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Amruta Ponkshe

ORF OBSERVER RESEARCH FOUNDATION

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ABOUT THE AUTHOR

Amruta Ponkshe is Associate Fellow with the Sustainable Development Programme at ORF. An engineer by training, she works on issues of sustainable mobility and urban infrastructure development. She holds academic degrees in urban development and public policy.

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ABSTRACT

Urban infrastructure projects using brownfield or greenfield development can cause damage to natural habitats. To achieve the Agenda 2030 goal of "leaving no one behind" while mitigating the destruction of habitats, an integrated approach towards infrastructure development must be adopted. This paper outlines the current paradigms of sustainable infrastructure provision, highlighting how and why sustainability outcomes are overlooked at different stages of the project management cycle. It makes recommendations for mainstreaming sustainability outcomes not only of individual projects themselves, but also at various levels of the government, and even while engaging with communities.

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INTRODUCTION

New and urban infrastructure provision using brownfield or greenfield development to previously unconnected areas—whether in suburban cities or through jungles and valleys—involves the destruction of natural habitats to varying degrees. How then can the Agenda 2030 goal[1] of "leaving no one behind" be achieved, while mitigating the negative impacts on habitats?

Countries such as India, which have yet to graduate to the status of developed countries in terms of per capita income, expenditure and various human development index parameters (HDIs), must adopt an integrated approach towards development. India cannot rely on the yardsticks used by developed nations to measure growth and economic realisation.[2]

The imperative is a strong commitment to both the Sustainable Development Goals (SDGs)[3] and the Agenda 2030, to which local and national governments, businesses and individuals alike must adhere. Such a commitment requires transformational lifestyle actions by individuals and communities; paradigm shifts in manufacturing; and service delivery by businesses, public entities and private entities. The goals must be incorporated in all social, economic and infrastructure projects planned by governments and private organisations.

Of the 17 SDGs and their 169 targets, several focus on cities and infrastructure development. Project prioritisation and infrastructure development at the local level are critical to achieving the SDGs. Infrastructure facilitates access to amenities; connects businesses, governments and people; and delivers critical services such as water supply and transportation. In its broadest sense, infrastructure lies at

the heart of the functioning of three dimensions of SDGs, i.e. economy, environment and society, and enables social inclusion, economic growth and environmental protection for all. Thus, it binds together the five dimensions critical for achieving the Agenda 2030: people, prosperity, planet, partnership and peace.

The SDG goals and targets, at least in theory, appear complementary. However, from a practitioner's perspective, they may actually conflict with each other. Different targets will require internal and integrated resolution and reconciliation. [4]

A case study conducted by the Overseas Development Institute (ODI) presents a scenario in the hypothetical country of Progressia to detail the push–pull factors and the inherent conflicts in achieving all the SDGs.[5] Achieving integrated solutions to meet these SDGs will require a fresh approach to all aspects of infrastructure-building, with a special focus on the most basic level of development, starting with the conceptual and blueprint stage of each project.

SUSTAINABILITY OUTCOMES IN BIG INFRASTRUCTURE PROJECTS

Achieving the SDGs and fulfilling the Agenda 2030 are primarily considered to be the obligation of governments and businesses. However, the critical responsibility lies on those who are working on the ground, on individual projects, such as the project managers, planners, architects, designers and engineers. To ensure that sustainability outcomes are achieved, the entire project management cycle for infrastructure projects must have built-in mechanisms to incorporate the SDGs at every step of the project lifecycle, i.e. conception, planning, financing, design, operationalisation, implementation and daily operations.

Sustainability Outcomes in the Matrix of Project Priorities

In most infrastructure development projects executed till date, environmental outcomes were treated only as an addendum to the main project document, receiving little attention in the larger scheme. Often, environmental aspects are completely neglected till the necessary clearances become mandatory for the main project to move ahead. This situation is exacerbated by other factors such as opaque government directives or loopholes in environmental laws, a lack of adequate and capable personnel, political and ideological interests and, increasingly, the rampant activism of environmental groups who view all development projects as detrimental to the environment.[6,7]

Typically, most projects use a simple cost-benefit analysis approach to incorporate environmental outcomes. Since the early 2000s, environmental impact assessments (EIAs) and environmental and social impact assessments (ESIAs) have also been prominently used, especially for projects for which local and national laws mandated an environmental clearance or an environmental audit. However, none of these frameworks and tools (used at the project level) takes into account the chain of ecosystems affected when an infrastructure project is executed.

In most countries, EIAs face governance, regulatory and organisational hurdles in realising their sustainability objectives.[8] In a 2015 study conducted on infrastructure projects in China, Finland and the US, the authors noted the importance of pre-existing governance coordination mechanisms to realise EIA objectives,[9] highlighting that the decisive factor is the level of professionalism exhibited by governance bodies and the decision-making powers granted to the

project teams. The study observed that the sustainability objectives achieved relied more on governance and business mechanisms, as compared to existing environmental laws and regulations.[10]

Case Studies

There are various challenges facing developing nations in infrastructure provision, such as inefficiency of operations, lack of maintenance, poor construction and design of infrastructure projects, weak fiscal policies with regard to infrastructure creation and operations, unresponsiveness to user demands, inequitable distribution of infrastructure provision and neglect of the environment. As megacities in a developing country, both Mumbai and Delhi face many of these issues.[11] Given the 'lock-in' nature of infrastructure projects, the choices that governments make are set in stone for a long time, and sustainability is often overlooked.

To understand the challenges involved and the nuanced correlation between measurable project outcomes and (often-intangible) environmental issues, this paper analyses five infrastructure projects, delineating their impacts on the city's economic, sociological and environmental sustainability as well as the salient features of each, with respect to sustainable outcomes. These projects have fostered huge economic and social benefits by increasing connectivity, providing access to services, and opening up employment opportunities for the communities involved. They have also caused significant changes to the environment in their respective cities. A few of the projects have reaped huge environmental benefits, either due to their inherent connectivity or through a deliberate attempt to incorporate sustainability measures.

Mumbai–Pune Express Highway (Yashwantrao Chavan Mumbai Pune Expressway)

a. Infrastructure Purpose and Outcomes:

A study conducted by the Ministry of Road and Surface Transport (MOST) during 1985–90[12] found the Mumbai–Pune corridor to be one of the most congested roads in the country, leading to travel delays, accidents and economic losses. This project aimed to build a six-lane concrete-paved road to connect two major metropolises in Maharashtra: Mumbai (state capital, financial and administrative centre) and Pune (an industrial and educational hub). The work started in the mid-1990s, and the highway was opened to traffic in a phased manner from 2000 onwards. The 94.6 km expressway provides fast and convenient access to over 130,000 vehicles per day between the Mumbai Metropolitan Region (MMR) and Pune (as per July 2018 estimates).[13] Additionally, it opened up connectivity to other cities in Maharashtra, such as Kolhapur and Satara, and paved the way for express road travel from Mumbai to Bengaluru, thus connecting two major metro regions in India.

b. Environmental Impacts:

i. Loss of Natural Habitat*:* The main environmental issues faced were the felling of trees in the right of way (RoW) and the creation of barriers along the rocky slopes to stop boulders from falling on the road, especially along the mountainous sections.
ii. Sustainability Measures Built into the Scope*:* The Maharashtra State Road Development Corporation (MSRDC) had economic, safety and environmental measures built into the project details. However, these measures were project-specific, e.g. the development of food plazas, rest areas and convenience stops along certain points on the expressway; the installation of road safety signs, barriers and

warnings; and the plantation of approximately 60,000 trees using drip-irrigation along the highway medians. The MSRDC ensured the transplantation of 500 trees cut down in the RoW.[14]

c. Key Institution(s) Involved:

The MSRDC was the nodal agency involved in the financing and asset management of this project. Created in 1996 through a resolution of the state government, it is responsible for providing asset-management services to road and bridge projects in Maharashtra. The Mumbai–Pune project only includes sustainability in terms of tree plantation along the highway and in the median. The major directives for the same came from the National Highways Authority of India and the MSRDC.

d. Challenges Faced:

The land acquisition was done through the MSRDC. Since this was one of the first large-scale infrastructure projects in the country, the MPE did not face much opposition from environmental groups. However, while the project paid a brief nod to sustainability outcomes, there was little acknowledgement of green technology that could be used in the construction and materials. Moreover, no effort was made to harness readily available technology, such as solar panels or energy-saving pavements. This highlights a lack of overall understanding of the issue of sustainability and the significance of sustainability as a key project goal. The construction was funded largely by indigenous financing, using debt, land-value capture finance and toll revenue. The lack of foreign investment eschewed any scope for international guidance or directives for sustainable measures to be built into the design. The CAG report highlighted several financial discrepancies in the execution of the project, including the lack of a detailed project report or a feasibility study conducted for optimum site selection.[15]

e. Way Forward:

As with most road development projects, the Mumbai–Pune Expressway is set to be widened to an eight-lane highway, from Adoshi Tunnel to Khandala exit. This stretch of the expressway is currently a six-lane road but bears the traffic of a 10-lane road (six-lane of Mumbai–Pune Expressway + four-lane of old Mumbai–Pune road or National Highway-4).[16] The proposed realignment aims to reduce travel time by 25–30 minutes and increase the MPE length to 100 km in all. This will affect 74.7102 hectares of forest cover and is estimated to cost INR 5,000 crore. As of September 2019, the tunnelling work for the missing link has begun.

Bandra–Worli Sea Link Project (BWSLP)[17]

a. Infrastructure Purpose and Outcomes:

The BWSLP aimed to connect two main arterial roads in Mumbai via a viaduct and a cable-stayed 5.6-km bridge with eight lanes, built in the open sea. The total cost of construction was around INR 1,600 crore. Originally intended for over 100,000 cars/day, the current vehicle estimate is around 30,000–50,000 cars daily.[18] This is a part of the larger Mumbai Coastal Road Project.

b. Key Environmental Impacts:

i. Loss of Natural Habitat: In a coastal city, changes along one part of the shoreline can affect tidal wave lengths and alter soil erosion conditions along other parts. The BWSLP has resulted in the narrowing of the Mahim Bay and the subsequent increase in the height of waves along the coast. The BWSLP required reclamation of land, which has had a detrimental impact on the mangrove

species in this region, according to a report by the Indian People's Tribunal.[19]

ii. CO_2 Emissions/Carbon Positive: No studies have been conducted till date to analyse CO_2 emissions from the project. Based on the data on the overall time saved by vehicles using the freeway, the project must have saved some degree of per-day carbon emissions since the operations began in June 2009. However, the carbon benefits of the project are not self-evident when juxtaposed with the increase in the overall number of vehicles on Mumbai roads and other construction-related CO_2 emissions.

iii. Sustainability Measures Built into the Scope: No sustainability measures were built into the scope of the BWSLP. On the contrary, several practices implemented were against contemporary environmental norms, which forced the construction to be halted, causing delays in the project. While the BWSLP obtained the requisite environmental clearances from the Ministry of Environment and Forests (MoEF), it did not mitigate the floodplain dangers that experts considered avoidable.

c. Key Institution(s) Involved:

The MSRDC, the MMRDA and the Government of Maharashtra (GoM).

d. Challenges Faced and Way Forward:

The BWSLP was intended to be part of the larger Mumbai coastal road project, which aims to connect the business hub of south Mumbai with the business, commercial and residential hub of north Mumbai through a series of linked roads and bridges along the western coast of the city.

As of 2019, construction has started on the coastal road project, despite significant opposition from environmental groups, who fear that this project will cause irreparable damage to the coastline, mangroves and livelihoods along the coast.[20] The numbers of cars accessing the BWSLP have gone down in the last few years. The upcoming Metro Line 3 intends to support ridership along the same route as the BWSLP, which has prompted experts to question the financing feasibility of the larger coastal road project.[21]

Delhi Metro Rail Corporation Limited (DMRC)

a. Infrastructure Purpose and Outcomes:

The DMRC was formed in 1995, and the first metro route became operational in 2002. The present mass rapid transit network of the Delhi Metro covers 389 km and has 285 stations, including the metro rails of Noida, Greater Noida and Gurugram.[22] Planned expansion in the fourth phase includes the addition of 60 km and 46 stations,[23] creating a comprehensive metro rail network for the National Capital Region (NCR) of Delhi to connect areas within Delhi and the neighbouring urban agglomerations in surrounding states. The DMRC also provides seamless public transit connectivity through feeder buses, cycling and collaborations with cab aggregators at or near its stations.

b. Environmental Impacts:

i. Loss of Natural Habitat: Although there are eight environmental impact assessment reports for various phases and other infrastructure on the DMRC website,[24] no detailed system-level impact assessment has been undertaken. The various phases of

the Delhi Metro development have caused the loss of natural habitat near the riverfronts, along tree-lined avenues and along informal housing settlements. Since the metro system consists of underground, at-grade and elevated systems, construction and operation activities affect the project areas differently.

ii. CO_2 Emissions/Carbon Positive: Since 2008, the DMRC has been registered in the Clean Development Mechanism (CDM),[25] which enables it to claim carbon credits for energy-saving aspects such as reverse braking on its rakes and solar electrification. In 2015, the United Nations Framework Convention on Climate Change (UNFCCC) recognised the DMRC as the world's first transport sector under its Program of Activities (PoA), and the DMRC leads the PoA for all other metros in India. Under the PoA, all Indian metro railways can claim carbon credits as sustainable mass rapid transport providers. As of 2015, the DMRC operations had helped remove 7.7 million tonnes of carbon dioxide equivalent [$tCO_2(eq)$]. It is expected to remove 45.78 million $tCO_2(eq)$ by 2031.[26]

iii. Sustainability Measures Built into the Scope: The DMRC lists energy, environment, sustainability, water, solar and waste management as its core policies.[27] Its green initiatives include recycling construction and operational materials, participating in the Clean Development Mechanism, adhering to the COP-21 protocol and Green Buildings Code,[28] and focusing on renewable energy. The DMRC is a sustainability leader, not only in India but also in the rest of Asia. The World Green Building Council has recognised it for "Industry Leadership in Sustainability."[29]

c. Key Institution(s) Involved:

To receive funds from multilateral donor agencies, on 3 May 1995, the DMRC was registered as a joint venture between the Government of the National Capital Territory of Delhi (GNCTD) and the Government of India (GoI).

d. Sustainability Goals Achieved:

The DMRC follows its own organisational principles as well as the GoI's guidelines on environmental protection. For the first three phases of the Delhi Metro, the DMRC has felled 31,855 trees, transplanted 6,636 of them and planted 344,251 new trees. The tree plantation initiatives alone are expected to help this infrastructure project sequester approximately 5,500 tonnes of CO_2 and produce 12,400 tonnes of O_2 per year. Its other initiatives, such as solar rooftop panels and regenerative braking in all its coaches, are estimated to help the organisation successfully achieve its targets for renewable energy.[30]

e. Way Forward:

While there may be concerns about the financial viability of the Delhi Metro, as a public infrastructure project, it has robust sustainability measures in place. From project planning and capacity-building to implementations, operations and public engagement, the DMRC management has worked closely with relevant stakeholders, encouraged the adoption of international best practices in metro construction and management, and enjoyed continuous support from the Centre as well as state governments and commuters. [31]

Mumbai Metro Rail Corporation Limited: Colaba–Bandra–Seepz corridor (Mumbai Metro Line 3)

a. Infrastructure Purpose and Outcomes:

The project aims to construct an underground metro line to connect six business districts, 30 educational institutes, 30 recreational facilities, and the existing domestic and international airport terminals in the heavily populated areas of Mumbai along the north–south corridor with key business hubs. The Mumbai Metro Line 3 would connect congested areas of south Mumbai—corporate and financial hubs of Cuffe Parade, the administrative district of Vidhan Bhavan and Churchgate and the business district of Bandra Kurla Complex—to residential areas in north, central and south Mumbai. The construction is being handled by the Mumbai Metro Rail Corporation Ltd. (MMRC) and is currently underway. Once operational, the line aims to provide fast and comfortable transit to more than 1.6 million commuters daily.

b. Environmental Impacts:

i. Loss of Natural Habitat: Creating space for important infrastructure within the overdeveloped and overpopulated city of Mumbai is an onerous task.[32] Since Mumbai is a megacity with a scarcity of green open spaces, the MMRC received substantial backlash from environmental activists on its decision to cut down over 2,100 trees to clear space for installing its end-of-the-line car shed near the Aarey Milk Colony.[33] The MMRC has since made it clear that it has already planted over 20,000 trees in addition to the compensatory plantation mandated by law.[34]

ii. CO_2 Emissions/Carbon Positive: In its inclusion report to the UNFCCC's Clean Development Mechanism (CDM), the MMRC claimed that it will reduce 261,968 $tCO_2(eq)$ under the Mass Rapid Transit System (MRTS) PoA during a 10-year period of metro operations, from 1 January 2021 to 31 December 2030.[35,36]

iii. Sustainability Measures Built into the Scope: The MMRC aims to build a reliable, sustainable and energy-efficient mass transit network for Mumbai as stated its mission statement. Moreover, the corporation has "community enrichment" built into the scope of its corporate social responsibility.

c. Key Institution(s) Involved:

The MMRC, the Maha Mumbai Metro Operation Corporation Ltd. (MMMOCL),[37] the Mumbai Metropolitan Region Development Authority (MMRDA), the GoM, and the Japan International Cooperation Agency (JICA). The MMRC is the agency responsible for Mumbai Metro Line 3, whereas the MMMOCL is the nodal agency for the entire Mumbai Metro network (as the DMRC is for Delhi). The organisational structure of the MMRC is well-defined and transparent, with a strong emphasis on sustainability policies. However, the policies of the MMMOCL and its points of interaction with the MMRC are still unclear, since the operations are yet to begin.

d. Salient Features:

An air-conditioned, underground railway network going through the heart of the city with stops at convenient locations will enhance the commuter experience, which in turn can convert many car users to sustainable public transport users. Additionally, the currently

overburdened and inadequate suburban railway line will get some respite, since a large chunk of its commuter base will shift to the metro line. Consequently, the suburban railway will be able to ensure timely repairs and upgradation of the rolling stock to function more efficiently.[38]

e. Way Forward:

The MMRC is still in its "build" stage. There are several sustainability measures it must adopt once it begins operations, including seamless coordination with the rest of Mumbai's metro network. The MMRC can achieve efficiency in operations and sustainability options if it ensures seamless connectivity to other mass transit options in the city, e.g. the suburban rail network and bus system, and provides sustainable options for last-mile transit.

Mumbai Urban Transport Project (MUTP)

a. Infrastructure Purpose and Outcomes:

The project was designed to upgrade Mumbai's transport sector through a multi-pronged approach of strengthening its railway network and bus system and resettling the people affected as a result. Currently, the MUTP is in its third phase, with Phase-I lasting from 2002 to 2011, Phase-II finalised in 2010, and Phase-III expected to be announced in 2020. The first two phases revamped Mumbai's railway and road network in the city and suburbs, and Phase-III is expected to connect the entire Mumbai Metropolitan Region (MMR). Since 2002, many road links have been created through the MUTP-I. While the city grew in the north–south axis, the MUTP-I provided important east–west links through the completion of the Santacruz–Chembur Link Road

(SCLR) and the Jogeshwari–Vikhroli Link Road (JVLR).[39] The Mumbai Railway Vikas Corporation (MRVC) oversaw the repairs for the existing railway network, the addition of new railway lines on the central and western routes, the extension of the Harbour route, the procurement of new rolling stock, and the conversion of the 1,500 V DC traction to 25 kV AC through the MUTP-II.[40] In the MUTP-III, the MRVC hopes to extend the suburban railway lines to the exurbs of Virar and Dahanu in the north, and Karjat and Panvel in the hinterland.[41]

b. Environmental Impacts:

i. Loss of Natural Habitat: The initial consolidated environmental impact assessment took seven years to complete. During this time, it had analysed various alternative site locations and proposed sites with minimal intervention. Due to the environmental monitoring plans at the project level, activities such as monitoring ambient air quality, lowering noise levels, and replantation were successfully carried out for the comprehensive project.

ii. CO_2 Emissions/Carbon Positive: CO_2 emissions were not calculated in the initial phases of the project.

iii. Sustainability Measures Built into the Scope: Of the projects studied in this document, the MUTP has followed the most sustainable practices, chiefly because it up-streamed the planning and strategic environmental impacts. The project was made economically, socially and environmentally sustainable, by connecting important locations in the city through roadways and train lines, efficiently resettling 100,000 project-affected persons through stakeholder consultations, suggesting alternative locations to safeguard environmentally sensitive sites, and implementing well-monitored afforestation measures and mangrove transplantations.[42]

c. Key Institution(s) Involved:

The MMRDA, the MRVC, the GoM, the GoI, the World Bank and the Municipal Corporation of Greater Mumbai (MCGM).

d. Salient Features and Issues Faced:

As a World-Bank-assisted project, the MUTP ensured that a consolidated SEA was carried out. According to the MUTP Environmental Impact Assessment (Vol. 4), it includes three components: "1) Sectoral Level Environmental Analysis (SLEA) for four strategic transport options for Mumbai Metropolitan Region identified as part of the Comprehensive Transportation Study; 2) Programmatic Level Environmental Assessment (PLEA) of generic sub-projects; and 3) Micro-level Environmental Assessment (MLEA) for sub-projects likely to have significant adverse environmental impacts."[43] This was one of the first successful examples of the implementation of the SEA process in India. Due to the regulations of the World Bank, which was the MUTP's primary financier, a rigorous SEA mechanism was followed. However, the successive phases of the MUTP have not shown similar rigour for the impact assessment process and have only conducted EIAs. In Phase-III, the Asian Infrastructure Investment Bank (AIIB) will invest US$500 million in the MUTP projects.[44] So far, no information has been made available regarding the sectoral-level planning or impact assessment for this phase.

e. Way Forward:

To ensure that sustainability measures are enforced in the upcoming phases of the MUTP, the implementing agencies must plan for probable impacts and minimise the ecological, social and economic damages. This has already been achieved in the MUTP-I.

ANALYSIS

Table 1: Matrix of Project Priorities

Project Priorities	Mumbai–Pune Express Highway	Bandra–Worli Sea Link	Delhi Metro Rail Corp	Mumbai Metro Rail Corporation Limited	Mumbai Urban Transport Project
Infrastructure Outcomes	A restricted toll-way; provides fast, convenient access to over 130,000 vehicles per day between MMR and Pune.	Part of the Mumbai Coastal Road Project; went over budget; recovery through toll revenues falling.	Mass rapid rail transit system of over 389 km in the national capital region of Delhi; integrated transit system with connections to other transit modes.	Part of the larger Mumbai Metro Rail Network; underground railway corridor connecting Mumbai's prominent business, residential and tourist districts.	Opened up Mumbai's transport sector by strengthening the railway network and bus system and creating east–west corridors in a city that lacked this connectivity.
Environmental Impacts	Felling of trees in the RoW; soil erosion along slopes.	Detrimental to mangroves and other coastal ecosystems; unmitigated flood plain dangers.	Well-documented losses in tree cover, natural ecosystems along rivers and lakes; mitigation measures adopted for most loses; registered as sustainable MRT provider; carbon-positive outcomes.	Felling of trees to create space for the end-of-line car shed at Aarey; aims to reduce 2,61,968 tonnes of CO_2 equivalent within 10 years of operations.	Creation of environmental monitoring plans at the project level; activities such as monitoring ambient air quality, lower noise levels, and replantation were successfully carried out throughout the project phases.

Project Priorities	Mumbai–Pune Express Highway	Bandra–Worli Sea Link	Delhi Metro Rail Corp	Mumbai Metro Rail Corporation Limited	Mumbai Urban Transport Project
Key Institution(s) Involved	NHAI and MSRDC.	MSRDC; MMRDA; GoM.	DMRC; GoI; Government of Delhi.	MMRC; MMMOCL; MMRDA; GoM, JICA.	World Bank; MRVC; MMRDA; MCGM; GoM; GoI.
Features	Indigenous financing; re-widening; extension of road project.	Intended project work on the coastal road started in 2019.	The DMRC follows its own sustainability principles and GoI environmental norms.	Rapid connectivity to unconnected places in Mumbai; comfortable services; reduced car dependencies.	Followed the SEA approach to ensure overall project sustainability, it involved a Comprehensive Transportation Study; PLEA for sub-projects; and MLEA for sub-projects likely to have significant adverse environmental impacts.
Way Forward	Can use retrofitting and urban forestry/ regenerative forestry measures to enhance sustainability outcomes.	No strong measures to mitigate dangers to coastal ecosystems.	DMRC has to align financial viability with sustainability outcomes.	Seamless integration with other transit routes and modes will determine if the MMRC achieves its SDGs.	Sustainability outcomes achieved in phase 1 of the project have so far not been demonstrated in the later phases.

POLITICAL–ECONOMIC DYNAMICS

It is important to highlight the political–economic realities that informed the projects used in this paper as case studies. The older projects, such as the Mumbai–Pune Expressway, were constructed without much understanding of sustainability outcomes from a leadership perspective. The later projects, however, fared much better in incorporating SDGs in their project outcomes due to the widespread leadership capacity-building through repeated trainings in SDGs.

Other political aspects, such as the same parties or coalition of parties being in power at both local and national levels, may also have accelerated or suspended fast-tracking of environmental clearances. For example, the Bandra–Worli Sea link started without adequate mandatory clearances. Work was stalled for years on other projects, such as the Santacruz Chembur Link Road (SCLR), a part of the Mumbai Urban Transport Project (MUTP) Phase 1, due to inadequate community support for the relocation of religious structures.[45] Other factors that play a significant role in incorporating sustainability in big infrastructure projects include project leadership, not only political but also individual, i.e. the person at the helm of project execution. To provide deterministic outcomes on this aspect, a detailed study must be conducted on the nature of project leadership and its impact on the outcome.

Observations

Using the five case studies, a few observations can be made about infrastructure development and sustainable outcomes.

Feedback Loops

The road development projects (the Mumbai–Pune Expressway and Bandra–Worli Sea Link) have minimal built-in sustainability outcomes. Due to the very nature of these projects, i.e. road development aimed at individual transport and not mass transit, the amount of CO_2 released will always be higher than that of mass rapid transit systems such as the metro systems.

Further, road projects have other outcomes. Expansions are characteristic of road transport projects, as evident in the upcoming extension of the Mumbai–Pune Expressway and the ongoing amalgamation of the Bandra–Worli Sea Link into the larger coastal road project. Building roads to allow more traffic to ply unfettered typically leads to a demand for more roads due to the ever-increasing traffic, setting in motion a vicious cycle. Congestion and pollution of roadways are common problems faced by most countries. While India is making policy changes to bring in more environment-friendly individualised transport options such as electric vehicles (EVs), the energy needed to run these EVs might still come from polluting energy sources, diminishing their value as sustainable transit options.[46]

The metro, on the other hand, creates a path dependency for lowering carbon emissions. Mass rapid transit systems operating in tandem with well-connected last-mile public transit options fuel the demand for speed and comfort. In this regard, the DMRC has taken appropriate action by connecting with the city's bus network, cycling options and para-transit. However, synchronisation remains a challenge, and getting caught in traffic congestions after metro rides

is par for the course. Pedestrian-friendly walkways, street lighting and street signage must be built and maintained if Delhi wants to lower its pollution and prevent metro users from opting to commute in private cars.

While Mumbai's MMRC metro route is yet to begin operations, measures to address last-mile connectivity and para-transit in the station development have been incorporated right in the design process. Further, the city's bus transit network has recently received a fillip, with the implementation of much-needed policy measures such as lowering fares and using mini-buses for shorter routes.[47] In future, the MMRC and BEST should collaborate and introduce mini-buses on the frequently used last-mile routes, as designed by the MMRC. During a recent student competition for station-area design and planning, conducted in collaboration with ORF, the MMRC received suggestions from several future architects and planners to focus on non-motorised means of last-mile connectivity in its station-area development plans.[48]

Retrofitting of Unwieldy or Unsustainable Infrastructure

For infrastructure projects constructed several years ago, when sustainable development was not considered a project priority, it is possible to modify unwieldy and unsustainable infrastructure through carefully drafted policy mechanisms and intentional execution. For example, dedicated bus lanes on the BWSL or the upcoming coastal road will the pave way for a faster, more affordable public transit to cater to more people, which is a step up from facilitating the comfort and speed of only relatively high-income private car users. The new section of the Mumbai-Pune Expressway can be constructed using greenery, energy-conserving pavements and green infrastructure. To create an equitable transit experience for citizens, the toll can be

increased to fund for public transit operations. Moreover, the existing expressway can be retrofitted in successive upgrades, to improve safety and sustainability.[49,50] Urban and regenerative forestry techniques, such as Miyawaki forests,[51] can help increase forest cover in depleted areas. Miyawaki forests[52] are dense urban forests that use native trees to create a thick green cover in a small urban pocket. Such trees can be planted along the medians, and native trees can be reforested along the highways to increase an area's green cover, which will also increase the amount of CO_2 being sequestered over the years, thereby mitigating long-term climate-change effects.

The Lack of a Systems Approach Results in Lower Sustainability Outcomes

For three of the five projects considered, a lack of systems approach at the organisational-, project- and policy-levels has resulted in lower sustainability outcomes. For the two road projects (constructed 20 and 10 years ago), the framework for the "missing link" of the expressway and the project report for the "coastal road project" were deemed unfeasible when the expressway and sea link were constructed, due to various political, economic and environmental reasons. These roads are now due for upgradation, and the MSRDC wants the original projects to be finally executed. If these projects been executed at when they had been planned, they would have prevented a burden on the public exchequer now and reduced much of the project's environmental damage: decades of saving 30 minutes per vehicle on the expressway would have helped sequester a substantial amount of CO_2.

Narrow Focus on Environmental Impact Assessments

Four out of the five projects discussed in this paper use environmental impact assessments as a way to include sustainability outcomes. However, EIAs are typically carried out after the project plan is in place

and focus mainly on the project-specific parameters of environmental impact. Thus, EIAs are often limited to mitigation plans as opposed to sustainability outcomes. While the MMRC and the DMRC, too, use the EIA as an analysis tool, they stand out from the other agencies by focusing on their sustainability goals, which are a mix of organisational principles and environmental directives of the GoI.

The Lack of a Holistic Approach to Project Planning

For greenfield infrastructure projects, the target users determine future use of the land adjacent to the project. For example, in the Mumbai–Pune Expressway project, the provision is made primarily for car owners, resulting in the construction of car-friendly exurbs with low housing densities, no pedestrian infrastructure along the highway, and largely exclusionary gated communities. Housing provision, in turn, determines the service infrastructure such as schools, hospitals and other educational institutions. Further, the exit points of the expressway determine the towns that will get developed as "transit hubs," their future real-estate values and their sustainable (or not) development.

However, as evident from the land-use patterns, the MSRDC did not plan adequately for potential transit-oriented development hubs to be developed along the highway. It acquired and sold real estate, but the lack of planning meant that much of it was developed in a haphazard and unsustainable manner, as evident in the kind of development seen on both sides of the expressway in the past two decades. Since the project priority was providing transit connectivity, sustainability outcomes were not given due consideration.

INTEGRATED APPROACHES TO SUSTAINABILITY

Infrastructure development plays a central role in achieving sustainability outcomes. The UN Environment Programme's (UNEP) 2019 paper titled, "Integrated Approached to Sustainable Infrastructure" (IASI)[53] argued for the planning and execution of infrastructure projects in a connected manner. "Integrated approaches have three main advantages over 'siloed' infrastructure approaches that consider infrastructure projects, systems, and sectors in isolation from others. First, they allow for **optimising infrastructure development** by considering the services that infrastructure systems deliver, and not just the assets created. Second, they result in **longer-lasting infrastructure** that is more resilient to climate change risks and human-made/technological disasters. Third, by identifying and addressing potential risks early in the planning process, they increase the **bankability of infrastructure projects**, making them more attractive to investors." Since these outcomes are highly desirable for any agency involved in infrastructure development, it is beneficial to unpack the approaches and modify them to fit the context of developing countries.

Experts at international development organisations, such as the World Bank, Asian Development Bank (ADB) and the Inter-American Development Bank (IDB), have provided extensive support and guidance to infrastructure projects in various countries across the globe. There are several models that incorporate sustainability outcomes into the framework of the project. Such tools bring together the economy, society and biosphere, and provide overarching guidelines and frameworks to help upstream sustainability outcomes in infrastructure project planning. The Envision Rating System (ERS) and

Strategic Environmental Assessment (SEA) provide good alternatives for overarching frameworks; the Category Assessment Tool for Infrastructure (CAT-I) provides guidelines for capacity-building; and the Ise-Shima principles provide guidelines for investing in sustainable projects.

The Envision Rating System (ERS)

The Zofnass Program for Sustainable Infrastructure at the Harvard University Graduate School of Design (Harvard GSD) and the Institute for Sustainable Infrastructure designed the ERS as a means to enhance sustainability for infrastructure projects at the early stages of planning and design and to quantify the sustainability of the project.[54] The Harvard GSD intends the ERS to become a benchmark tool for projects worldwide, to standardise sustainability outcomes for all infrastructure projects. It has five measures, with individual rating systems for each. **Quality of life** is measured by analysing a project's impact on general well-being and community, and whether the idea is a right fit for the aspirations of end-users. **Leadership** is measured through indicators for collaboration, management and planning amongst multi-institutional project teams typical of large-scale infrastructure projects. **Resource allocation** and **natural-world impacts** are measured through a reduction in energy and water utilisation, and the **preservation of biodiversity** by selecting geologically optimum site locations and minimising the interference of existing land and water sources. The ERS stresses on reducing greenhouse gas emissions and mitigating climate risks through built-in climate resilience.

The ERS has been used by local and regional government bodies such as the Los Angeles County, Detroit Metropolitan Wayne County Airport Authority, the New York City Department of Environmental

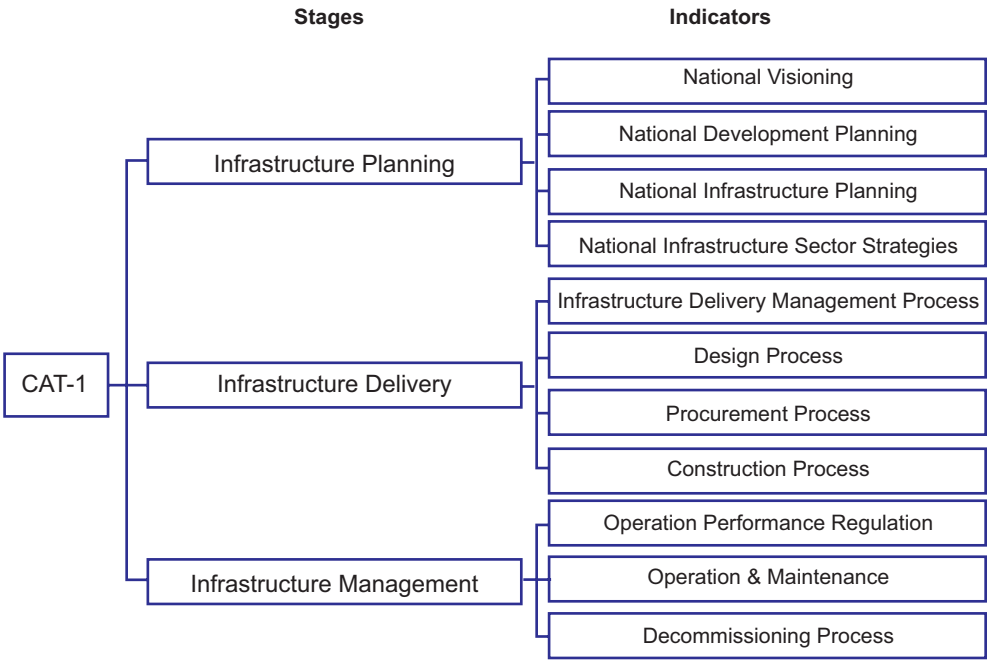
Protection; as well as professional bodies and businesses such as Water Environment Federation and C&S companies. Currently, the system provides four award categories for infrastructure projects of six different scales.[55,56]

Strategic Environmental Assessment (SEA)

The SEA is conducted at the strategic-planning stage, and an environmental-impact assessment is conducted at the individual project level. The SEA suggests the optimum course of action to achieve sustainable outcomes according to a predefined objective.[57] In the context of developing countries, the SEA offers an all-round solution to ensuring sustainability outcomes as it combines social, environmental and economic factors to identify the optimum plans, policies and projects to be developed. This helps to upstream planning and to proactively plan for a project's impact on its immediate environment and ecological systems. In a detailed report on the SEA,[58] Asha Rajvanshi traces the evolution of the method from the early 1970s to its current applications in the second decade of the 21st century. While the SEA was formalised by international development agencies in 1989, it was applied by the developing world only in the 2000s. In its current iterations, it is often integrated with other types of impact assessments and is offered as a tool in the wider impact-assessment toolkit. The SEA, or its variations, have been used in various infrastructural projects in India, e.g. for water-resources planning, tourism, and locating a possible nuclear power plant.[59] One drawback of the SEA is that unlike the other tools discussed in this paper, which have fixed indicators and measurable benchmarks, it is governed by a loose set of principles and guidelines. As evident in the MUTP case study, due to its lack of indicators and targets, the SEA does not enforce strong legacies for subsequent project phases.

Capacity Assessment Tool for Infrastructure (CAT- I)

The CAT-I[60] is the newest framework amongst the ones discussed in this paper. It is the most top-down approach and tackles an important lacuna in infrastructure development and delivery—that of capacity-building. The CAT-I is an online assessment framework that helps governments analyse their capacities to fulfil their infrastructure needs. Through three stages of infrastructure planning, delivery and management, the indigenous capacity of a country (or a regional or local government) is analysed.[61] Once the gaps are identified, the tool is used to chalk out a series of measures to enhance the managerial, technical and advisory capacities of the respective government. This self-assessment is done by answering a set of 93 yes/no questions that provide inputs to the online tool. The analysis is a part of an eight-step process, which includes interviews with key stakeholders, the communication of findings, the creation of a roadmap for filling in capacity gaps, and the potential reassessment for gauging the success of the initial CAT-I assessment and recommendations. The CAT-I has been used by project agencies in countries such as Brazil, Serbia and Nepal, with more countries seeking to adopt the framework.



Source: Capacity Assessment Tool for Infrastructure [CAT-I]: Explainer Document.[62]

Ise-Shima Principles for Promoting Quality Investment

The "principles for promoting quality investment" were adopted by the G7 nations during the Ise-Shima Summit in 2016.[63] The Ise-Shima Principles work at a macro level and promote quality infrastructure by fostering projects that ensure economic efficiency, inclusiveness for target communities, safety, resilience, sustainability, convenience and amenities. Additionally, they target aspects of human resource development, e.g. the proposed contribution of projects to local society and economy.[64] These principles have been used as guidelines to highlight good practices in Japanese investments in infrastructure projects,[65] and they serve as a blueprint for future investment decisions. They focus on engaging with the private sector and local stakeholders through public–private partnerships. The Ise-Shima principles

guide Japanese agencies such as the JICA, the Official Development Assistance Japan (ODA), and business entities such as the Overseas Construction Associate of Japan, Inc. (OCAJI), informing them about sustainable best practices.

ADDITIONAL FRAMEWORKS

The systems discussed in the previous section have worked well for developed countries with robust and integrated approaches to sustainable infrastructure development, by giving them evolved environmental governance mechanisms. However, developing countries such as India, which do not have well-defined integrated approaches, cannot rely solely on these. They must also aim to build the following holistic frameworks to mainstream sustainability outcomes in big infrastructure projects.

Integrated Climate Action Plans

One way to build a robust framework is by implementing Climate Action Plans (CAP) at the local or metropolitan level, or a level of governance that has the authority to make independent decisions. Various cities in the world such as Chicago,[66] New York[67] and Stockholm have reworked their priorities for development. Due to climate change and extreme weather changes, national and sub-national governments are adopting climate measures as a part of their policy priorities. For small islands and developing states (SIDS), such as Maldives, Papua New Guinea and the Caribbean islands, environmental outcomes are "high priority," since they bear the worst and most-extreme impacts of climate change.

Many cities have CAPs that determine their contribution to climate-related outcomes at the international level. These serve as the baseline for carbon emission reductions at the city and metropolitan level

which, in turn, determine infrastructure project priorities, spending priorities and service delivery at the local level. A city-specific CAP is tailored according to the city's developmental and economic needs as well as political priorities. The CAP eliminates a city's dependence on the national and sub-national governments for climate change policies and the requisite funding for sustainable projects and mitigation. To integrate infrastructure across systems and sectors for developing countries, city governments should formulate city-specific CAPs, in close coordination with the national and sub-national governments.

Integrating Institutions

This is arguably the most difficult aspect for developing countries and their cities. The nature of governance in developing states is such that the more rigid the governance structures, the more difficult it is to implement systemic changes. A new rule gathers dust after making a few rounds of the governance machinery through various departments or ministries, only to be resurrected when a formal inquiry is ordered by the judiciary or a legal petition is filed by citizens or opposition parties. Due to colonial-era structures, repeated governance instability and party politics in bureaucracy, governance institutions in developing countries are often fragmented and power rests in the hands of a few ministries. In countries as diverse as Uganda and India, studies show that due to governance structures being disjointed or uncommunicative, implementing agencies are either unaware of legislations related to climate change or uninformed about the stipulations of such legislations.[68,69] The case is similar in many cities, where the regulatory bodies responsible for environmental sustainability are often overlooked and have minimal interaction with the rest of the city governance processes, with little power to amend key decisions made by more other, more powerful departments.[70]

However, the recent international recognition of the significance of climate-change mitigation can help improve this situation.

Strengthening and aligning institutions requires political will at the national level.[71] As infrastructure finance by international agencies becomes increasingly contingent upon achieving sustainability outcomes, the UN and other international organisations can play a huge role in the creation of countrywide institutional mechanisms for strengthening environmental agencies. Fixing national climate-action goals and sustainability targets through a national-level climate-action plan will help create or adopt a framework such as the CAT-I for institutional capacity-building and coordination. This can empower environmental ministries or agencies to fight for their rightful place as the nodal integrator of climate-action plans and climate-mitigation efforts.

Collaborating with Communities

The crux of the action for sustainability efforts lies in collaborating with communities. So far, the global community—UN agencies, multilateral donors, international stakeholders—has provided sustainability directives for projects and plans. However, these have been poorly accepted and implemented by governments in developing countries. A case in point is the controversy over the MMRC's car shed at the Aarey Milk Colony, which could have been avoided by integrating and educating the community at the early stages of project planning.

The earth is rapidly inching towards a point of no return. As students, youth, scientists and citizens across the globe march for action on sustainable outcomes, it is time for the governments in developing countries to do their part. The imperative is for a "climate action force," a structured group of citizen volunteers and government officials from

a range of income, political and bureaucratic strata. Such a force can be the first line of defence against proven malpractices and a tool to forge sustainability outcomes in all tiers of government. In the coming years, governments in developing countries with burgeoning populations and scarce resources will face the brunt of climate-related mishaps. Thus, it is crucial to consolidate the efforts and opinions of citizens and state officials and incorporate them in climate-action plans, allowing them to veto unfavourable developments and facilitate planned infrastructure developments for the benefit of the planet.

CONCLUSION

Infrastructure development promotes physical growth, demographic and functional changes, and economic enhancement and lifestyle changes for its target citizens. Therefore, sustainability outcomes must be prioritised as early as possible in the infrastructure development cycle. This paper presents several frameworks to help project managers, policymakers and implementers to upstream decision-making and ensure balanced growth, keeping in mind the SDGs' agenda of "leaving no one behind." The onus of achieving sustainable infrastructure is on policymakers, project managers and an informed citizenry at various stages of the project life cycle.

This paper touches upon several aspects critical to bringing infrastructure project development to the centrestage of climate change mitigation. Business analysts and climate change researchers can use this as a base to delve deeper into the daily actions of infrastructure project management teams. Comparative analyses of teams that prioritise overall sustainable development and those that work on specific projects can provide a fuller understanding of the requirements to achieve sustainable outcomes.

Other possible studies include comparisons and case analyses of projects in developed countries with strong institutional and legislative frameworks and those in countries with weaker institutional mechanisms. Specialists from relevant disciplines (such as project management, engineering, policymaking, citizen activism, and environmental conservation) can analyse infrastructure development through their own lens, with insights that can benefit other disciplines. This will help create a body of work to inform policymaking in developing countries and enable more infrastructure projects to achieve their full 'sustainable development' potential.

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71 Yamide Dagnet, Eliza Northrop and Dennis Tirpak, "How to Strengthen the Institutional Architecture for Capacity Building to Support the Post-2020 Climate Regime," World Resources Institute, December 2015, https://www.wri.org/publication/capacity-building-post-2020-climate-regime.

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20, Rouse Avenue Institutional Area, New Delhi - 110 002, INDIA
Ph. : +91-11-43520020, 30220020. Fax : +91-11-43520003, 23210773
E-mail: contactus@orfonline.org
Website: www.orfonline.org