDA, 2016). For tackling this problem without hampering the economic state, the most common approach can be to further increase the number of trips of buses and trains, add double decker coaches to trains and accommodate advanced technology in the region other than Mumbai city. Mumbai city is already saturated with the heavy transport system. Hence, diverting trip directions, avoiding un-necessary trips and reducing the trip length will be a better approach. Newer concepts like flexible working environments and telecommuting should also be explored. Sushil et al., (2016) examined these opportunities and found a huge market for it in Asia.

The second Biennial Update Report (BUR) of India's states that road transportation in India in 2010 accounted for 90% of the emissions from transportation sector (MoEFCC, 2018). For reducing emissions in this area, generally strategies like control on speed limit, advanced toll collection system and wider roads for smooth traffic movements are suggested. However, these are only a partial measure to control emissions as in a longer time span, a smoother flow tends to increase traffic; further increasing the emissions. Hence new road projects if unavoidable in MMR, should be implemented with strong measures to manage traffic congestion; implementation of road pricing, toll collection, and controlled parking system. The collected fund should be utilized to develop public transit system.

A study by Asian Development Bank (ADB, 2010) concludes that construction emission related to expressways are lower than that of railways. But the operation related emissions of railways are much lower than expressways as after being implemented, railways divert a huge proportion of travellers to more efficient modes of travel. Hence, for MMR, investment in road infrastructure should be reconsidered. Green building materials should be used for construction and repair. This typically holds true for the heavy traffic roads meant for trucks and lorries. Hence, freight operations mode be changed to railways or inland transport is highly recommended. This approach is proposed in a view to counter the environmental effect of the 55000 vehicles entering MMR every day from outside the region (ADB, 2010).

7.3.2 Regional Development Strategy

According to AHP, Regional Development Layout, Transportation System and Energy Usage are the important interventions that can make an effect in reducing GHG through the Transportation component of Regional Plan (Table 6-11). Some parameters from Regional Development Layout and Transportation systems strongly overlap. Hence, for ease of explanation the recommendations for both the categories were grouped under Planning.

In the draft Regional Plan 2016-2036, this components is renamed as Regional Structure (MMRDA, 2016). Areas in MMR are sufficiently dense and have mixed landuse too, but lack infrastructure provision for the huge population, which in turn leads to environmental degradation. Table 7-3 presents recommendation for this component for emission reduction.

Table 7-3: Recommendations for Weak Pledges- Regional Development Strategy

		Government Regulations		**Government Incentives**	
		Mitigation	**Adaptation**	**Mitigation**	**Adaptation**
Planning	**Population density**	Connectivity to resource market	Effective signalling system, cross roads, pedestrian friendly roads	Pedestrian and cycle friendly urban form; Promote growth in already developed places, making it more dense	
	Mix Land Use				
	Urban Function	Adequate housing infrastructure Use of trees in coastal protection practices;	Invest in flood protection measure and drainage systems	Conservation of biodiversity;	
Energy Usage	**Energy efficiency**	Promote growth around public transport	Requirement of energy consumption data from industries	Energy efficiency certification for all new and retrofitted buildings	Energy performance check for old buildings; Reuse of construction waste
	Energy choice			Avoid subsidizing fossil fuel energy use	Encourage use of solar power; Employ climate advisors to teach the users the necessities, benefits, methods of climate change
	Appliance use	Impose minimum energy performance standards for big buildings		Big Industries to pay carbon tax	

The high density in MMR is not more than government policies, it is the result of increasing populations in MMR. Infrastructure is not adequate to take this load. For catering to the need of increasing population, the green and open share of land has been converting to formal and informal housing. Even then, tens of thousands of houses are left unsold or vacant (Kaul, 2015; Gandhi and Munshi, 2017). High pricing policies of the state are deduced as one reason for this. Solving this issue is important for MMR's climate strategies. Singapore has successfully attended similar issue with the help of government policies (Ching and Tyabji, 1991 and Phang and Helbe, 2016) and MMR can use it as a case study. Development of social housing can also be a solution. Social housing idea has already shown positive results in Paris (Paris Climate and Energy Action Plan, 2012) and New York (The Fourth Regional Plan, 2019).

Furthermore, the big industries in MMR should be required to audit their energy usage for a year and a threshold should be set for emissions above which they should be liable to pay carbon taxes. Climate conscious building design should be mandated for commercial building to get construction permit. Solar power usage should be a regulation for large floor areas and there should be regulation for energy performance certification of buildings.

Additionally, conservation of green spaces, forests and parks is important for emission reduction. The share of green (agriculture, grassland, forest) has decreased from the 2nd Regional Plan to the third. Moreover, the green landuse zones in Regional Plans should be protected from construction activities. Currently, the Regional Plan allows activities of different level in every landuse zone. This provision has is a huge threat to conserving green spaces.

7.3.3 Development Control Regulation

According to the AHP results, the intervention categories that can affect this component are Planning and Energy Efficiency. This component is crucial for controlling the development activities in MMR and hence is important for climate priorities too. Regional Plan has some policies for environmental protection which are too complex and conflicting. For example, Green Zone 1 (G1) (see appendix B for landuse zoning details) in Regional Plan II was aimed to protect agricultural activity and control urban sprawl. However, the aim was manipulated in the plan itself and certain construction activities with Floor Space Index (FSI)[12] 0.05 were allowed. And the new Draft regional plan III allows FSI 0.2 in G1 and 0.1 in G2. Some sort of construction activities in all types of land uses with smaller FSI in 'Green Zones' and higher FSI in 'Urbanizable' zones are allowed. Industrial development with certain conditions is allowed to be proposed in green zone 1. Such policies have been heavily misused to convert green into built up areas. Hence, there is a strong need to sort out the policies and regulations in favour of environmental protection.

Many recommendations in this component coincide with the Regional Development Strategy. Other than the ones already enlisted in the previous section, the large population can be used as a tool for collecting development taxes, and subsidizing green planning. Moreover, mandatory regulations can be made to make the private companies (with huge share in economy) use renewable resources for manufacturing their products (example electricity).

[12] FSI indicates the total amount of area (all floors) that can be built on a land parcel. FSI= Floor space covered on all floors/ Area of plot

Additionally, there are recommendations for imposition of green taxes and subsidies for green construction; briefed in Table 7-4.

Table 7-4: Recommendations for Weak Pledges- Development Control Regulation

		Government Regulations		Government Incentives	
		Mitigation	**Adaptation**	**Mitigation**	**Adaptation**
Planning	**Population density**		Strict regulations against usage of agricultural/green spaces for urban use; development tax		
	Mix Land Use				
	Urban Function	Green tax; greening subsidy	Transition away from places that can't be protected		
Energy Usage	**Energy efficiency**	Compulsion of designing big sites as per environmental measures;	Disclosure of energy usage statement for industries	Incentives on on-site renewable energy technology use	Incentives to private companies for providing green infrastructure
	Energy choice				
	Appliance use				

7.3.4 Prospective Outcomes

A successful implementation of above recommendations is expected to reduce GHG emissions of MMR. For a 16.8% reduction; 10,345 Gg emissions need to be avoided in the region. In 2011, emissions from road transport and electricity accounted for 14% and 16.5% of the region's overall emissions respectively. For a 16.8% reduction, all the emission sectors will need to be focused. With the above recommendations, reductions from energy consumption (from transport, cooling, conserving green landscape etc.) can be expected. Following this, MMR will be able to play a positively strong role in meeting India's INDC target.

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The recommendations are made for the three priority components only. But, with the implementation of the above approaches, all the component of MMR are expected to be effected. With incorporation of these changes; CCPI is also expected to change. Assuming that these recommendations are included in Regional Plan, the modified Regional Plan was analysed for a new CCPI. Table 7-5 presents the new CCPI and Figure 7-2 shows the modified sunburst diagrams.

Table 7-5: Expected changes in CCPI pertaining to the recommendation proposed for Weak Pledges

Regional Plan Components	Original CCPI Mitigation CCPI	Original CCPI Adaptation CCPI	New CCPI (Weak Pledges) Mitigation CCPI	New CCPI (Weak Pledges) Adaptation CCPI
Regional Development Strategy	1.00	1.00	3.00	4.00
Industrial Growth Policy	1.70	1.70	3.33	3.33
Office Location Policy	5.00	1.70	6.67	3.33
Shelter Needs and Strategies	0.00	0.00	1.25	3.75
Urban Land Policy	0.00	0.00	5.00	3.33
Water Resource Development	3.00	2.00	2.00	3.00
Transportation	7.50	1.25	10.00	10.00
Environmental Management	3.37	5.77	6.06	7.69
Revised Land Use Plan	2.50	5.00	3.33	6.25
Development Control	2.50	1.00	3.00	2.00
CCPI of the Regional Plan	**2.65**	**1.94**	**4.36**	**4.67**

The improvement in the scores is evident. Most of the components have a better score with inclusion of the recommendations. Some components which scored 0 in the original analysis have also scored fairly well with the modified components. Transportation component can be seen to have the best score with the recommendations while Regional Development Strategy and Development Control have improved too. Overall, mitigation score increased to 4.36 from 2.65 while adaptation score increased to 4.67 from 1.94.

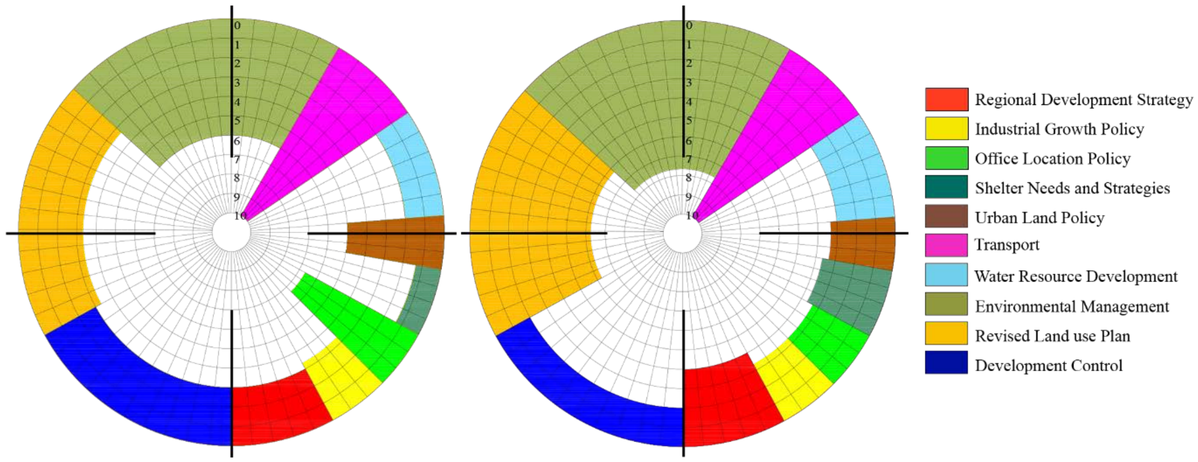

Figure 7-2 CCPI results for Weak Pledges Scenario

7.4 Strong Pledges

This scenario aimed to address the Paris Agreement's targets in MMR. Here, the goal was to achieve emission reduction to meet the budget consistent with 2 degrees warming limit. The target aimed in this scenario is not a voluntary target hence was termed strong pledges. The approaches recommended in the weak pledge scenario apply to this scenario too. Additionally, some robust recommendations were made in this scenario. It is speculated that these recommendations may have certain impact on the economy of the region. Hence, a very brief look into the economic impact and carbon finance was also drafted in the end.

7.4.1 Transportation

In addition to the recommendations made in weak pledge scenario, some stronger approaches may be made through the transportation policies. Table 7-6 presents the additional possible approaches.

Table 7-6: Recommendations for Strong Pledges- Transportation

		Government Regulations		Government Incentives	
		Mitigation	**Adaptation**	**Mitigation**	**Adaptation**
Planning	**Population density**	Safety measure for walking and cycling			
	Mix Land Use				
	Urban Function	Consideration of Urban Heat Islands	Sprinkling of water to reduce UHI effect		Plantation of high foliage trees for providing shade
Transportation System	**Travel Activity**	Parking and road prizing according to location and peak hours; Increase in number buses, trains and bus stops;	Mandatory give-ways to public buses		Wider road design; more coaches in trains, double decker buses
	Travel mode	Control Car ownership		Introduction of a Bike sharing, e-biking system	
	Energy Intensity	Improvement of roads; advanced signalling system; Employ Quality check officers			
Energy Usage	**Fuel choice**				
	Energy efficiency	Parking prices; Speed limit control; Road Pricing system;	Water borne transport facility for passengers and freight operations		
	Energy choice				Encourage alternate technology for vehicles
	Appliance use	Freight operations through rail routes instead of road; Mandatory Environmental performance description on vehicle purchase		Replace old coaches with new efficient ones	

For passenger travel activities, public transport system supported by integrated travel demand management is recommended. Advanced technology for travel information system, real time road and operation management services greatly increase the travel demand efficiency. This requires development of an efficient information system and communication setup. Currently, MMR is considering a ‘Regional Information System for Planning and Action Research’. Transportation is currently not an objective of the system for now, but this system if set up as a separate department in MMR, can be a huge support for all the planning activities. From planning perspective and also from environmental perspective, transportation component holds huge potential owing to the large population and travel demand. Hence, a completely new department dedicated to govern transportation in MMR could be a huge support to the MMRDA.

Currently, cycling is not a common transportation mode in MMR. The lack of cycle lanes, and unfavourable weather conditions contribute in this culture. The 'European Cyclists' Federation' enlists the advantages of cycling and proves that it is the most environment friendly mode of transportation (Blondel, 2011). Using the updated technology like pedelec and e-bikes, cycling can be conveniently used to cover a distance from 3 to 10 kilometres. Biking culture should be slowly introduced in MMR for high density areas. This will also promote mixed land use approach of the regional plan.

Wider roads, smooth vehicular movement slightly reduce the CO2 emissions but greatly increase the shift to motored vehicles. Road investment without provision of pedestrian and cycling degrades the environment for these modes in many ways. Hence investment in road transport should focus on adding pedestrian friendly pathways, cycle lanes, street furniture and rest stations instead of widening of roads as a standard part of project. Moreover, keeping safety measures high in the high density areas encourage walking. Also, in the hot weather of MMR, high temperature may be a disappointment. Hence, taking Urban Heat Island reduction measures is recommended. Plantation of trees, using shading in the pedestrian roads can also alleviate heat effects.

Also, old and inefficient train coaches should be scrapped. In this case, the cost of implementing new coaches need to be balanced with the cost of emissions.

MMR has the potential to develop water transport infrastructure too. Inland waterways offer more efficient and lower emission transport for long journey and freight operations than railways and road transport (Bloemhof, 2010). Inland transportation should be explored as alternate transportation system for passenger and freight operations. Mumbai, the core city should be more connected to the region as well as outside through inland transport.

7.4.2 Regional Development Strategy

Table 7-7 shows the approaches (in addition to weak pledges scenario) recommended for MMR to substantially reduce emissions.

Table 7-7: Recommendations for Regional Development Strategy Component

		Government Regulations		Government Incentives	
		Mitigation	**Adaptation**	**Mitigation**	**Adaptation**
Planning	**Population density**	Smaller block design with availability of resource shops; Building Social Housing/ Self continued communities		Promote growth around public transport	Incentives to real estate developers for designing flexible/convertible buildings
	Mix Land Use				Design greenways connecting the green areas of the region
	Urban Function	Use of trees in coastal protection practices; Developing eco-tourism	Compulsion of a fixed share of green in big buildings	Incentives to green buildings; promotion of teleworking, telecommuting	
Energy Usage	**Energy efficiency**	Employing a team of pollution inspectors; Audit of commercial buildings 'energy performance after fixed time period	Monitoring, reporting and verification system- Requirement of energy consumption data from non-residential buildings	Easy loan system with added incentives for energy efficiency of building: transferable to the next owner if the building is sold; Avoid subsidizing fossil fuel energy use	
	Energy choice	Renewables Obligation to electricity suppliers; Road Transport Fuel Obligation; Establish a system providing information about each buildings' suitability for solar power generation			
	Appliance use	Communal cooling system			

MMR is a huge market for private companies. If a renewable obligation is strictly applied to these companies, a huge reduction can be expected in the region. Additionally, cap and trade system can be introduced in MMR. This can prevent deflecting the economic trade in MMR from the induced renewable obligations on private investors.

Additionally, for construction projects, energy efficiency should be mandated. Minimum standards should be set and should be made a pre-requisite. At the time of sale, green certifications should be required from the property. Moreover, emission monitoring, reporting and verification system should be implemented.

For coastal protection, soft measures should be the priority. South Korea has gained success in reducing emissions by designing greenways to connect the green land pockets ahead of the Han River redevelopment project (Kim, 2010). Similar approach can be made use of in MMR.

Other than the Transportation measures, the issue of heavy travel demand in MMR, can be tackled by planning interventions too. Planning new train stations and surrounding region can be an effective approach. Planning a new station calls for many land use changes in the nearby areas. This characteristic should be used for the benefit of the region by formulating favourable land use policies.

Also, Regional employment generation can be an effective strategy to reduce the high traffic in the peak hours. However, previous studies show that transport network connectivity has more impact on travel behaviour than planning patterns (Ewing R and Cervero R, 2010; Salon et al., 2012). In 1960s, New York faced similar situation where augmentation of road network reduced the travel demand significantly. However, the economy of the city was severely affected (Regional Plan Association, 2018). The succeeding regional plans of New York had to tackle this issue.

The region is equipped with and is also surrounded by many tourism destinations. This characteristic can be used to generate funds for development by attracting economy from tourism. Biodiversity protection and developing opportunities for eco-tourism is also recommended. Economic returns from tourism can be projected as the benefit for promoting this measure. The Heritage Conservation Society of MMRDA has recently commissioned nine heritage maps of MMR (called Heritage circuits of MMR) that provide a list of heritage attractions of the region (Pressreader, 2018). Such initiatives in the direction of conservation and eco-tourism need to be taken.

7.4.3 Development Control

Most of the proposals for this component are the same as that of the Weak Scenario. Some additional approaches can be regarding involvement of compulsory environmental measures in site planning, using community cooling system for central business districts. However, for strong pledges, certain issues in the Regional Plans need serious attention. For strict implementation of Development Control, it is important to develop flood risk maps and high tide maps for coastal areas in MMR because in certain zones, construction restriction on based on these. But absence of these plans make the implementation impossible. Stringent guidelines on land under 'No Development Zones' need to be defined. Sound action against illegal development should be framed and effectively implemented.

7.4.4 Other Recommendations:

Mumbai, the core city of MMR is the economic hub of the country. External factors like political interference, economic status and growth strongly challenge the integration of climate inclusive planning in MMR. Hence environmental protection is not seen as fundamental issue at present. Instead of the climate change perspective, the economic; health and societal benefits of climate priorities should be presented as compelling goals for gaining the political support. To integrate climate change in planning process, it should be made to look like an investment and not an additional responsibility.

MMR already has many city level Pollution Control Boards (PCB). Other than water quality and noise pollution, real time air quality index is monitored and reported in many cities in MMR. A study by Asian Development Bank (ADB, 2010) confirms that local pollution reduction and emission reduction are related. Thereafter, besides monitoring pollution indicators, PCBs in MMR can be engaged to monitor Climate change indicators too. Currently, there is no institutional cooperation between the Pollution Control Boards and MMRDA. Integration of the two authorities can be a huge step in monitoring GHG of the region.

Inviting cooperation of MMR’s big corporations in planning emission reduction strategies can be a good approach. Direct involvement of corporations in achieving climate targets will aid the region as well the corporations, which is beneficial for the economic stability of the region.

Along with the Government initiatives and policies, social systems are equally significant for sustainable development of a region. The culture of saving environment should be inculcated by spreading awareness. Providing knowledge in multiple languages through media, leaflets, workshops, description on local products etc. is recommended. Along with this, the sense of environmental consciousness needs to be ingrained in the Youth right from childhood. The kids should be taught about the importance of sustainable growth and consequences of climate change as a part of primary level education. This will eventually improve the social infrastructure of MMR and support the efforts of the Government.

The component of waste management is totally absent from the Regional Plan. Managing waste is an important part of planning process. A failed waste management system can lead to sanitation and drainage problems. The consequences have been witnessed after flood disasters and heavy rains. Including this component should be on priority for the planning authorities.

Currently, MMR has an ‘Environmental Status Report’ made by TERI (2014). The report provides documentation of environmental parameters. Climate change is also listed as one of the parameters and need for integration of climate change in planning is emphasized. However, the report does not aim to provide detailed research analysis on this. Also, the state of Maharashtra has a State Adaptation Action Plan. These documents can serve a strong basis for the purpose. It is highly recommended to set up a dedicated climate change research team in MMR responsible for drafting a climate action plan for the region.

With the implementation of these recommendations, MMR’s Regional Plan is expected to be more responsive to climate change priorities, resulting in reduction of GHG emissions.

7.4.5 Prospective Outcomes

The approaches recommended here are rigid steps towards emission reduction. Maximum reduction can be expected from changing to usage of advanced technology in transportation and renewable energy systems. Conservation of green areas can be useful in carbon sink while reduced energy consumption in transportation, electricity sector will further aid in reducing regional emissions. An addition of waste management component in the Regional Plan is mainly expected to assist in adaptation measures. Additionally, strict implementation of Development Control Regulations will be the tool to assure the results of efforts made for governing climate change. With successful implementations, MMR is expected to reduce a huge share of GHG emissions and achieve the Paris Agreement’s 2 °C target.

Climate Change Planning Index

Assuming that all these recommendations are included in the Regional plans, analysis was done again to find the modified CCPI for strong pledge scenario. Table 7-8 presents the new CCPI and Figure 7-3 presents the modified sunburst diagrams.

Table 7-8: Expected changes in CCPI pertaining to the recommendation proposed for Strong Pledges

Regional Plan Components	Original CCPI		New CCPI (Strong Pledges)	
	Mitigation CCPI	Adaptation CCPI	Mitigation CCPI	Adaptation CCPI
Regional Development Strategy	1.00	1.00	8.00	9.00
Industrial Growth Policy	1.70	1.70	6.67	6.67
Office Location Policy	5.00	1.70	8.33	6.67
Shelter Needs and Strategies	0.00	0.00	6.25	7.50
Urban Land Policy	0.00	0.00	10.00	8.33
Water Resource Development	3.00	2.00	5.00	6.00
Transportation	7.50	1.25	10.00	10.00
Environmental Management	3.37	5.77	10.00	10.00
Revised Land Use Plan	2.50	5.00	6.67	7.91
Development Control	2.50	1.00	9.50	8.50
CCPI of the Regional Plan	**2.65**	**1.94**	**8.04**	**8.06**

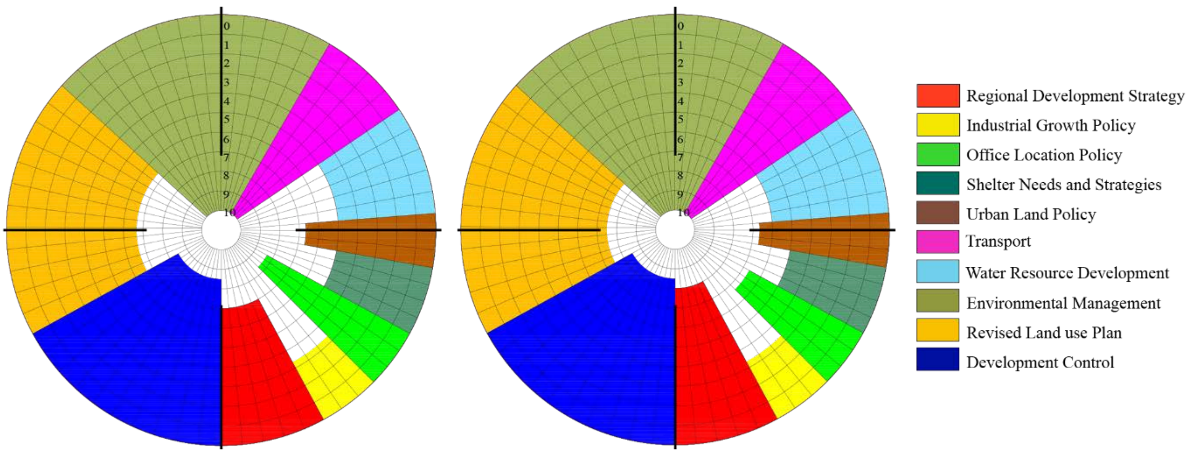

Figure 7-3 CCPI results for Strong Pledge Scenario

For a strong reduction, there will be a need to increase the importance of climate priorities in the regional Plan. All the components will be required to focus on mitigation and adaptation aspects. However, some approaches were found to have conflicting results for mitigation and adaptation. For example, coastal areas need to be protected and conserved as an adaptation measure. But, strengthening public transportation infrastructure may disrupt coastal areas or protected areas. Several other actions can have potentially conflicting approaches. Hamin and Gurran (2009) discussed these conflicts in detail in their study. Pertaining to such conflicts, all the components of MMR could not be made 100% climate responsive. Hence, the overall CCPI of Regional plan is still not 10. However, a huge improvement from the original CCPI score was observed. Transportation and Environmental Management scored a 10, while all the other components scored either 5 or more than 5 for both mitigation and adaptation. Overall, mitigation score of Regional plan increased to 8.04 from 2.65, while adaptation score increased to 8.06 from 1.94.

Economic and Carbon Finance Perspective

For implementation of these approaches for strong pledges, MMR will need to revive the energy sector and turn towards extracting a major share of its energy from renewable sources. Additionally, for building green transport infrastructure, technological advancement will be required to upgrade the existing systems. These advances are speculated to affect the economy to a certain extent. While these effects may be abated at a smaller level by carbon taxing, MMR can strategically plan its climate actions by making use of the cost-effective mechanisms defined by Kyoto Protocol (UNFCCC, 2019a). The 'Clean Development Mechanism (CDM)' (UNFCCC, 2019b) and 'Emission Trading' (UNFCCC, 2019c) are two most common measures designed for the developing countries. In CDM, the Annex 1 countries are allowed to implement an emission reduction project in developing countries. The CDM project's aim is to earn 'Certified Emission Reduction (CDR)' which is equivalent to one tonne of CO2. This CDR can be used by the Annex 1 country to meet Kyoto Protocol's emission targets. Emission trading on the other hand is referred to buying and selling of emission units. This can be made use of in local, national and international scale.

7.5 Conclusion

Using the results of all the previous chapters, this part of the study aimed at suggesting recommendations for Regional Plans of MMR for different climate targets. Climate scenarios were determined with a purpose to address the INDC and Paris Agreement's targets. Depending on the results from chapter 6, various planning strategies for components of Regional Plans were suggested. The impact of those suggestions on the Regional Plan's CCPI and regional emissions was also explained. It was found that MMR will need lesser alterations in Regional Plans and lesser amount of reduction in emissions to meet India's INDC goal. However, in order to meet Paris Agreement's targets, stronger efforts will be required. Robust changes in Regional Planning strategies and more effective mitigation actions will be required.

For INDC target, a 16.8% reduction in absolute emissions from 2005 levels is required in 2030, while for Paris Agreement's target, reduction in every consecutive year is required; which makes Paris Agreement's target more alarming than INDC targets. Accordingly, stronger recommendations were proposed for MMR's regional plans in the strong pledges scenario.

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CHAPTER 8 SUMMARY AND CONCLUSION

8.1 Summary

The study is related to climate change and urbanization issues in a developing country. The key purpose is to find that how a rapidly urbanizing metropolitan region caters to the needs of development while managing the climate change issues. The background of this research is explained in Chapter 1, describing the climate change issues in India. MMR located on the western coast of India was chosen as the study area because of its vulnerability to climate change related disasters and economic significance. India's circumstances and it's communication to UNFCCC is detailed in Chapter 2. This chapter also describes MMR's location, basic features, and urbanization history. The aim was to find a research based solution to the climate change issues by integrating mitigation and adaptation measures in the current planning priorities of MMR.

To fulfil this goal, firstly, MMR's regional plans were studied and analysed for climate change measures in Chapter 3. The analysis was based on two principles; first was measures to reduce emissions- called mitigation; and the second was measures to make the region climate prepared, called adaptation. A new tool, CCPI, was developed for this purpose. Two regional plan documents of MMR were thoroughly examined and CCPI for mitigation and adaptation were found. The outcome of this analysis depicts the strength (or weakness) of planning documents from climate change perspective. The results showed that climate change priorities were not the focus of the plans. The CCPI score was 2.65 and 1.94 for mitigation and adaptation respectively. The analysis also aided in identifying that which component of the plan is the weakest and needs improvement. The results were translated into sunburst diagrams which made the results easily decipherable.

Secondly, MMR's status in the global and national climate targets was to be found. For this, MMR's overall CO_2 emissions, and emissions from road transportation, fugitive and electricity were calculated in Chapter 4. The per capita emissions were compared with India's per capita emissions and it was found that MMR's per capita emissions are higher than that of India's per capita emissions. Following this, MMR's position in meeting the climate targets was found in Chapter 5. Paris Agreement's 2 °C target as the global target and India's INDC target as national target were studied for this purpose. With the baseline scenario, i.e. when no new climate policies are added, MMR was found to be lacking in meeting the targets. To meet India's INDC target, MMR was found to be lagging only by a small extent, while to meet the Paris Agreement's 2 °C target, MMR was found to be lagging with a substantial amount. For the INDC target, a 16.8% reduction in absolute emissions was required and for Paris Agreement' 2 °C targets a 40 to 46% in reduction in cumulative emissions was required. Mitigation rate required by MMR to meet Paris Agreement's targets were also estimated.

The third and the final part was to give recommendations to make MMR's planning climate responsive. For this, MMR's planning components which can affect emissions the most were to be determined. This was done in Chapter 6 by employing multi criteria decision analysis using Analytical Hierarchy Process as a tool. Different planning components were examined against each other to deduce their competitive dominance for aiming to reduce emissions. In the end, three components namely ‘Transportation’, ‘Regional Development Strategy’, and ‘Development Control’ from MMR’s planning documents were found to be at priority in emission reduction potential. Finally, recommendations were made in Chapter 7. In this chapter, three scenarios were proposed. The first was the baseline scenario (no climate policy to be added); second was the weak pledges scenario (aiming to meet India’s INDC target), and third was the strong pledges scenario (aiming to meet Paris Agreement’s target). Planning suggestions were proposed for weak pledges scenario and the strong pledges scenario. To provide empirical support to the suggestions, prospective outcomes of these proposals were also drafted. New mitigation and adaptation CCPIs for both the scenarios were found. The CCPI calculated for weak pledges scenario proved that the proposals can make MMR’s planning more climate efficient and aid in reducing emissions. 4.36 and 4.67 was the new score for mitigation and adaptation CCPI respectively for the weak pledges scenario. The new CCPI calculated for the strong pledges scenario was 8.04 and 8.06 for mitigation and adaptation respectively. This change shows that MMR’s planning has a huge potential to adopt emission reduction strategies. However, strong changes in the planning system in future will be required. Proposals made for the strong pledge scenario are speculated to affect regions’ economy, hence, initiatives under Kyoto Protocol meant to aid developing countries in governing climate change are discussed in the end.

8.2 General Observations and Recommendations for MMR

Each region has a different planning problem and a different solution. The difference in context, scope and concern make the problem unique and demand a unique solution. And when it comes to climate change planning, no standard approach can be followed for reaching the objectives. In the process of finding MMR’s planning limitations and strengths, some general observations were made. This section summarizes those observations and suggests some climate intensive alternatives below:

Firstly, the regional plans of MMR are developed for a period of 20 years. For a growing region like this, it is a long duration for a plan to be implemented. Moreover, there is a large conflict in development boundaries due to the overlapping responsibilities of regional planning authorities and ULBs. Also, the Regional Plan’s Control Regulations stays valid only for areas which are not under governance of ULBs. This creates complications in marking development boundaries which can be easily misused. Hence, instead of the 20 years Regional Plan, an environmentally conscious ‘Concept Plan’ is suggested for the region. A concept plan that may provide an overview of regional development objectives might be a better strategy. It can become a base document to guide the local development plans to be prepared by ULBs and make them a derivative of the concept plan.

Secondly, the Revised Land Use Plan and Environmental Management component of the Regional Plan define landuse zones with conflicting descriptions (Appendix A). Especially for coastal areas, development restriction is defined by a number of laws rendering it ambiguous.

Also, the draft regional plan III permits quarrying and construction of highways, roads and all public activities in Green zone 1 and 2. 'Gaothan and Gaothan expansion[13]' reserves a special landuse zone and are also permissible in green zones. Regional plan II itself noticed illegal construction and illicit practices being conducted in the region. In response to which, instead of strengthening the laws, alterations were drawn in the plan. This is a very adverse shift. For an effective system, it is recommended to make more lucid and strict restrictions on development which should be applicable in all contexts.

Third and the final issue was that MMR's planning does not consider climate change issues as a direct concern. Environmental conservation is an objective which indirectly relates to climate change. However, no direct intention to address climate change matters was observed. MMR has an extensive local train network, country's major sea port, and airport which are prime source of emissions. But emission data from these sectors is not studied in the planning process. For a better development plan, this aspect needs to be included in planning objectives. The planning perspective of MMR needs to be synchronised with the changing global viewpoint towards climate change.

8.3 Final Conclusion

Economic development at the cost of climate change or climate change management at the cost of economic development; both of these strategies are at the extremes of planning objectives and implementation of any one of the extremes does not display a long term sustainable growth pattern. In the process of this research, it was learnt that climate change and economic growth need to be complimentary. For a sustainable future, long term strategy should include a balance of both the extremes.

Planning for Climate Change can have multiple approaches. There are advantages and disadvantages of all the approaches and with context, the impact also changes. Some approaches may condense each other and some may even show potential conflicts. And, when it is about a developing and rapidly urbanizing country, the issues are different and dire. MMR has many priorities including providing facilities to its people, eradicating poverty and ensuring an average standard lifestyle. In such a situation, it is impossible to avoid conflicts between regional priorities and climate change priorities for a long time. The current study has tried to integrate climate change planning into MMR's current planning. Many approaches were applied to reduce emissions and to make the region more resilient. It was observed that some methods are subtle and easy to adopt, while some need a huge change in the planning systems. Some mitigation measures oppose the adaptation measures and vice versa. Also, some ideas are already present in the plans but are weak or are overshadowed by other priorities. That is why, scoring a CCPI 10 is challenging for MMR. However, changes are difficult but not impossible to make. A balance between region's development priorities and climate change priorities can be brought with a strategic shift to mitigation measures and

[13] Gaothan is part of land of the village which is ordinarily used for settlement (Lands of Maharashtra, 2013). Gaothan and Gaothan Expansion Scheme by the state of Maharashtra is aimed to fulfil the need of growing population in the villages. Limited construction activities are permissible in these areas.

adaptation actions. MMR's planning has a huge scope for adopting climate conscious practices. This study highlights the same in two different scenarios. Results proved that with strong efforts and mitigation actions, MMR can achieve both the climate targets. The recommendations made for both the scenarios were able to score well for mitigation and adaptation CCPI which assures the finding.

The study benefits MMR by providing a base for climate responsive planning in future. It establishes the linkage between climate change protocols and planning policies of MMR and therefore can ensure the adherence of climate priorities in the planning process. It can be used by policymakers and planning professionals in formulating climate change related strategies for the region.

The study shows how this global problem can be tackled at a local level. Similar studies should be conducted across the country starting with the large cities and metropolitan areas. A combined effort of all the high emitting cities will eventually reduce national emissions and alleviate the climate change related issues in the world.

8.4 Perspective on Future Study

In the present study, the first step was the analysis of MMR's Regional Plans with respect to climate change protocols. Development of CCPI tool was the outcome of this part and scores for mitigation and adaptation were found. As mentioned earlier, CCPI score in this study was the author's individual work. By involving more experts and scoring the plans based on their understanding, a more cohesive study can be done at this level. This will increase the redundancy of CCPI results. Also, Regional Plan III which is still not sanctioned by the Government, needs to be analysed when available. In addition, development plans of all the cities in MMR can be taken up for future analysis. More number of planning documents adhering to climate change governance would result into a more comprehensive climate oriented planning system for the region.

Further, in the emission calculation part, only three sectors namely, road transportation, electricity consumption, and fugitive emissions were accounted. For future studies, emissions from other means of transport can be included in the assessment. Also, bottom up approach for calculating overall emissions from MMR can be a better approach. However current unavailability of data makes it impossible at present.

Also, the recommendations in the present study were focused on three components of Regional Plan which were found to be on priority for emission reduction. For further assessment, more components can be taken into account for recommendations. Also, the scope of recommendations was limited by the aspect of economic development which is an explicit collateral damage in the efforts taken for governing climate change. If this aspect is governed and guaranteed by other means of policies, new doors will open for climate change research in the region.

Appendix A

Intensity of Importance	Definition	Explanation
1	Equal importance	Two actives contribute equally to the objective
3	Weak importance of one over another	Experience and judgement slightly favour one over another
5	Essential or strong importance	Experience and judgement strongly favour one over another
7	Demonstrated importance	An activity is strongly favoured and its dominance demonstrated in practice
9	Absolute importance	The evidence favouring one activity over another is of highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgements	When compromise is needed
Source: Saaty, 1988		

Saaty TL. **1988**. What is the Analytic Hierarchy Process? In: Mitra G., Greenberg H.J., Lootsma F.A., Rijkaert M.J., Zimmermann H.J. (eds) Mathematical Models for Decision Support. NATO ASI Series (Series F: Computer and Systems Sciences), vol 48. Springer, Berlin, Heidelberg. DOI: https://doi.org/10.1007/978-3-642-83555-1_5

Appendix B

Different Landuse zones and their definitions in MMR's Regional Plans

Landuse zone	Description
Urbanizable Zone 1 (U1)	All areas which are built and are under municipal boundaries.
Urbanizable Zone 2 (U2)	All areas which are built and are outside the municipal boundaries.
Recreational Zone 1 (R1)	A belt of 500 meters from coast from Alibagh to Rewas. There is severe restriction on new development.
Recreational Zone 2 (R2)	A 500 meters belt next to R1. Only a limited range of activities are permitted.
Coastal Regulation Zone (CRZ)	All areas up to 500 meters from high tide line. Severe restriction on development have been imposed by MOEFCC.
Safety Zone	1km belt around industrial area in Thane
No Development Zone	Areas of wetlands around sea coast in the island city. Within 200 m belt, there are severe restriction on development.
Green Zone	Areas beyond urban centres (There is no specific boundary)
Green sub zone 1	Land with future development potential
Green sub zone 2	Prominently agricultural land where limited non-agricultural activities are allowed
Green sub zone 3	Fragile ecosystem –wetlands, mangroves, coastal areas, protected forests
Green sub zone 4	300 m belt on either side of river and areas prone to flooding. No development allowed.
Green Zone 1 (G1)	Areas of irrigation projects, network canals, pockets of land surrounding forests, areas with large tribal populations and areas with slow current development and less connectivity. Only low order activities are allowed in these areas.
Green Zone 2 (G2)	Areas other than G1