SRI VENKATESWARA INTERNSHIP PROGRAM FOR RESEARCH IN ACADEMICS (SRI-VIPRA)

SRI-VIPRA

Project Report of 2024: SVP-2462

"Studying the impact of infrastructure development on the country's economic activity (GDP)"

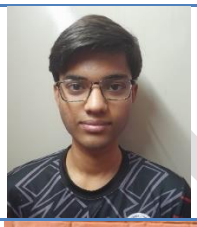
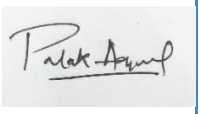
IQAC
Sri Venkateswara College
University of Delhi
Benito Juarez Road, Dhaula Kuan, New Delhi
New Delhi -110021

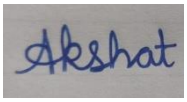
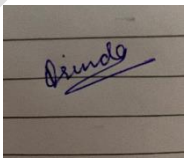
SRIVIPRA PROJECT 2024

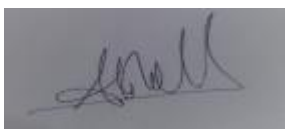
Title: Studying the impact of infrastructure development on the country's economic activity (GDP)

Name of Mentor: Dr. Abhishek Malhotra **Name of Department:** Economics **Designation:** Assistant Professor	**Photo** 

List of students under the SRIVIPRA Project

S.No	Photo	Name of the student	Roll number	Course	Signature
1		Ayush Kumar	0523023	B.A. (H) Economics	
2		Palak Agarwal	1022144	B.Com (hons.)	
3		Divita Diwan	1922013	B.Sc (H) Statistics	

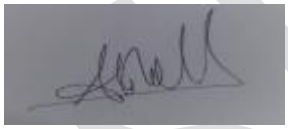
4		Akshat Shukla	0122003	B.A Program	
5		Gracy Gupta	0522005	B.A. (H) Economics	
6		Mannat Kataria	0522013	B.A. (H) Economics	
7		Vrinda Chanana	1022023	Bcom. (H)	
8		Hardik Madan	1922012	B.Sc. (H) Statistics	
9		Tanirikaa Gandhi	1922004	B.Sc. (H) Statistics	



Signature of Mentor

Certificate of Originality

This is to certify that the aforementioned students from Sri Venkateswara College have participated in the summer project SVP-2462 titled "Studying the impact of infrastructure development on the country's economic activity (GDP)". The participants have carried out the research project work under my guidance and supervision from 1st July, 2024 to 30th September 2024. The work carried out is original and carried out in an online/offline/hybrid mode.



Signature of Mentor

Acknowledgements

We would like to express our deepest gratitude to our mentor, Dr. Abhishek Malhotra, for his invaluable guidance, encouragement, and support throughout this research project. As part of the SRIVIPRA Research Internship, this project provided us with a unique opportunity to engage with complex academic research under his mentorship. His insights and constructive feedback have enriched our understanding of the subject and inspired us to think critically and creatively, for which we are sincerely thankful.

We are also immensely grateful to our co-interns for their collaboration, enthusiasm, and camaraderie throughout this journey. Working alongside them created an environment of shared learning and intellectual exchange that truly enhanced the quality and depth of this project. Their perspectives, teamwork, and support were invaluable in helping us overcome challenges and gain new insights.

Lastly, we extend our appreciation to everyone involved in making this project possible, from those who provided us with resources to those who offered encouragement along the way. The internship provided us with the structure and support necessary for our growth as researchers, and we are grateful for the opportunity to have been part of such an enriching program.

TABLE OF CONTENTS

ABSTRACT:

This research paper investigates the multifaceted impact of infrastructure development on a nation's economic activity, with a particular focus on India. Spanning six comprehensive sections, the paper delves into key infrastructure domains—transportation, digital transformation, waste management, and energy—highlighting their individual and collective contributions to economic growth and Gross Domestic Product (GDP).

The paper begins with an analysis of India's road infrastructure, tracing the evolution of Public-Private Partnership (PPP) models from the Build-Operate-Transfer (BOT) Toll model to the Hybrid Annuity Model (HAM). This transition demonstrates the importance of risk-sharing frameworks in sustaining infrastructure growth and attracting private sector participation. Subsequently, the transformative potential of Dedicated Freight Corridors (DFCs) is examined, revealing their capacity to enhance freight efficiency, regional development, and international competitiveness, thereby acting as catalysts for industrial and economic expansion.

Addressing the persistent challenges of land acquisition, the paper evaluates the implications of the Land Acquisition, Rehabilitation, and Resettlement Act (LARR) 2013 on infrastructure projects. It underscores innovative solutions, including leveraging non-core revenue streams in transport and airport infrastructure, to mitigate financial burdens and ensure project sustainability.

The study also explores India's digital transformation journey, showcasing initiatives such as Digital India and UPI as pivotal drivers of financial inclusion, digital entrepreneurship, and sectoral growth. Despite significant advancements, the analysis highlights persistent challenges like the urban-rural divide and cybersecurity risks, advocating for strategic investments and ethical frameworks to sustain digital growth.

Turning to urban infrastructure, the paper presents Indore's exemplary waste management model, emphasizing its blend of behavioral change, innovative waste-to-energy solutions, and revenue-generation techniques. This model underscores the financial and environmental sustainability achievable through replicable waste management strategies.

Finally, the role of energy infrastructure is examined, with a focus on its direct and indirect contributions to GDP, employment generation, and economic expansion. The analysis highlights the interplay of public and private investments in renewable energy and traditional energy projects, presenting actionable insights for policymakers and stakeholders.

The findings collectively emphasize that a dynamic, integrated approach to infrastructure development, characterized by innovation, risk-sharing, and diversification, is critical to fostering sustainable economic growth and achieving broader development objectives.

TABLE OF CONTENTS

Introduction

In the years following India's independence in 1947, the government took the lead in developing and maintaining the country's road infrastructure. This government-centric model was necessary for nation-building but eventually became inadequate as India's economy expanded and modernized. A key issue that emerged over time was a significant lack of funding. As a developing country with numerous pressing needs, India found it difficult to allocate enough financial resources for road construction and maintenance. This funding shortfall slowed the expansion of the road network, particularly in rural areas where improved connectivity was essential for economic growth. Existing roads often deteriorated due to insufficient maintenance budgets, creating a vicious cycle of neglect and rising repair costs. The quality of the roads was another major concern. Many were built with subpar specifications, which made them vulnerable to damage from heavy use and harsh weather conditions. This led to frequent repairs, increased long-term costs, and posed significant safety risks for road users. Accident rates on Indian roads became alarmingly high, raising concerns for both the government and the public. The inefficiency of the government-led approach was further compounded by bureaucratic hurdles. Road projects were often delayed due to lengthy approval processes, coordination issues between departments, and red tape. The slow pace of road development clashed with India's rapid economic growth and urbanization, which called for swift infrastructure improvements to support expanding business activities and a growing urban population. One case that illustrates these pre-PPP challenges, and the eventual shift towards private sector involvement, is the development of the Mumbai-Pune Expressway. By the early 1990s, the existing road between these two major cities was overwhelmed by traffic and insufficient to handle the growing demands. The Maharashtra State Road Development Corporation (MSRDC) was tasked with constructing a new expressway, but the project quickly encountered a series of difficulties. Initially conceived as a fully government-funded project, the Mumbai-Pune Expressway faced delays and cost overruns. Land acquisition proved to be a significant hurdle, with protests from local communities and environmental concerns complicating the process. The high cost of the project strained the state government's financial resources, prompting a re-evaluation of how the expressway should be executed. This situation led to the consideration of Public-Private Partnerships (PPPs) as a potential solution. PPPs are collaborative arrangements between government bodies and private companies to deliver public services or build infrastructure. In recent years, this model has gained traction as an effective way to manage public resources and provide services. At its core, a PPP is a collaboration where the government and private

sector contribute their respective strengths. Government agencies provide oversight and ensure public welfare, while private companies offer efficiency, expertise, and financial investment. The partnership enables projects that serve the public interest to benefit from business acumen and operational efficiency. PPPs are particularly appealing because they help address the challenge of limited government resources. By involving private investment, governments can undertake large-scale infrastructure projects that would otherwise be difficult to fund independently. This model not only alleviates immediate financial pressures but also brings private-sector efficiency to public service delivery. For example, in a PPP model for building a water treatment plant, the private company might finance and build the plant, then operate it for a designated period, while the government ensures water quality standards are met and fair pricing is maintained. This allows cities to get modern facilities without bearing the full upfront cost, and the private sector secures a steady, long-term business opportunity.

PPPs have been applied to a range of public services, from highways and airports to public transportation systems. They have also found their way into healthcare, where private companies may manage public hospitals or clinics, and into education, where private organizations sometimes run public schools or universities. However, PPPs are not without their challenges. Critics argue that the profit-driven motives of private companies can sometimes conflict with the public interest. There is also a delicate balance between transparency in public services and the need for confidentiality in business dealings. Additionally, setting up and managing PPPs can be complex, and government agencies may struggle with the technical expertise required. If a PPP fails, it is often the public that bears the cost. For example, if a privately managed public service falls short of standards, the government may have to step in to rectify the situation, potentially at a significant expense. Concerns also exist that PPPs could lead to job losses in the public sector or reduce public control over essential services. Despite these challenges, PPPs continue to be viewed as an important tool for governments to modernize public infrastructure. By introducing private sector innovation and efficiency, PPPs hold the potential to improve the delivery of public services, though it is essential that both parties understand their roles and responsibilities clearly. In the case of the Mumbai-Pune Expressway, the government decided to involve the private sector in 1997. The project was divided into five packages, with private companies invited to bid for construction. While the government retained control and provided funding, private sector expertise helped accelerate construction. This hybrid approach, although not a full-fledged PPP, marked a significant departure from the traditional government-led model. The expressway was completed in 2002, reducing travel time between the cities and showcasing the benefits of private sector involvement in public infrastructure

projects. This success story, along with similar experiences in other sectors, encouraged policymakers to adopt more comprehensive PPP models for future road projects. The push for PPPs in road infrastructure gained momentum after the economic liberalization of 1991 and culminated in the launch of the National Highways Development Project (NHDP) in the late 1990s. This ambitious program aimed to modernize and expand India's highway network, using various PPP models. While the transition to PPPs was not without its difficulties—such as ensuring fair risk allocation, overcoming land acquisition hurdles, and balancing profit motives with public welfare—it marked a significant shift in India's road development strategy. Today, PPPs have become a key part of India’s approach to infrastructure development, playing an important role in improving the country’s road network.

Different PPP Models in India

Public-Private Partnership (PPP) models have been essential in India's infrastructure development since the early 1990s. These models were introduced to address the massive infrastructure gap by engaging private sector expertise and financing in public projects. Over the years, several PPP models have evolved in India, each with a unique risk-sharing structure and project financing arrangement. The most notable models include the Build-Operate-Transfer (BOT) Toll, Hybrid Annuity Model (HAM), Engineering, Procurement, and Construction (EPC), and Design-Build-Operate-Transfer (DBOT). Their introduction has been a key factor in speeding up large-scale infrastructure projects, especially in sectors like highways, ports, and urban development.

BOT Toll Model

The Build-Operate-Transfer (BOT) Toll model was one of the earliest PPP models introduced in India during the late 1990s, especially in the road sector. Under this model, the private entity takes on the responsibility of financing, constructing, and operating the project for a pre-agreed concession period. In return, they collect user fees, such as tolls, from the public. Once the concession period ends, the asset is handed over to the government. The BOT Toll model allows the private player to recover their investments and earn profits through toll revenue. This model was heavily used during the National Highways Development Project (NHDP), launched in 1998, particularly for projects like the Golden Quadrilateral, which aimed to connect India’s four major cities: Delhi, Mumbai, Chennai, and Kolkata. For instance, the Mumbai-Pune Expressway, which became operational in 2002, was built using the BOT Toll model. The private sector bore the financial burden of construction and maintenance while recovering costs through toll collections. By 2010, over 60% of the projects under the NHDP were executed through the BOT Toll model, making it one of the most popular forms of PPP in India. However, the BOT Toll model faced some challenges, especially during economic downturns when traffic volumes dropped, making it difficult for private players to recover their investments. To address these issues, alternative models like HAM were introduced.

Hybrid Annuity Model (HAM)

The Hybrid Annuity Model (HAM) was introduced in 2016 as a response to the financial challenges faced by private developers in the BOT model. HAM was designed to reduce the risk for private players by

allowing a hybrid arrangement where both the government and the private sector shared the project cost and risks. In this model, the government provides 40% of the project cost upfront during the construction phase, while the private entity invests the remaining 60%. Once the construction is complete, the private player receives fixed annuity payments from the government over a set period, reducing the reliance on toll collections for revenue. HAM quickly gained popularity in the road sector, particularly under the National Highways Authority of India (NHAI). By 2018, more than 40 road projects, worth around ₹50,000 crore, had been awarded under the HAM model. This model effectively addressed the issues faced in the BOT Toll model, such as revenue risks due to lower-than-expected traffic, making it a safer option for private players. HAM continues to be an important tool for infrastructure development in India, especially for projects where the toll-based revenue model may not be sufficient.

Engineering, Procurement, and Construction (EPC) Model

The Engineering, Procurement, and Construction (EPC) model is different from traditional PPP models like BOT and HAM. In the EPC model, the government finances the entire project, while the private sector is responsible for designing, procuring the necessary materials, and constructing the project. Once the project is completed, the government takes over its operation and maintenance. The private player is paid a lump sum for their work based on pre-defined milestones during construction.

Although EPC does not involve the same risk-sharing mechanisms as BOT or HAM, it is widely used for projects where the government does not expect significant revenue generation, such as rural roads or projects in economically weaker regions. The EPC model has been particularly effective in speeding up project execution, as the financial risk to the private sector is minimal. By 2020, a substantial portion of India’s road projects, especially under the Pradhan Mantri Gram Sadak Yojana (PMGSY), were completed using the EPC model.

Design-Build-Operate-Transfer (DBOT) Model

The Design-Build-Operate-Transfer (DBOT) model is another significant PPP structure used in India, introduced as part of the government’s broader effort to involve private players in complex projects. In the DBOT model, the private sector takes full responsibility for the design, construction, and operation of the infrastructure asset for a fixed concession period. The "transfer" part indicates that after the concession period, the project ownership reverts to the government. DBOT is particularly suitable for projects requiring high technical expertise, such as airports, seaports, and large urban infrastructure

developments. For instance, many of India's major airports, including Delhi and Mumbai, were modernized under the DBOT model. These projects required the private sector's advanced technological know-how, and the risk-sharing aspect allowed for efficient delivery. The DBOT model reduces the burden on public finances, while also providing high-quality infrastructure developed by private players.

Viability Gap Funding (VGF) and Support Mechanisms

To further enhance the viability of PPP projects, especially in the road sector, the government introduced the Viability Gap Funding (VGF) scheme in 2004. Under this scheme, the government provides financial assistance to PPP projects that are economically justified but not financially viable, covering up to 40% of the total project cost. VGF has been crucial in promoting PPP projects in less commercially attractive regions where revenue from tolls or user fees would not be enough to cover investment costs. Between 2005 and 2020, nearly ₹5,000 crore was provided as VGF for various infrastructure projects across the country, ensuring that even rural or less developed areas could benefit from private sector participation. The VGF scheme continues to support infrastructure projects that may otherwise struggle to attract private investment.

BOT Toll Model in India (2006-2016)

The Build-Operate-Transfer (BOT) Toll model is one of the earliest Public-Private Partnership (PPP) frameworks used in India, particularly in the road infrastructure sector. Introduced in the late 1990s, this model was implemented to address India's growing road infrastructure needs amid limited government funding. Under the BOT Toll model, a private company is responsible for financing, designing, constructing, operating, and maintaining a road project. In return, the company is allowed to collect tolls from users for a specified period, known as the concession period, to recover its investment and generate profits. After the concession period ends, the road or highway is transferred back to the government.

The BOT Toll model was first introduced as part of the National Highways Development Project (NHDP), which commenced in 1998. This project aimed to significantly upgrade India's road network, including constructing and modernizing thousands of kilometres of national highways. One of the most prominent projects under the NHDP was the Golden Quadrilateral, which connected India's four largest cities—Delhi, Mumbai, Chennai, and Kolkata. While the BOT Toll model saw early success, it also encountered several challenges. One of the primary issues with the model was traffic risk. The profitability of the project for private companies depended heavily on toll collections, which in turn relied on the volume of traffic using the roads. When traffic fell below expectations, private developers often struggled to generate enough revenue to cover their investment, leading to financial difficulties. Additionally, delays in land acquisition, regulatory approvals, and unforeseen cost increases made these projects less appealing to private investors. In response to these challenges, the Indian government introduced several measures to improve the feasibility of BOT Toll projects. One of the most significant steps was the introduction of Viability Gap Funding (VGF), a mechanism that allowed the government to finance up to 40% of the project costs for projects that were economically necessary but financially challenging. This funding model helped attract private sector participation in areas where traffic volumes were lower, but road connectivity was still critical.

Private Sector Investment in Roadway Projects (2006-2016)

During the early years, the BOT model had a significant influence on driving private sector investment in road projects. The investment trends from fiscal year (FY) 2006 to FY 2016 reflect how the BOT model shaped private sector engagement.

1. **Fiscal Year 2006 to Fiscal Year 2009:** Private sector investment in road infrastructure experienced steady growth during this period. In FY06, private investment was ₹649 crore, and it increased to ₹8,185 crore by FY09. The share of private investment in total road sector spending rose from 5% in FY06 to 29% in FY09. This growth was driven by increased reliance on the BOT Toll model, which helped attract private capital for large highway projects like those under the NHDP.
2. **Fiscal Year 2010 to Fiscal Year 2012:** This period saw a significant surge in private investment, with a peak in FY12. In FY12, private investment in the road sector reached an all-time high of ₹25,999 crore, accounting for 42% of total investment. Several factors contributed to this peak:
    - The government launched multiple large-scale highway projects under the BOT Toll model.
    - Strong economic growth during this period led to higher traffic volumes, making toll-based projects more attractive to private developers.
    - The introduction of financial mechanisms like VGF encouraged greater private sector participation.

The convergence of these factors—government initiatives, robust economic growth, and the success of earlier projects—fuelled the surge in private investment in FY12.

3. **Fiscal Year 2013 to Fiscal Year 2016:** After the peak in FY12, private sector investment began to decline. By FY16, private investment had dropped to ₹19,232 crore, and its share of total investment fell from 42% in FY12 to 30% in FY16. This decline was largely due to the increasing challenges faced by private developers, including traffic risk, delays in project approvals, and difficulties in raising capital due to high debt levels. These issues resulted in stalled projects and a slowdown in new investments.

Why the Peak in 2012?

The peak in private sector investment in 2012, as seen in the graph, was driven by a confluence of economic growth, government support, and a favourable environment for infrastructure development. To better understand why investment reached its highest point in 2012, let's delve deeper through the lens of

a key case study: the GMR Group's highway projects, one of India's largest infrastructure developers, and how it contributed to the peak through its projects under the BOT Toll model.

Case Study: GMR Group's Expansion of Highway Projects (2008-2012)

The GMR Group, a leading infrastructure company in India, played a crucial role in the development of highways under the BOT Toll model during the early 2000s. The company aggressively expanded its portfolio, particularly during 2008-2012, when infrastructure development was seen as critical to India's economic growth.

By 2012, GMR had invested heavily in several key highway projects, particularly in South and North India. Some of the major projects undertaken by the GMR Group included:

- **Tindivanam-Ulundurpet Project**: A 73-km four-lane highway in Tamil Nadu.
- **Hyderabad-Vijayawada Expressway**: A critical 181-km stretch of highway in Andhra Pradesh.
- **Kishangarh-Udaipur-Ahmedabad Expressway**: A 555-km six-lane highway, one of the largest BOT projects awarded to GMR in 2011.

These projects collectively contributed significantly to the surge in private investment in infrastructure, especially highways, leading to the peak in 2012.

Key Factors Leading to the Peak

1. **Aggressive Push by the National Highways Authority of India (NHAI)**: Between 2008 and 2012, the Indian government, under the NHAI, aggressively rolled out several large-scale highway projects to boost connectivity and economic growth. The period marked the third phase of the National Highways Development Project (NHDP), which aimed to construct thousands of kilometres of highways across the country.

GMR and other private players like Larsen & Toubro (L&T) and Reliance Infrastructure were awarded major contracts under the BOT Toll model during this phase. The government's push towards public-private partnerships encouraged companies to bid for these projects, which in turn spurred a massive rise in private investment.

2. **Favourable Financing and Lending Environment**: One of the key factors that helped GMR and other developers during this period was the easy availability of financing. Between 2009 and

2011, India's economic growth was strong, and banks were willing to lend aggressively to infrastructure companies. GMR was able to raise significant capital from Indian banks and international financial institutions, which enabled them to invest in large-scale projects. In fact, during the years leading up to 2012, the Reserve Bank of India (RBI) reported that infrastructure loans accounted for more than 25% of total loans issued by Indian banks. GMR secured large loans for its Kishangarh-Udaipur-Ahmedabad project and Hyderabad-Vijayawada Expressway during this period, contributing to the surge in private sector investment in 2012.

3. **Economic Boom and Traffic Projections**: India's economy was booming between 2009 and 2012, with annual GDP growth averaging over 7%. The strong economic performance led to increased vehicular traffic on highways, which in turn boosted toll collections. Developers like GMR projected higher toll revenues due to increased traffic, making the BOT Toll model more attractive. The Kishangarh-Udaipur-Ahmedabad project, for example, was expected to generate substantial toll revenue because of its strategic location connecting key cities in Rajasthan and Gujarat, both commercial hubs. The prospect of high returns from toll collection motivated private players to invest heavily in projects, contributing to the peak in 2012. GMR reported record toll revenues from its highways during this period, reinforcing the optimism in the sector.
4. **Government Incentives and Support**: To further encourage private sector participation, the government introduced various incentives during this period. One of the most impactful was the Viability Gap Funding (VGF) mechanism, which allowed the government to provide financial support for economically viable but financially challenging projects. GMR benefited from VGF for its Kishangarh-Udaipur-Ahmedabad project, where the government provided up to 40% of the project cost through VGF. This reduced the financial burden on GMR and made the project more viable. The availability of VGF funding in several highway projects helped spur further investment in 2012, as private companies were able to reduce their risk while still pursuing large-scale projects.

Why the Peak was Unsustainable

While 2012 marked a high point for private investment, it also represented the limits of the BOT Toll model in its existing form. By 2013, several of the projects that reached financial closure during the 2010-2012 period began facing challenges. GMR itself, despite its earlier success, encountered difficulties:

1. **Declining Traffic Volumes**: As India's economic growth slowed after 2012, the expected rise in traffic volumes did not materialize. This meant that toll revenues were lower than projected, putting financial strain on projects like the Kishangarh-Udaipur-Ahmedabad expressway, which had been expected to generate high toll income.
2. **Rising Debt Levels**: Infrastructure developers, including GMR, had taken on significant amounts of debt during the boom period to finance large projects. As revenues fell short, companies found themselves unable to meet their debt obligations. GMR's highway division, like many others, faced liquidity issues in the years following the 2012 investment peak.
3. **Regulatory Delays**: While projects were awarded aggressively during 2008-2012, delays in land acquisition and regulatory approvals meant that many projects faced cost overruns. For example, the Kishangarh-Udaipur-Ahmedabad project faced delays due to land acquisition issues, increasing costs and reducing profitability.

Decline of BOT Toll Model in India

The Build-Operate-Transfer (BOT) Toll model was the dominant form of Public-Private Partnership (PPP) in India until around 2012. However, several factors led to its decline after that period, and the introduction of the Hybrid Annuity Model (HAM) in 2016 brought about a significant shift in preference. Let's examine why the influence of the BOT Toll model began to wane after 2013 and what led to the shift towards HAM during 2012-2016.

Decline of BOT Toll Model After 2012

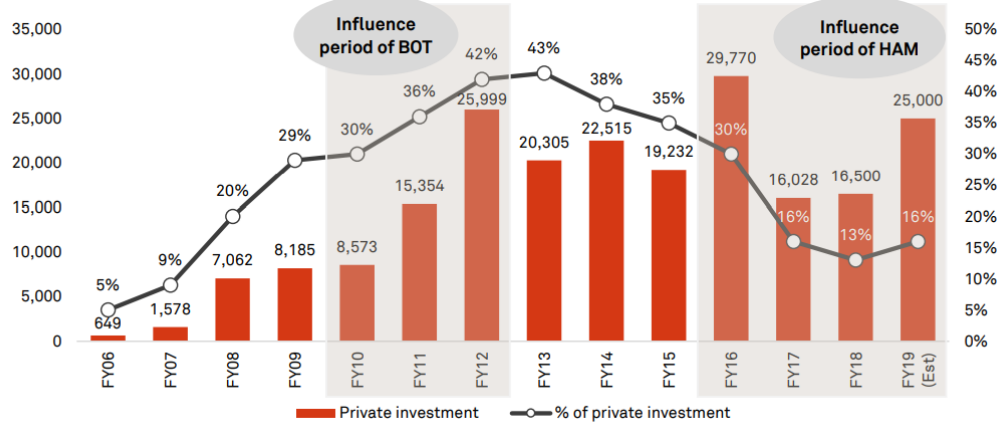
The BOT Toll model, once the backbone of India's highway development, started to lose its appeal post-2012 for a variety of reasons. Some of the key factors that contributed to the decline include:

- **Financial Stress and Over-Leveraging of Private Developers**: Many private companies that took on BOT Toll projects in the early 2000s found themselves over-leveraged by 2012-2013. Projects required substantial upfront investment, and developers had raised large amounts of debt to finance these ventures. However, traffic volumes—and thus toll revenues—did not always meet expectations. Companies such as GMR and GVK struggled with lower-than-projected toll collections, leading to a significant liquidity crunch.
- **Traffic Risks**: One of the inherent risks of the BOT Toll model was its dependence on traffic volume. Developers' revenue was directly tied to the number of vehicles using the highway. If the actual traffic was lower than the forecasts, as often happened after 2012, developers found it difficult to meet their debt obligations. The slowdown in India's economic growth during this period also dampened traffic volumes, further exacerbating this issue.
- **Delays in Land Acquisition**: Delays in land acquisition and regulatory clearances were significant challenges in many BOT Toll projects. Many projects stalled because the necessary land could not be acquired on time, leading to cost overruns and financial stress for the private developers.
- **Economic Slowdown Post-2012**: After the global financial crisis and a period of rapid growth, India's economy began to slow down around 2012-2013. Slower growth meant reduced demand

for transport infrastructure, fewer vehicles on the roads, and lower toll revenues. The optimism of the earlier BOT Toll model could not be sustained in this changing economic landscape.

In **Figure 1**, we see that private sector investment in PPP projects peaked in 2012, reaching ₹25,999 crore, and then steadily declined in the years following. By FY16, private investment had plummeted to ₹16,028 crore, with the share of private investment also dropping from 42% in FY12 to 30% by FY16. This reflects the declining attractiveness of the BOT Toll model.

Figure 1: Increase in Private Sector Investment under PPP models (Rs crore)[1]



The Shift to HAM (2012-2016)

The decline of the BOT Toll model set the stage for the introduction of the Hybrid Annuity Model (HAM) in 2016. This period from 2012 to 2016 was marked by experimentation with other PPP models, but HAM ultimately emerged as the preferred choice. Several factors explain this shift:

- **Risk Redistribution in HAM**: Unlike the BOT Toll model, where the private developer bore the entire traffic risk, the HAM model split the risk between the government and the private developer. In HAM, the government covers 40% of the project cost during the construction phase, while the private player finances the remaining 60%. The key difference is that the government also guarantees semi-annual payments to the private player over the concession period, reducing

[1] Crisil Report: March 2019

the reliance on toll collections. This risk-sharing mechanism made HAM much more attractive for private developers.

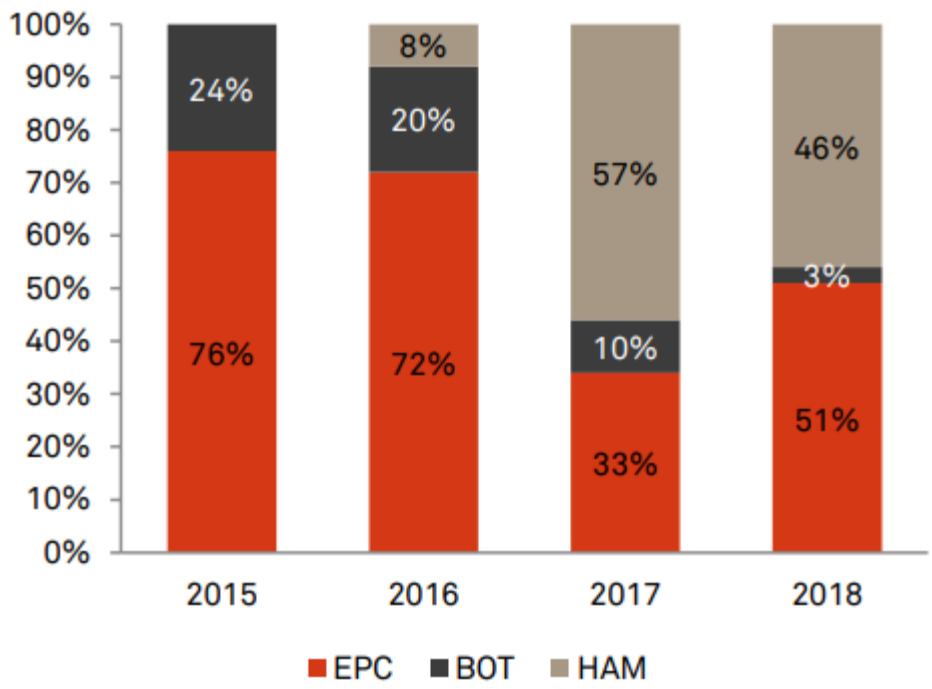
- **Addressing Financial Constraints**: By 2016, many infrastructure companies were burdened with high debt levels. The HAM model, with its reduced risk and government payments, provided a more sustainable path for companies to participate in highway development without taking on large amounts of new debt. The semi-annual payments from the government ensured a steady cash flow, making it easier for developers to manage their finances.
- **Government Support and Policy Push**: Recognizing the issues with the BOT Toll model, the Indian government introduced HAM as part of its policy shift towards reviving infrastructure development. The model was especially well-suited for projects in areas with low traffic volumes where toll-based revenue models were not feasible. The government's commitment to reviving infrastructure through a more balanced approach made HAM the preferred model.

Quantitative Trends (2015-2018)

Looking at **Figure 2**, we can see the clear shift in preference from the BOT Toll model to HAM between 2015 and 2018:

- **2015**: In 2015, the Engineering, Procurement, and Construction (EPC) model dominated, with 76% of the projects executed under EPC, while BOT accounted for 24%. HAM had not yet been introduced.
- **2016**: By 2016, BOT had shrunk to 20%, while HAM entered the picture, accounting for 8% of projects. EPC still dominated, indicating that private players were cautious and preferred less risky government-funded models.
- **2017**: The shift became much more pronounced in 2017, with 57% of projects executed under HAM, while BOT was reduced to just 10%. EPC's share also decreased to 33%. This reflects the growing preference for HAM due to its risk-sharing features.
- **2018**: By 2018, HAM had firmly established itself as the dominant model, accounting for 46% of projects, while BOT had shrunk to a mere 3%. EPC accounted for 51%, showing that private players preferred models with less financial risk.

Figure 2: Shift in Preference to HAM[2]



Key Takeaways from 2012-2016

- **BOT Toll Model's Decline**: The decline of the BOT Toll model was primarily driven by financial stress, traffic risks, and economic slowdown. Private developers found it increasingly difficult to manage the risks associated with toll-based projects, especially in a period of slower growth.
- **Shift to HAM**: The introduction of HAM addressed many of the challenges of the BOT Toll model. By redistributing risk between the government and private players, and ensuring steady payments during the operational phase, HAM became a more sustainable and attractive option.
- **Government's Role**: The shift towards HAM was also facilitated by strong government support. Recognizing the limitations of BOT, the government promoted HAM as the preferred model to revive private sector participation in road infrastructure.

[2] Crisil Report: March 2019

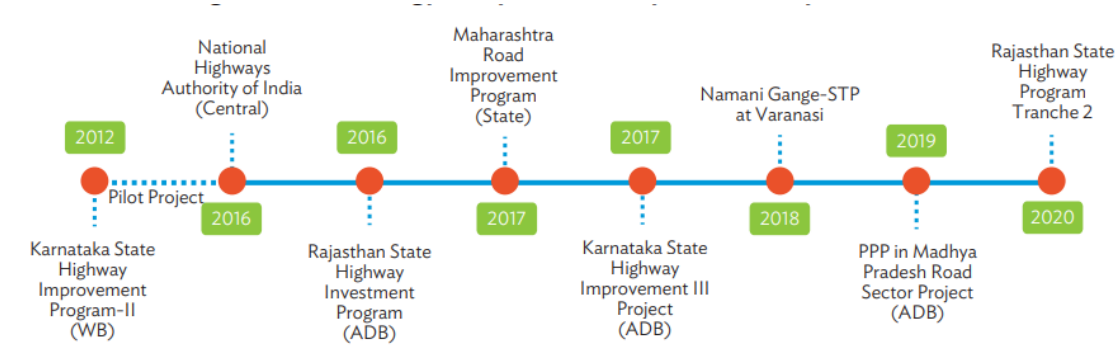
HAM Model in India (2016-Present)

The **Hybrid Annuity Model (HAM)** was introduced in India in 2016 as a new form of Public-Private Partnership (PPP) in road construction. The Government of India, realizing the limitations of previous models like the Build-Operate-Transfer (BOT) toll model, needed a framework that would encourage private investment while reducing risks for both the government and private players.

Chronology of HAM Adoption in India:

1. **Pilot Project (2012)**: The concept of HAM was initially explored through a pilot project under the **Karnataka State Highway Improvement Program-II**, with financial assistance from the World Bank (WB). This pilot was intended to assess the feasibility of a new risk-sharing model.
2. **National Highways Authority of India (NHAI)** (2016): The **NHAI** adopted the HAM model for its national highway projects. This marked the official launch of HAM across major highway projects in India. The NHAI focused on making the model the preferred option due to its risk-sharing benefits.
3. **Rajasthan State Highway Investment Program (2016)**: The state of Rajasthan also adopted HAM under a program funded by the Asian Development Bank (ADB). This was a major step in decentralizing HAM from national-level projects to state-level projects.
4. **Maharashtra Road Improvement Program (2017)**: Maharashtra followed suit in adopting HAM for state-level projects, signalling wider acceptance at both central and state levels.
5. **Namami Gange STP at Varanasi (2018)**: HAM was extended beyond road projects into other infrastructure domains, such as sewage treatment plants under the **Namami Gange** program.
6. **Madhya Pradesh Road Sector Project (2019)**: In 2019, PPP projects in Madhya Pradesh also adopted the HAM model for road improvements, with financial backing from ADB.
7. **Rajasthan State Highway Program Tranche 2 (2020)**: This project marked continued expansion of HAM at the state level, demonstrating its long-term viability.

Figure 3: Chronology of Hybrid Annuity Model Adoption in India[3]



ADB = Asian Development Bank, PPP = public–private partnership, STP = sewage treatment plant, WB = World Bank.

Why HAM Outclassed BOT Toll Model:

The HAM model outperformed the BOT Toll model for several reasons:

1. **Risk Sharing**: In the BOT toll model, the private sector took on all financial and operational risks, including traffic risk, which discouraged private players from investing in many projects. Under HAM, the government assumes 40% of the project cost during the construction phase, reducing the financial burden on private entities.
2. **Guaranteed Payments**: HAM provides guaranteed annuity payments to the developer for the remaining 60% of the project cost over a period of 15 to 20 years. This predictable revenue stream is more attractive compared to BOT Toll, where the developer's income is dependent on uncertain toll collection.
3. **Reduced Market Risk**: BOT Toll was highly dependent on traffic projections and toll revenues, which were unpredictable. HAM separates revenue generation from toll risk, making it more suitable for projects in regions with lower traffic volumes.

Trends in Private Sector Investment

Figure 1 highlights key period: the influence period of HAM (FY16 onwards).

1. **Influence Period of HAM:**

[3] Source: Literature analysis by authors based on ADB, state, and central government websites

- With the introduction of HAM in FY16, the model gained rapid traction. However, private investment did not immediately recover to previous high levels. In FY16, private sector investment stood at ₹29,770 crore, but the percentage of private investment was just 30%.
- Over the next few years, private investment continued to decline in absolute terms: ₹16,028 crore in FY17, ₹16,500 crore in FY18, with the share of private investment dropping to just 13%.
- By FY19, investment saw a slight resurgence to ₹25,000 crore, but the percentage share remained modest at 16%. This reflects that while HAM encouraged more projects, the structure of HAM, with its reduced financial risks for the private sector, led to smaller total private investment, as the government took on a larger role in financing.

HAM has clearly outperformed the BOT Toll model by attracting private players who were previously deterred by high-risk, toll-dependent revenues. It shifted a significant portion of risk to the government while ensuring predictable returns for the private sector. Although the overall share of private investment in infrastructure has decreased in terms of percentage (as evident in the graph), the predictability and success of the HAM model have led to a steady continuation of investment at more sustainable levels. This has allowed India to continue expanding its infrastructure base even in regions where the BOT model failed to attract private sector interest.

Figure 4: Private and Government Investment Year-wise[4]

Expenditure / Release during the last six years and current year for NHDP/ Bharatmala Phase-I

(Amount in Rs. crore)

Year	CRF Cess	Toll Remittances	TOT Remittances	Total (GBS)	IEBR Raised	Total Budgetary	Pvt. Sector Investment	Grand Total
2014-15	9,565	5,448		15,013	3,343	18,356	19,232	37,588
2015-16	21,018	6,500		27,518	23,281	50,799	29,770	80,569
2016-17	7,410	7,500		14,910	33,118	48,028	16,029	64,057
2017-18	15,429	8,462		23,891	50,533	74,424	16,501	90,925
2018-19	16,567	9,570	9,682	35,819	61,217	97,036	20,618	1,17,654
2019-20	15,733	10,600	5,000	31,333	74,988	1,06,321	21,926	1,28,247
2020-21	27,249	11,500	7,262	46,011	65,036	1,11,047	12,476	1,23,523
2021-22	36,210	12,650	5,000	53,860	65,150	1,19,010	19,206	1,38,216
2022-23*	95,161	13,915	0	1,09,076	798	1,09,874	16,347	1,26,221

** Till 31.12.2022*

Revised approval of BMP-I is under process

Table 1: Percentage of Government and Private Sector Investment Year-wise

Year	Pvt. Sector Investment (Rs. crore)	Public Sector Investment (Rs. crore)	Pvt. Sector Investment (%)	Public Sector Investment (%)	Grand Total (Rs. crore)
2014-15	19,232	18,356	51.17	48.83	37,588
2015-16	29,770	50,799	36.95	63.05	80,569
2016-17	16,029	48,028	25.02	74.98	64,057
2017-18	16,501	74,424	18.15	81.85	90,925
2018-19	20,618	97,036	17.52	82.48	1,17,654
2019-20	21,926	1,06,321	17.1	82.9	1,28,247
2020-21	12,476	1,11,047	10.1	89.9	1,23,523
2021-22	19,206	1,19,010	13.9	86.1	1,38,216
2022-23	16,347	1,09,874	12.95	87.05	1,26,221

The comparison between the Government and Private spending on Indian roadway infrastructure during the influence periods of BOT and HAM, as reflected in Figure 4 and Table 1, reveals a fundamental

[4] Source: MORTH Annual report 2023

transformation in how India finances its road infrastructure projects. During the BOT era, private sector participation was at its highest. In FY12, private investment peaked at ₹25,999 crores, contributing a substantial 42% of the total investment in road projects. This model placed significant financial responsibility on private players, who were expected to fund the construction and then recoup their investments through toll revenues over a concession period. However, BOT's high-risk profile, particularly in terms of revenue uncertainty and long payback periods, began to deter private sector participation by FY15, when investment levels fell to ₹19,232 crores, comprising only 35% of total investments. By this time, the challenges of the BOT model were evident, particularly in high-risk, long-gestation projects. In response, the government introduced HAM, which emerged as a more balanced and attractive option by redistributing the financial burden. Under HAM, the government shoulders 40% of the project cost upfront, reducing the capital requirement and risk for private players, while the remaining 60% is paid in instalments linked to project milestones over a long-term concession period. This shift led to a notable decline in BOT-financed projects, which by 2018 accounted for just 3% of total projects, while HAM became the dominant financing method, supporting 46% of projects.

This transition is further supported by the expenditure data in Figure 4, where the government's budgetary support (GBS) for road infrastructure projects increased dramatically, from ₹18,356 crores in 2014-15 to ₹1,09,874 crores in 2022-23. The CRF Cess also surged significantly, jumping from ₹9,565 crores in 2014-15 to ₹95,161 crores in 2022-23, reflecting a clear shift towards government-led funding mechanisms under the HAM model. Concurrently, private sector investment declined from ₹29,770 crores in 2015-16 under BOT to a lower but stable ₹16,347 crores by 2022-23, with much of the burden of funding now borne by public finances and innovative models like Toll Operate Transfer (TOT), which had modest contributions starting in 2018-19 (₹9,682 crores) and peaked at ₹7,262 crores in 2020-21.

In contrast to BOT, which saw a gradual decline in private investment as the risks became untenable, HAM allowed for sustained growth in overall investment, with the grand total of expenditure on road infrastructure increasing steadily from ₹37,588 crores in 2014-15 to ₹1,38,216 crores in 2021-22. This was primarily driven by increased public funding, facilitated by the HAM model, while reducing the direct financial risk for private players. By 2021-22, despite the decreased contribution from the private sector, the overall project investment remained robust, reflecting the efficiency of HAM in maintaining investor confidence while delivering on infrastructure growth.

Moreover, Figure 2 illustrates the stark change in project financing composition over time. In 2015, 76% of projects were funded through the EPC (Engineering, Procurement, Construction) model, and 24% were funded through BOT. By 2017, the rise of HAM was evident as it financed 57% of road projects, with BOT dropping to 10%. This shift toward HAM is indicative of the government's intent to bear a larger share of the financial risk while keeping private players engaged, tho at reduced exposure. The trend continued in 2018, with HAM constituting 46% of projects, EPC at 51%, and BOT relegated to only 3%.

The quantitative data clearly illustrate the shift in India's road infrastructure financing from a BOT-dominated era to one led by HAM. Under BOT, while private investment was high, risks deterred sustained participation, leading to a shift where the government, through HAM and increasing budgetary support, took on more financial responsibility. This transition enabled overall infrastructure investments to continue growing, from ₹37,588 crores in 2014-15 to over ₹1,38,000 crores in 2021-22, ensuring the continued expansion and development of India's roadways. HAM's success lies in its ability to de-risk projects for private players while still attracting investments, whereas BOT's riskier profile saw a sharp decline in its use, especially after FY15. This marks a significant transformation in public-private partnerships in India's road infrastructure sector.

Conclusion

The research paper highlights the transformation of India's road infrastructure development through Public-Private Partnership (PPP) models, focusing on the Build-Operate-Transfer (BOT) Toll model and its evolution into the Hybrid Annuity Model (HAM). This shift marks a strategic adaptation to the challenges encountered in earlier models and reflects broader trends in infrastructure financing, risk distribution, and the role of the private and public sectors. The BOT Toll model was instrumental in the initial phases of India's infrastructure boom, particularly during the implementation of the National Highways Development Project (NHDP). By allowing private developers to finance, construct, and operate roads while recouping their investments through tolls, this model attracted substantial private investment in the early 2000s. Between 2006 and 2012, private investment surged, peaking in 2012 as private firms, such as GMR, aggressively expanded their highway portfolios. The strong economic growth and optimistic traffic projections further fuelled confidence in the BOT Toll model, leading to record investments in infrastructure. However, several challenges became apparent as the economic landscape shifted. The profitability of BOT projects was highly dependent on traffic volumes, which proved unpredictable and fell short of projections in many cases. As India's economic growth slowed after 2012, toll revenues declined, creating financial stress for private developers who had taken on significant debt to finance these projects. Additionally, delays in land acquisition and regulatory approvals compounded the financial strain, leading to stalled projects and liquidity issues for firms. By 2016, private sector investment had dropped significantly, and the limitations of the BOT Toll model became evident. This decline set the stage for the introduction of the Hybrid Annuity Model (HAM) in 2016. HAM was designed to address the key risks and financial challenges faced by private developers under BOT. Unlike BOT, where developers bore the full traffic and revenue risk, HAM allowed for a more balanced distribution of risks between the government and private players. The government financed 40% of the project cost upfront during the construction phase, while the private developer funded the remaining 60%. Crucially, instead of relying solely on toll revenues, developers under HAM received semi-annual annuity payments from the government, ensuring a steady cash flow and mitigating the risks associated with fluctuating traffic volumes. The introduction of HAM revitalized private sector interest in road infrastructure projects, as it reduced the financial burden on developers and provided more predictable returns. This model proved particularly effective in regions with lower traffic volumes, where toll-based revenue models were insufficient. Furthermore, HAM's risk-sharing structure encouraged a more sustainable approach to infrastructure development, allowing projects to proceed in areas that were

previously deemed commercially unattractive under the BOT model. Quantitative data from the research underscores this shift. During the BOT era, private sector investment peaked at 42% of total road infrastructure spending in 2012 but declined rapidly as the risks became untenable. By contrast, under HAM, private sector investment, though lower in percentage terms, remained stable, reflecting a more balanced approach to project financing. The government's share of infrastructure spending increased significantly, with budgetary support and public investment surging to 87% by 2022-23. This shift indicates the government's recognition of the need for greater public involvement to ensure the continued expansion of India's road network. The research also highlights how the government's proactive role, through mechanisms such as Viability Gap Funding (VGF) and increased budgetary support, has been crucial in sustaining infrastructure growth. The introduction of HAM reflects a pragmatic response to the challenges faced by private developers, ensuring that infrastructure development remains on track even in regions where market-driven models, like BOT, are less viable.

In conclusion, the research paper demonstrates that the evolution from BOT to HAM was not only a response to financial challenges but also a strategic realignment of public and private sector roles in infrastructure development. The success of HAM in attracting private participation while reducing risk for developers has enabled India to maintain steady progress in its road infrastructure projects. This transition underscores the importance of flexible, adaptive models in addressing the dynamic challenges of infrastructure development in a rapidly growing economy. The government's increasing role in financing and risk management, coupled with private sector expertise, sets the stage for continued expansion and modernization of India's transportation network, ensuring long-term sustainability and balanced regional development.

TABLE OF CONTENTS

The Economic Impact of Dedicated Freight Corridors (DFCs) on India's Economy: A Comprehensive Analysis

1. Introduction

Infrastructure development is a critical driver of economic growth, and efficient logistics networks play a pivotal role in enhancing productivity, facilitating trade, and driving competitiveness. In this context, India's Dedicated Freight Corridors (DFCs)—the Eastern and Western Corridors—represent a transformative infrastructure project designed to revolutionize the country's freight transport system. By providing dedicated rail tracks for freight, DFCs address longstanding inefficiencies within the Indian Railways (IR), where passenger and freight trains coexist, often resulting in delays, increased transit times, and higher costs.

With a network spanning over 2,843 kilometers, the DFCs aim to significantly improve the speed, capacity, and reliability of freight movement across India's most industrialized and densely populated regions. One of the primary objectives is to reduce India's logistics costs, which currently stand at 14-15% of GDP, significantly higher than the global average of around 10%. By modernizing and streamlining freight movement, DFCs are expected to contribute to reducing logistics costs to below 10%, as outlined in the National Logistics Policy. Currently, more than 10% of freight traffic is handled by the DFC network, and its expansion is key to increasing the railways' modal share to 45%.

The DFCs serve as a catalyst for regional development, supporting the establishment of multimodal logistics hubs, industrial corridors, and better connectivity between economic centers. The Western DFC is integral to the development of the Delhi-Mumbai Industrial Corridor (DMIC), a 1,483 km stretch aligned with the DFC, aimed at creating a globally competitive industrial zone. The Eastern DFC supports the Amritsar-Delhi-Kolkata Industrial Corridor (ADKIC), enhancing trade connectivity between the hinterland and major ports. These corridors not only boost industrial activity but also create avenues for employment, investment, and international trade.

In addition to logistics efficiency, the DFCs are poised to generate significant economic benefits by reducing transit times, especially for critical goods such as coal, steel, and export-import (EXIM) cargo. Improved efficiency translates to cost savings in energy consumption and reduced inventory levels

Furthermore, the DFCs will alleviate congestion on the IR network, leading to faster passenger services and better train punctuality. Beyond logistics efficiency, the environmental benefits of shifting freight from road to rail are substantial, with rail transport emitting significantly lower CO2 per ton-kilometer compared to road transport. Over 30 years, the DFCs are expected to save an estimated 457 million tonnes of CO2 emissions, contributing to India's sustainability goals.

Ultimately, the DFCs are not just an upgrade to India's freight infrastructure but a foundational step toward economic modernization. By reducing logistics costs, improving connectivity, promoting industrial corridors, and fostering regional development, the DFCs align with India's broader goals of economic growth, enhanced global trade competitiveness, and environmental sustainability. This paper aims to evaluate the multifaceted impacts of the DFCs on India's logistics infrastructure, economic development, and environmental sustainability, providing insights into how this landmark project will shape the nation's future.

2. Objective of the Research

The primary objective of this research is to critically evaluate the economic impact of Dedicated Freight Corridors (DFCs) in India by focusing on both direct and indirect effects. Specifically, this paper aims to:

1. **Assess the impact of DFCs on logistics efficiency** and how reduced transport costs and time have influenced industrial production, trade, and supply chain management.
2. **Analyze the economic contributions of DFCs** by examining their role in increasing GDP, employment, and investment across connected regions.

3. **Evaluate the regional development effects**, including the growth of industries and cities along DFC routes.

---

3. Background and Literature Review

3.1 Theoretical Framework

Infrastructure Economics: The role of infrastructure in economic development is well-established in economic theory. Aschauer (1989) introduced the concept that public infrastructure investments contribute to economic productivity and growth by reducing transaction costs and improving market efficiency. This theory is particularly relevant to DFCs, as they represent a significant infrastructure investment aimed at enhancing freight transport efficiency.

Logistics and Supply Chain Management: Theories in logistics and supply chain management emphasize that efficient transport networks are crucial for economic competitiveness (Christopher, 2016). Dedicated Freight Corridors, by improving rail transport efficiency, are expected to enhance supply chain management by reducing costs and transit times, which aligns with the theoretical expectations of logistics optimization.

Regional Development Theory: Myrdal's (1957) theory of regional development highlights how infrastructure can stimulate economic activity in underdeveloped regions. DFCs are designed to link economically lagging areas with major industrial hubs, potentially fostering regional development and reducing economic disparities.

3.2 Review of Existing Literature

Infrastructure and Economic Growth: Several studies underscore the positive impact of infrastructure on economic growth. Calderón and Servén (2014) argue that investments in transportation infrastructure significantly boost economic performance, particularly in developing countries. They find that infrastructure development improves productivity and reduces transaction costs, which can lead to higher economic output. This framework supports the expected benefits of DFCs, which aim to enhance India's logistics efficiency and economic growth.

Impact of Dedicated Freight Corridors: The specific impact of DFCs has been the subject of recent research. Singh (2021) provides a detailed analysis of the economic benefits of India's DFCs, estimating that these corridors could reduce logistics costs by up to 40%. This reduction is significant, considering that logistics costs currently account for about 14-15% of India's GDP. Singh's study highlights how improved freight efficiency can enhance India's trade competitiveness and stimulate industrial growth.

Verma and Roy (2020) focus on the Eastern Dedicated Freight Corridor (EDFC) and its potential to transform regional economies. They argue that the EDFC will boost industrial output and facilitate trade by improving connectivity between eastern India and major ports. Their analysis indicates that the EDFC will play a critical role in integrating rural areas with larger economic centers, thereby promoting regional development.

Regional Development and Industrial Growth: The relationship between infrastructure and regional development is well-documented. DFCCIL (2022) reports that the Western Dedicated Freight Corridor (WDFC) is expected to enhance industrial activity in Gujarat, Maharashtra, and Rajasthan. This corridor is anticipated to facilitate the movement of goods from major ports to industrial hubs, thereby boosting local economies. Bhattacharya (2019) supports these findings, noting that improved infrastructure can lead to increased industrial output and foreign direct investment (FDI) in connected regions.

Environmental and Social Impacts: The environmental benefits of DFCs are also significant. Banerjee (2024) highlights that the shift from road to rail transport can reduce carbon emissions substantially. The electrification of DFCs is expected to contribute to India's sustainability goals by lowering CO2 emissions. Additionally, reports by KPMG (2024) and ITLN (2024) discuss the social benefits of improved connectivity, such as enhanced ease of doing business and better supply chain efficiency for small and medium-sized enterprises (SMEs).

Gaps in the Literature: Despite the wealth of studies, there are notable gaps in the existing literature. For example, while Singh (2021) and Verma and Roy (2020) provide insights into the economic and regional impacts of DFCs, there is limited research on the specific impacts of DFCs on various sectors such as agriculture and e-commerce. Additionally, the interaction between DFCs and other infrastructure projects, such as the Gati Shakti initiative, remains underexplored. Future research should focus on these areas to provide a more comprehensive understanding of the full range of impacts that DFCs may have.

A growing body of literature supports the idea that infrastructure, particularly transport networks, plays a pivotal role in economic development. Studies have shown that efficient transportation systems reduce the cost of doing business, improve market access, and attract foreign investment. DFCs could reduce logistics costs by 30–40%, a significant boost for sectors like manufacturing, agriculture, and e-commerce. The potential of DFCs in driving regional development, particularly in underdeveloped areas along the Corridor

---

4. Overview of Dedicated Freight Corridors (DFCs) in India

4.1 Western Dedicated Freight Corridor (WDFC)

The Western DFC stretches over 1,500 kilometers and caters primarily to industrial hubs in Gujarat, Maharashtra, Rajasthan, and Haryana. This corridor is expected to improve connectivity between India's largest ports and its most industrialized regions. Key industries benefiting from the WDFC include automobile manufacturing, petrochemicals, and textiles.

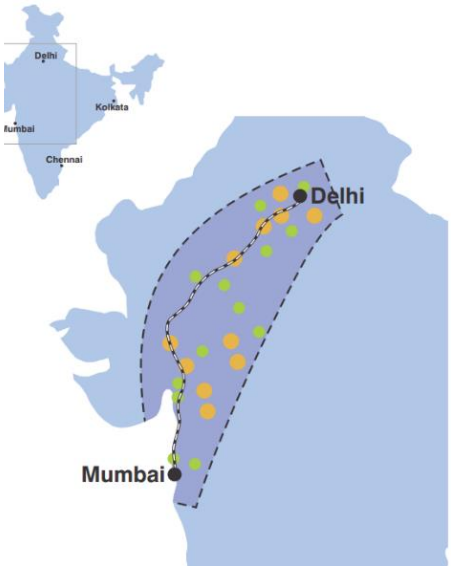
Western Dedicated Freight Corridor (WDFC) along DMIC

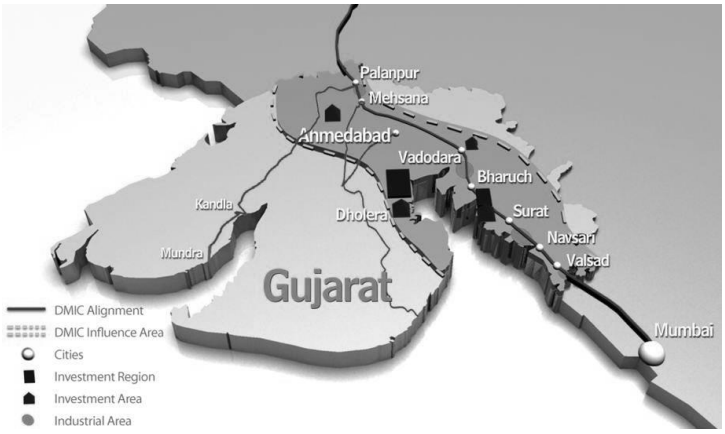
Government of India is developing the Delhi Mumbai Industrial Corridor (DMIC), first industrial corridor on the backbone of Western Dedicated Freight Corridor (DFC) between Delhi and Mumbai covering an overall length of 1504 km and passing through the states of Uttar Pradesh, Delhi NCR, Haryana, Rajasthan, Gujarat and Maharashtra, with end terminals at Dadri in the Delhi NCR and Jawaharlal Nehru Port (JNPT) near Mumbai. The project spans the states of Uttar Pradesh, Haryana, Rajasthan, Madhya Pradesh, Gujarat and Maharashtra along the Western Dedicated Freight Corridor (DFC). Following are the projects under DMIC in various phases of development:

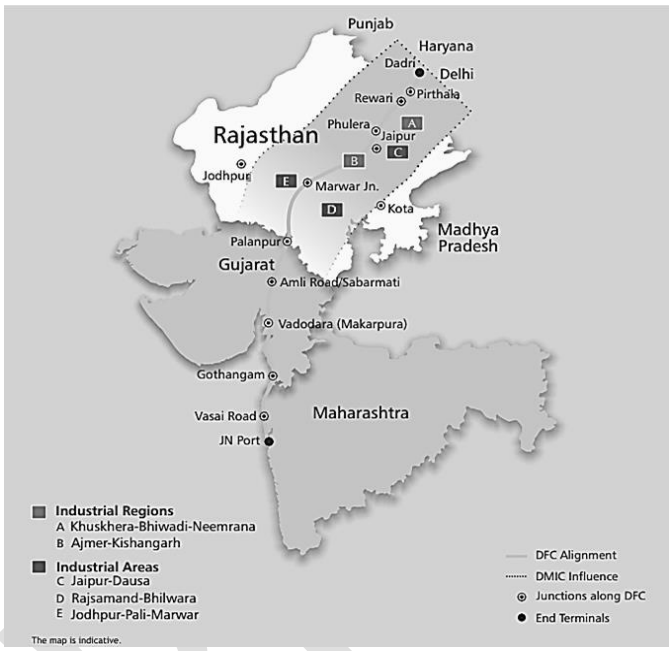
- *Dholera Special Investment Region (DSIR), Gujarat(22.5 sq. kms/ 5560 acres)*
- *ShendraBidkin Industrial Area (SBIA), near Aurangabad, Maharashtra (18.55 sq. kms/ 4583 acres).*
- *Integrated Industrial Township – Greater Noida (IITGN), Uttar Pradesh (747.5 acres)*
- *Integrated Industrial Township – Vikram Udyogpuri (IITVU), Madhya Pradesh (1,100 acres)*
- *Integrated Multi-Modal Logistics Hub, Nangal Chaudhary, Haryana (886 acres)*
- *Multi-Modal Logistics Hub (MMLH) and Multi-Modal Transport Hub (MMTH), Uttar Pradesh 479 Ha (1184 acre)*
- *Dighi Port Industrial Area, Maharashtra (6056 acres)*
- *Jodhpur Pali Marwar Industrial Area (JPMIA), Rajasthan (6,570 acres)*
- *KhushkheraBhiwadi Neemrana Industrial Area, Rajasthan (1378 acres)*
- *Mandal -Becharaji Special Investment Region (MBSIR), Gujarat (2,849 acres)*

Western DFC (1504 KMs)	
Haryana	191
Rajasthan	561
Gujarat	552
Maharashtra	183
Uttar Pradesh	17
Total	1504

The freight corridor runs almost parallel to the Delhi-Mumbai section of the Golden Quadrilateral

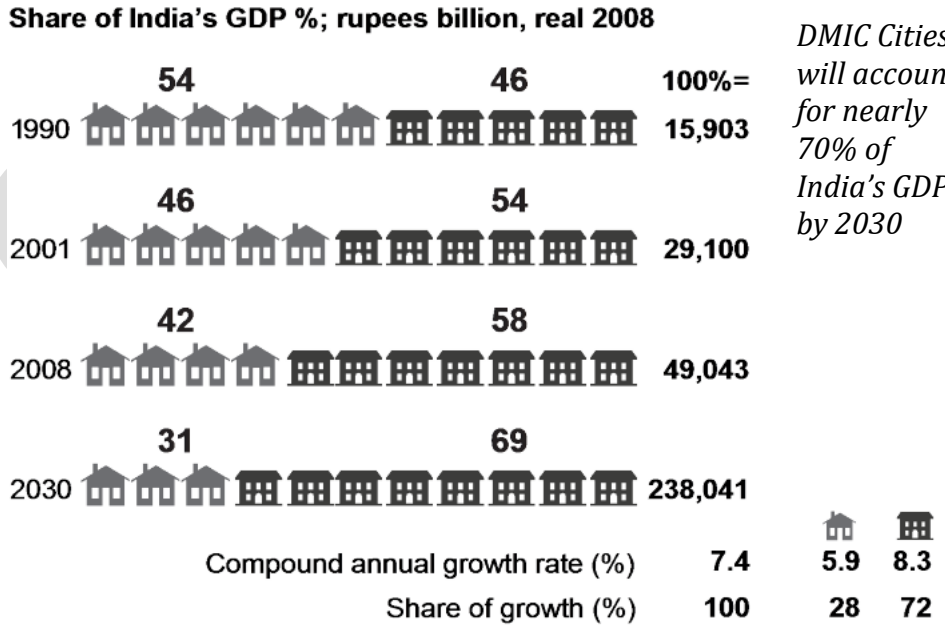




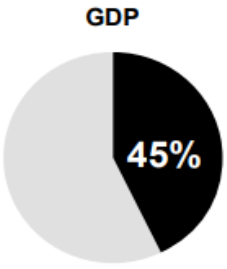


Nearly 39% of the DFC passes through Rajasthan, and about 60% of the state's area is within the project's influence area

The distribution of the corridor shows that Gujarat constitutes 38 percent of the total length of the alignment of the freight corridor. The Ahmedabad-Dholera industrial area lies within 100 km of the DFC in the Ahmedabad District and has been identified by the government of Gujarat for developing a Special Investment Region.



DMIC Cities will account for nearly 70% of India's GDP by 2030



Contribution of DMIC States

4.2 Eastern Dedicated Freight Corridor (EDFC)

The Eastern DFC covers approximately 1,800 kilometers and passes through Punjab, Haryana, Uttar Pradesh, Bihar, Jharkhand and West Bengal. It serves agricultural regions, coal mines, and manufacturing hubs. By linking the eastern hinterland to ports on the eastern seaboard, the EDFC is expected to boost export-oriented industries and agriculture.

Eastern Dedicated Freight Corridor (EDFC) along AKIC

The Government of India is developing Amritsar-Kolkata Industrial Corridor (AKIC) along the alignment of the Eastern Dedicated Freight Corridor (EDFC) traversing a route length of 1839 km in six states. The objective of AKIC is to optimize the present economic and employment potential of the region, stimulate investments particularly in manufacturing, agro-processing, services and export-oriented units and promote overall economic development of the area through creation of high standard infrastructure and an enabling business environment. AKIC is proposed to be developed in a band of 150-200 Kms on either side of EDFC, in a phased manner. AKIC will have an influence area across seven states of Punjab, Haryana, Uttar Pradesh, Uttarakhand, Bihar, Jharkhand and West Bengal. Further, the BaddiBarotiwalaNalagarh (BBN) area in Himachal Pradesh is located at around 70 kms from the Eastern Dedicated Freight Corridor (EDFC), thus, falling in the influence zone of AKIC and the same has also been included in the AKIC Corridor for development.

The availability of world class infrastructure along the Corridor shall also enable increased investments in manufacturing and industrial activities in these eight states. In the first phase, following Integrated

- *Hisar Integrated Manufacturing Cluster IMC, Haryana 2988 acre (2 phase development*
- *PragKhurpia Integrated Manufacturing Cluster, Uttarakhand (1,002 acres)*
- *Rajpura-Patiala IMC, Punjab (1,100 acres)*
- *IMC at Agra, Uttar Pradesh (1,059 acres)&Saraswati Hi Tech city, Prayagraj, Uttar Pradesh (1,141 acres)*
- *New Bahri Node, Jharkhand*
- *IMC at Gaya, Bihar (1,600 acres)*

Eastern DFC (1861 KMs)	
States	KMs
Punjab	**88**
Haryana	**72**
Uttar Pradesh	**1063**
Bihar	**239**
Jharkhand	**196**
West Bengal	**203**
Total	**1861**

Manufacturing Clusters (IMCs) have been identified for development:

5. Economic Impact of Dedicated Freight Corridors

5.1 Direct Economic Impacts

5.1.1 Logistics Efficiency and Cost Reduction

The Dedicated Freight Corridors (DFCs) have been designed to significantly enhance freight transportation by handling heavier loads and increasing speed. Freight trains on DFCs are capable of running at speeds up to 100 km/h, compared to 25-30 km/h on conventional lines. This improvement in speed results in a drastic reduction in travel time for goods. Consequently, logistics costs are expected to decrease by up to 40%, according to estimates from the Ministry of Railways. This cost-efficiency will enable Indian goods to become more competitive, particularly in global markets. Lower freight costs make Indian products more attractive internationally, thus supporting the country's export-driven sectors such as textiles, agriculture, and automotive industries.

5.1.2 Boost to Industrial Output and Trade

The enhanced logistics environment fostered by the DFCs will have a profound impact on industrial production. Sectors such as manufacturing, pharmaceuticals, agriculture, and electronics are expected to benefit from the quicker and more reliable transportation of raw materials and finished goods. The increase in efficiency will likely reduce production bottlenecks, minimize supply chain disruptions, and decrease operational costs, leading to higher output. This boost in industrial activity is expected to positively influence India's export volumes and attract increased foreign direct investment (FDI) by improving the ease of doing business. For example, the Western DFC's connection to ports on the western coast like Mundra and JNPT will facilitate faster movement of export-import goods, giving Indian industries a competitive edge in international trade.

5.2 Indirect Economic Impacts

5.2.1 Regional Development and Employment

One of the transformative impacts of DFCs is their role in regional development. By connecting rural and semi-urban areas to major markets, these corridors provide new economic opportunities. For instance, regions along the DFC routes are seeing increased investment in infrastructure such as logistics parks,

freight terminals, and industrial hubs. This infrastructure development creates jobs and stimulates local economies. The Delhi-Mumbai Industrial Corridor (DMIC) and Amritsar-Delhi-Kolkata Industrial Corridor (ADKIC), aligned with the DFCs, will also help generate employment by supporting industries like manufacturing, warehousing, and logistics.

Moreover, improved freight efficiency will encourage local industries to expand their market reach, further increasing employment opportunities in both formal and informal sectors. Small and medium-sized enterprises (SMEs), in particular, stand to benefit from the easier movement of goods, as lower logistics costs will enable them to compete more effectively in national and international markets.

5.2.2 Environmental and Social Benefits

In addition to economic impacts, DFCs are designed to deliver significant environmental advantages. The shift from road-based freight to rail freight on electrified tracks will drastically cut down carbon emissions. Rail transportation is more energy-efficient, and DFCs are expected to reduce emissions by millions of tons annually, contributing to India's efforts to combat climate change. This transition supports the country's broader green economy initiatives and aligns with global sustainability goals. Moreover, the reduced congestion on roadways caused by the modal shift to rail will help decrease fuel consumption and lower vehicle emissions, further benefiting the environment.

5.2.3 Reduced Inventory Costs and Just-in-Time Logistics

Another notable economic benefit of DFCs is the reduction in inventory holding costs, made possible through more reliable and predictable freight schedules. The faster turnaround times for wagons result in fewer delays, allowing businesses to adopt just-in-time (JIT) logistics strategies. This minimizes the need for large stockpiles of goods, reducing warehouse costs and freeing up capital for other investments. Real-time tracking systems integrated with DFCs also enhance operational transparency and supply chain management, enabling businesses to optimize their logistics in line with market demand.

5.2.4 Enhanced Connectivity to Ports and Export Hubs

DFCs provide faster and more direct routes between industrial production centers and major ports. The Western DFC, for instance, improves connectivity between northern India and key western ports like Jawaharlal Nehru Port Trust (JNPT), Mundra, and Pipavav. This enhanced connectivity is expected to stimulate export growth by reducing lead times for international shipments. Industries relying on exports, such as agriculture, pharmaceuticals, and textiles, will benefit from the improved access to ports, boosting India's trade balance and increasing its presence in global markets.

6. Policy Implications and Future Outlook

To harness the full potential of the DFCs, the government needs to focus on:

- **Expanding the DFC Network**: The current corridors primarily focus on the western and eastern regions. Expanding the DFC network to the southern and northeastern parts of India will provide comprehensive freight solutions, connecting key industrial regions across the country and reducing bottlenecks in underserved areas.
- **Public-Private Partnerships (PPP)**: To maximize operational efficiency and infrastructural development, the government should actively promote PPP models. Encouraging private sector involvement in the establishment of multimodal logistics parks, freight terminals, and value-added services along the corridors would not only increase capacity but also optimize supply chains and reduce government expenditure. These logistics hubs can integrate warehousing, packaging, and distribution activities, enhancing end-to-end freight solutions.
- **Seamless Integration with Other Transport Systems**: A holistic approach to transport infrastructure is essential. Ensuring that DFCs are well-integrated with other transportation modes—such as highways, ports, and airports—will boost intermodal connectivity. The **Gati Shakti initiative**, a master plan for multimodal connectivity, can play a crucial role in linking DFCs with road and air networks, allowing for seamless movement of goods across the country.
- **Leveraging DFCs for E-Commerce and Manufacturing Growth**: The rapid expansion of India's e-commerce sector, along with growing domestic and international demand for Indian manufactured goods, calls for efficient freight infrastructure. DFCs are ideally positioned to support these high-growth sectors, providing faster, more reliable transportation that can meet the time-sensitive demands of e-commerce. In manufacturing, faster movement of raw materials and finished products across states will enhance productivity and competitiveness.
- **Achieving National Logistics Policy Goals**: One of the key objectives of India's **National Logistics Policy** is to reduce logistics costs from the current 14-15% of GDP to below 10%. DFCs will play a central role in achieving this target by streamlining freight transport, reducing congestion on road networks, and cutting overall transit times. Lower logistics costs will enhance India's position as a competitive player in global markets, encouraging more trade and industrial growth.

- **Promoting Sustainability**: DFCs are designed with environmental considerations in mind, using electrified tracks to reduce carbon emissions. Future policy should emphasize the continued greening of freight transport, potentially expanding renewable energy sources and energy-efficient technologies to further reduce the carbon footprint.

Future Outlook

In the future, DFCs are expected to serve as the backbone of India's freight transport network, revolutionizing how goods are moved across the country. With proper policy support and investment, the DFCs will contribute to the modernization of India's logistics ecosystem, aligning it with global best practices. Integration with initiatives such as **Make in India** and **Aatmanirbhar Bharat** will further strengthen domestic manufacturing, supporting India's goal of becoming a global economic leader.
Key to the success of DFCs is continued government focus on expanding infrastructure, improving integration, and encouraging private investment to ensure that India remains globally competitive in logistics and trade.

---

7. Conclusion

The Dedicated Freight Corridors (DFCs) represent a transformative leap in India's logistics and transport infrastructure, with far-reaching implications for economic growth, regional development, and global competitiveness. By significantly improving the speed, capacity, and efficiency of freight transport, DFCs address long-standing challenges within the Indian Railways network, particularly the bottlenecks caused by shared passenger and freight services.
The DFCs are poised to revolutionize the logistics ecosystem by drastically reducing transit times and lowering costs. This increased efficiency can make Indian goods more competitive in global markets, aligning with the objectives of the **National Logistics Policy** to bring logistics costs down to below 10% of GDP. In addition, the shift to dedicated corridors allows Indian Railways to focus on both freight and passenger services without compromise, improving punctuality and service quality across the board.
Beyond logistics, DFCs catalyze regional economic growth, encouraging the development of industrial corridors, such as the **Delhi-Mumbai Industrial Corridor (DMIC)** and the **Amritsar-Delhi-Kolkata Industrial Corridor (ADKIC)**, which link key production hubs with national and international markets. The creation of **multimodal logistics parks** along these routes also enables the efficient movement of

goods and facilitates the growth of new industries. This infrastructure boost can stimulate investment, generate employment, and foster regional development, particularly in underdeveloped areas.

From an environmental perspective, DFCs offer a greener alternative to road transport, significantly reducing carbon emissions and contributing to India's sustainability goals. Electrified rail corridors offer a cleaner, more efficient mode of transportation, helping the country transition to more sustainable logistics practices.

However, realizing the full potential of DFCs requires continued government support, investment, and expansion, particularly to regions such as the south and northeast. **Public-private partnerships (PPPs)** will be instrumental in developing essential infrastructure like private freight terminals and logistics hubs, while initiatives such as **Gati Shakti** can ensure seamless integration between various modes of transport, from highways to ports and air cargo.

In conclusion, while challenges remain, the Dedicated Freight Corridors are set to play a pivotal role in modernizing India’s transport infrastructure. With sustained focus on expansion, integration, and innovation, DFCs have the potential to reshape the nation's logistics landscape, reduce costs, promote industrial growth, and position India as a global economic powerhouse. The success of this project will depend not only on its implementation but also on strategic policies that support its evolution in line with India's long-term economic goals.

---

8. References

- https://www.itln.in/railway/dedicated-freight-corridors-transforming-indias-logistics-backbone-1352140?infinitescroll=1
- https://kpmg.com/in/en/blogs/home/posts/2024/06/indias-dedicated-freight-corridors.html
- https://www.conquerornetwork.com/blog/2024/01/18/how-dedicated-freight-corridors-are-becoming-a-game-changer-for-the-indian-transportation-and-logistics-industry/
- https://economictimes.indiatimes.com/news/economy/infrastructure/dedicated-freight-corridor-targets-december-2025-for-completion/articleshow/111867214.cms?from=mdr
- https://www.deccanherald.com/india/dedicated-freight-corridor-to-be-completed-by-december-2025-3113288
- https://pib.gov.in/PressReleasePage.aspx?PRID=2004494

- https://pib.gov.in/newsite/PrintRelease.aspx?relid=124598
- https://uic.org/IMG/pdf/d2_s4_mechanised_maintenance_philosophy_of_railway_assets_punit_agrawal_india_part2.pdf
- https://mbsirda.gujarat.gov.in/overview-of-gujarat-dmic.aspx
- https://environment.rajasthan.gov.in/content/dam/industries/pdf/bip/home/downloads/publication/dmic.pdf
- Aschauer, D. A. (1989). Is Public Expenditure Productive? Journal of Monetary Economics, 23(2), 177-200.
- Banerjee, K. (2024). Dedicated Freight Corridor (DFC): Current Scenario and Socio-Economic Benefits – An Analytical Study.
- Bhattacharya, S. (2019). Impact of Infrastructure on Economic Growth: Case of India's DFCs. Economic and Political Weekly.
- *Calderón, C., & Servén, L. (2014). The Effects of Infrastructure Development on Growth and Inequality. Policy Research Working Paper No. 7034. World Bank.*
- *Calderón, C., Easterly, W., & Kambourov, G. (2018). Infrastructure and Economic Growth: An Empirical Study. Journal of Development Economics, 131, 24-40.*
- *Christopher, M. (2016). Logistics & Supply Chain Management. Pearson UK.*
- *DFCCIL (2022). Annual Report 2022-23. Dedicated Freight Corridor Corporation of India Limited.*
- *ITLN (2024). Dedicated Freight Corridors: Transforming India's Logistics Backbone.*
- *Jeetendra Singh (2021). Economic Analysis of the Heavy Haul Dedicated Freight Corridors in India. Railway Board, Ministry of Railways, India.*
- *Myrdal, G. (1957). Economic Theory and Underdeveloped Regions. Routledge.*
- *Shobhit Verma & Prof. Uttam Kumar Roy (2020). Eastern Dedicated Freight Corridor: Strengthening Industrial Development.*

- *Singh, J. (2021). Economic Impact of Dedicated Freight Corridors on India's Logistics.*
- *Verma, S., & Roy, U. K. (2020). Impact of Dedicated Freight Corridors on Regional Development.*
- *https://invest.up.gov.in/corridors-parks/*

TABLE OF CONTENTS

1. INTRODUCTION

The discussion below underscores the critical need for a dynamic business model in modern urban transportation services, one that goes beyond traditional ticketing revenue. As infrastructure projects, particularly transportation networks, face mounting costs—partially driven by expensive and time-consuming land acquisition processes—it becomes essential for these projects to diversify their revenue streams. Non-core operations, such as property development, leasing, and commercial operations, provide a strategic solution to this challenge, enabling transportation services to generate extra revenue that can offset investment costs and improve financial viability.

Infrastructure development is a key driver of economic growth, particularly in a rapidly urbanizing country like India. However, the path to developing large-scale infrastructure projects is often obstructed by the challenges posed by land acquisition laws, most notably the Land Acquisition Act of 2013 (LARR). While the Act was designed to safeguard the rights of landowners by requiring measures such as Social Impact Assessments (SIA) and placing restrictions on acquiring multi-crop land, these provisions have often resulted in substantial delays and escalated costs for infrastructure projects. This paper explores the issues associated with LARR 2013, particularly how its stringent provisions have slowed down infrastructure development, and offers possible policy solutions that could expedite land acquisition without compromising the rights of landowners.

A prominent example of the detrimental effects of delays in land acquisition is the Mumbai-Ahmedabad Bullet Train project. Originally slated for completion in 2023, the project has faced repeated delays due to the slow pace of land acquisition, taking over five and a half years to secure all the required land. By January 2024, the cost had ballooned from ₹1.08 lakh crore to over ₹2 lakh crore, and the completion timeline has been pushed to 2028. This example underscores the need for more efficient land acquisition processes to prevent cost overruns and project delays, which are often the result of prolonged land acquisition negotiations and legal hurdles.

Given that reforming land acquisition laws is a highly complex and politically sensitive process requiring significant political will, many states and the central government may be reluctant to push for changes that reduce protections for landowners. This paper explores how, in the meantime, infrastructure projects can resort to non-core revenue generation to offset the financial strain caused by these delays. Until reforms are implemented, projects can adopt dynamic business models that enhance their revenues through non-core operations, allowing them to better manage the high costs of land acquisition and other associated expenses.

This paper explores how transportation infrastructure projects, with special emphasis on Delhi Metro, can increase their financial sustainability by focusing on non-core revenue streams. Particularly, Delhi Metro has successfully generated a portion of its revenue from non-ticketing sources such as property development, advertisements, and space rentals. By capitalizing on these alternative revenue streams, Delhi Metro has been able to cover part of its operational costs and reduce its dependence on ticket sales. However, there is significant potential for further expansion of these non-core activities, especially in the area of property development, which remains underutilized. This paper examines how maximizing such revenue opportunities can improve the financial performance of transport infrastructure projects.

Additionally, the paper delves into how Indian airports, similar to Delhi Metro, have leveraged non-aeronautical revenues from activities like retail, space rentals, and advertisements to enhance their financial viability. These additional revenue streams not only help cover operational costs but also facilitate further investment into infrastructure development, creating a cycle of reinvestment and improvement.

In conclusion, this paper highlights the importance of adopting a dynamic business model for modern infrastructure projects. Such a model, which enables the generation of extra revenue beyond ticket sales, is essential for covering high investment costs and ensuring financial sustainability. Efficient infrastructure, particularly in transportation, is critical for both national and local economic development, and the extra revenue generated through non-core operations can drive continuous improvement, leading to a virtuous cycle of growth and development in India's infrastructure landscape.

1. LAND ACQUISITION (PROCESS AND REGULATIONS) IN INDIA

Infrastructure projects in India continue to face significant challenges, one of the most prominent hurdles is the acquisition of land for such projects. When large tracts of land are required for the construction of roads, railways, urban housing, or other public infrastructure, land is acquired compulsorily by the government on payment of compensation in accordance with land acquisition laws. This process, known as land acquisition, differs fundamentally from a land purchase.

In a purchase, the transfer of land occurs through a mutual agreement between a willing buyer and seller on agreed terms. By contrast, acquisition is where the land owner has no choice over parting with the land, and is forced to relinquish his property. The owner's property rights are overridden, justified only when there is a broader public interest at stake.

In India, while land is a state subject, but land acquisition happens to be a concurrent subject, governed by both central and state laws. The principal legislation at the national level is the Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013 (2013 Act), which replaced the outdated Land Acquisition Act of 1894. Many states have enacted their own laws to regulate the process further.

The 2013 Act introduced significant changes. It restricted the definition of 'public purpose' to more narrowly define the projects for which land could be acquired. It mandated the consent of landowners for projects under public-private partnerships (PPPs) or private enterprises. Compensation was increased, requiring payment of two to four times the prevailing market rate, along with mandatory norms for the rehabilitation and resettlement of displaced persons. Additionally, the Act introduced the requirement of a Social Impact Assessment (SIA), a process to evaluate whether the societal benefits of a project outweigh its social costs. However, several provisions of the 2013 Act have introduced new challenges, often slowing down infrastructure development. From the length of the acquisition process, the need for landowner consent, and determining fair market value, to the complexities of conducting a Social Impact Assessment, these requirements have become significant obstacles in India's pursuit of large-scale infrastructure development.

2.1 Problems with land acquisition in India

As of July 2023, 809 infrastructure projects in India were delayed, with 213 of those projects still behind schedule even after receiving extensions. The petroleum sector had the most delayed projects, with 89, and seven of the most delayed projects were rail lines. The cost escalation of these projects was more than Rs 4.65 lakh crore as of July 2023. In December 2023, 431 infrastructure projects experienced cost overruns

of more than Rs 4.82 lakh crore, and 848 of those projects were delayed. The average time overrun for these delayed projects was 36.59 months.

2.1.1 Consent Requirements Under the Land Acquisition Act 2013

One of the key provisions of the 2013 Act pertains to the consent of landowners. The Act mandates that for Public-Private Partnership (PPP) projects, the consent of 70% of affected landowners is required, while for private projects, this threshold rises to 80%. This requirement introduces significant challenges, as it implies obtaining agreement from a large majority of landholders before proceeding with land acquisition.

The notion of consent is inherently problematic in the context of land acquisition. Unlike a land purchase, where both parties—the buyer and the seller—enter into a transaction willingly and on mutually agreeable terms, acquisition occurs precisely when the landowner is reluctant to sell. Requiring the consent of those who are fundamentally opposed to relinquishing their property may, therefore, be impractical. Furthermore, it is unclear why the consent threshold should vary based on the ownership structure of the project (PPP vs. private), given that the nature of acquisition remains the same regardless of who owns or operates the infrastructure.

This consent requirement often delays the land acquisition process, as obtaining agreement from such a large portion of landowners can be time-consuming and contentious. These delays, in turn, have an adverse effect on infrastructure development, stalling projects and escalating costs, which is counterproductive for rapid infrastructure growth of the nation.

2.1.2 Social Impact Assessment (SIA) Provisions Under the Land Acquisition Act 2013

The Social Impact Assessment (SIA) is a critical component of the land acquisition process introduced under the 2013 Act. It is conducted to evaluate whether the potential benefits of a proposed project would outweigh its social costs. In essence, the SIA aims to ensure that infrastructure development does not come at an unreasonably high social cost to communities affected by land acquisition.

The SIA is mandatory for all projects, with two key exceptions:

1. Cases of urgency, and
2. Irrigation projects that require an Environmental Impact Assessment (EIA).

The process of conducting an SIA is lengthy, taking a minimum of eight months to complete. Despite this, there is no specific time limit prescribed for the examination of land acquisition proposals or the SIA by the government, potentially leading to indefinite delays in the process.

Another issue with the SIA framework lies in the lack of clear guidelines regarding the composition of the SIA Unit, which is responsible for selecting the SIA team. The Act does not prescribe the procedure for the selection of this critical unit, leaving it to the discretion of the government. Instead of delegating such a crucial responsibility, the Act itself should have outlined the composition and independence of the SIA Unit to ensure that the team responsible for assessing the social impact is impartial and properly qualified.

It is also important to note that while physical costs and benefits can be more easily quantified, the cultural and emotional costs of land acquisition are far more subjective. These factors are often determined by the value judgments and perspectives of the individuals assessing the SIA, making the process inherently variable.

The Expert Group, tasked with assessing the SIA report, consists of:

- Two non-official social scientists,
- Two representatives from the Panchayat and Gram Sabha,
- Two experts on rehabilitation and resettlement, and
- One technical expert related to the project.

Although this group includes diverse expertise, there is still room to make it more representative and inclusive of other stakeholders.

However, even with the Expert Group's assessment, their recommendations are not binding on the government. This means that even if the Expert Group recommends that a project be abandoned due to negative social impacts, the government may still proceed with the land acquisition.

Another concern is related to the financial implications of SIA delays. According to Section 30(3) of the Act, in addition to the market value of the land, the Collector must award an amount at the rate of 12% per annum on the market value of the land from the date of notification of the SIA until the date of the award or the taking of possession of the land. Therefore, any delays in the SIA process can lead to cost overruns.

2.1.3 Acquisition of Irrigated Multi-Cropped Land

The 2013 Act imposes strict restrictions on the acquisition of irrigated multi-cropped land. According to Section 10, such land can only be acquired as a last resort and under exceptional circumstances. Each state government sets a limit on how much irrigated multi-cropped land can be acquired for public or private projects.

In cases where irrigated multi-cropped land is acquired, the Act mandates that an equivalent area of culturable waste land must be developed for agricultural purposes, or an amount equivalent to the value of the acquired land must be deposited with the appropriate government. This deposit is meant for investment in agricultural activities to enhance food security, which is a key consideration when acquiring land that is already being used for productive farming.

However, the Act does not prescribe a time limit for the commencement or conclusion of the process of developing equivalent culturable waste land. This lack of a clear timeline creates uncertainty and delays in compensating for the loss of agricultural land, which can negatively impact food security in the long run.

Moreover, the Act requires private companies and Public-Private Partnerships (PPPs) to bear the inflated cost of compensating for the acquisition of irrigated multi-cropped land twice. First, they must pay the landowner for the acquired land, and second, they must deposit an equivalent amount with the government to enhance food security. This dual financial burden can significantly increase the cost of infrastructure projects involving the acquisition of irrigated multi-cropped land.

2.1.4 Lengthy Land Acquisition Process

The land acquisition process under the 2013 Act is notoriously time-consuming, with a minimum duration of 50 months—over four years. A significant portion of this time is taken up by the Social Impact Assessment (SIA), which alone requires at least 8 months to complete. Additionally, the Act does not specify any time limits for the government to examine proposals for land acquisition or the completion of the SIA, leading to further delays in the process.

These extended timelines can cause substantial and often unimaginable delays to infrastructure projects, escalating costs and slowing down development of infrastructure projects.

Below is a table summarizing the sequential steps outlined in the 2013 Act and the time limits specified for each step under the LARR 2013 Act.

Sequential steps outlined in 2013 Act	***Time limit specified in LARR Act, 2013***
Social Impact Assessment (SIA)	*6 months*

Appraisal of SIA by expert group	*2 months (from the constitution of the group)*
Examination of proposal for land acquisition and SIA by the government	*No time limit specified*
Preliminary notification to acquire land	*12 months (from the appraisal of the SIA by the expert group) but extendable by the government*
Declaration to acquire land	*12 months (from preliminary notification) but extendable by the government*
Land acquisition award (compensation)	*12 months (from declaration) but extendable by the government*
Possession of land	*6 months (from award)*
Total time for possession of land (without extensions)	*50 months*

2.1.5 Issues with the Definition of "Public Purpose"

While the 2013 Act attempts to provide a clearer definition of "public purpose," there are still significant concerns regarding its potential misuse. Section 2(1)(b)(vii) of the Act states that land can be acquired for any infrastructure facility as notified by the Central Government, provided such notification is tabled in Parliament.

This broad provision creates room for the government to potentially acquire land for reasons that may not align with genuine public purposes. The lack of stringent oversight or criteria for what constitutes "public purpose" leaves this definition open to interpretation, which could lead to the misuse of land acquisition powers.

2.1.6 Compensation to Landowners and Market Value Computation

The 2013 Act stipulates that landowners are entitled to compensation amounting to four times the market value in rural areas and twice in urban areas. While this provision is designed to benefit landowners, it significantly increases the overall cost of infrastructure projects.

Section 26 of the Act defines market value as the higher of: (a) the minimum land value as per the Indian Stamp Act, 1899, (b) the average sale price for similar land in the vicinity, or (c) the amount of compensation already paid or agreed to be paid in private or PPP projects. However, the provision that bases market value on the average sales price for similar land in the vicinity is susceptible to misuse. Landowners or real estate agents could manipulate sales prices by coordinating to sell parcels of land at artificially inflated prices, leading to a misleadingly high market value.

The date for the determination of the market value shall be the date on which the preliminary notification has been issued. From that point, all land transactions are restricted. This notification is valid for 12 months. If the declaration under Section 19(1) is not made within that period, the notification is automatically rescinded. However, the government may extend the 12-month period under "justifiable circumstances," which raises concerns about potential misuse of this power. The Act does not specify a maximum period for this extension, leaving room for delays that could disrupt both landowners and infrastructure projects.

From the landowners' perspective, an extension based on unjustifiable grounds could result in lengthy delays, leaving them waiting for compensation and benefits under the Rehabilitation and Resettlement (R&R) schemes. Additionally, since the market value is determined at the time of the preliminary notification, a long delay may result in landowners receiving significantly lower compensation compared to the current market value.

The Act empowers the Collector to reject sale prices or guidance values that do not reflect the actual prevailing market value. However, this raises questions about the method the Collector uses to determine the true market value. The serious question is, what is, according to him, the authentic source of information to depend upon and what is the criterion to be adopted for determining the actual prevailing market value.

Section 30 of the Act mandates that in addition to the compensation payable to the landowner, a solatium amounting to 100% of the compensation shall be added to arrive at the final award. While this solatium is meant to compensate for non-monetary hardships, it further increases the cost of land acquisition, adding to the financial burden of infrastructure projects.

2.2 Proposed Policy Solutions and Recommendations:

2.2.1 Exemptions from Certain Provisions: Implement provisions similar to those proposed in The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement (Second Amendment) Bill, 2015, which did not pass can help to simplify and expedite the process of land acquisition in India. This includes exempting specific project categories from requirements such as:

- Social Impact Assessment (SIA)
- Restrictions on the acquisition of multi-cropped land
- Consent requirements for private and public-private partnership (PPP) projects Categories for exemption could include:
    - Defense projects
    - Rural infrastructure
    - Affordable housing
    - Industrial corridors (including Special Economic Zones, SEZs)
    - Infrastructure projects including PPPs where the government owns the land

2.2.2 Special Exemptions for Industrial Corridors and SEZs: Provide special exemptions under the law for industrial corridors set up by the government and SEZs. This could facilitate more efficient land acquisition processes for these critical development projects.

2.2.3 Alternative Land Acquisition Mechanism: Introduce a hybrid mechanism combining direct purchase through negotiations with acquisition. For instance, 50-70% of the land could be acquired through negotiation, with the remaining portion acquired under the provisions of LARR, 2013. The compensation for acquired land should be benchmarked against the negotiated prices to ensure it aligns with market values.

2.2.4 Streamlining Acquisition Timelines: Reduce the minimum duration of the land acquisition process from 50 months. Set strict time limits for the examination of proposals for land acquisition and SIA by the government. Amend provisions allowing for the extension of time limits for issuing preliminary notifications, declarations, and land acquisition awards from 12 months to more expedient periods.

2.2.5 Revising the SIA Unit Composition: The Act should prescribe the procedure and composition of the Social Impact Assessment Unit, rather than delegating this power to the government. This would ensure a more standardized and independent assessment process, critical for fair evaluations.

2.2.6 Standardizing Cultural and Emotional Cost Assessments: Establish clear and standardized parameters for evaluating cultural and emotional losses. Consider factors such as:

- Historical significance of the land
- Community ties
- Religious or cultural practices by defining these aspects, the SIA process can achieve a more objective and consistent approach, reducing variations in assessments and ensuring equitable compensation for affected communities.

2.2.7 Leveraging State Laws for Land Acquisition

Several special statutes have been enacted by state governments that give them the authority to acquire land. These states have their own specific laws for land acquisition and have been utilizing them for state purposes. Under Section 103 of the new Act, if states find their own laws more practical or easier to implement, they are free to use those laws instead of the new Central Act. As a result, it is not mandatory for state governments to rely on or apply the 2013 Act for land acquisition.

Several special statutes have been enacted by Parliament that authorize the Central Government to acquire land, and the government has been using these special laws for land acquisition for Union purposes. Under Section 103 of the new Act, if the Union Government finds its own laws more efficient or easier to apply, it is free to use them instead of the 2013 Act. Therefore, it is not obligatory for the Central Government to rely on or implement the new Act for land acquisition.

Further, the provisions of this Bill shall not apply to acquisitions under 16 existing legislations including the Special Economic Zones Act, 2005, the Atomic Energy Act, 1962, the Railways Act, 1989, etc.

This flexibility allows states to adopt laws that better align with their specific needs for infrastructure development while also ensuring the protection of landholders' rights. By tailoring land acquisition practices to local contexts, states can facilitate faster and more efficient acquisition processes. One such example has been amendments made by the states of Andhra Pradesh and Maharshtra.

Under amendments, Andhra Pradesh and Maharashtra have exempted certain projects from the provisions of Chapter II and Chapter III of the Land Acquisition Act, 2013.

Chapter II of the Act deals with the Social Impact Assessment (SIA) process, which is required to evaluate the impact of land acquisition on the affected communities. Chapter III pertains to the restrictions on the acquisition of irrigated multi-cropped land, setting limits on how and when such land can be acquired.
The amendments in these states specify that certain projects are exempt from these requirements, allowing for a more streamlined and expedited acquisition process for crucial infrastructure developments.
In Andhra Pradesh, the amendment states:
Power of State Government to Exempt Certain Projects
The State Government may, in the public interest, by notification in the Andhra Pradesh Gazette, exempt any of the following projects from the application of the provisions of Chapter II and Chapter III of this Act, namely:
(a) Such projects vital to national security or defense of India and every part thereof, including preparation for defense or defense production.
(b) Rural infrastructure including electrification.
(c) Affordable housing and housing for poor people.
(d) Industrial corridors set up by the State Government and its undertakings (in which case the land shall be acquired up to one kilometer on both sides of designated railway lines or roads for such industrial corridor).
(e) Infrastructure projects, including projects under public-private partnership where the ownership of the land continues to vest with the Government.
Maharashtra has adopted a similar approach, illustrating how states can amend the Act to support infrastructure development while managing land acquisition processes effectively.
Andhra Pradesh has also bought out an amendment that involves addition of Chapter IVA after Chapter IV of the Principal Act, focusing on the voluntary acquisition of land:
Acquisition of Land by the State Government by Entering into Agreement

1. *Notwithstanding anything contained in the Principal Act or any other law, whenever it appears to the State Government that land is needed in any area for any public purpose, the State Government or its Authorized Officer shall enter into an agreement with the willing landowner to sell the land to the State for the purposes specified in a prescribed form.*

2. *The State Government or its Authorized Officer shall pass an order in terms of the agreement under sub-section (1) for acquisition, and the substance of the order shall be notified in the Gazette. Upon*

publication of this notification, the title, ownership, and all interests of the landowner who enters into the agreement shall vest with the State, free from all encumbrances.

3. *Notwithstanding anything contained in the Registration Act, 1908 (Act 16 of 1908), no agreement entered under sub-section (1) shall be liable for registration under that Act.*

4. *If any family, other than the family of the landowner who entered into the agreement, is affected by the acquisition of land under this section, the State Government shall pay a lump sum amount towards rehabilitation and resettlement, as prescribed in the rules framed hereunder.*

   Provided that no agreement or the lump sum amount towards rehabilitation and resettlement shall be abnormally at variance to the disadvantage of the landowners.

This amendment introduces a voluntary mechanism for land acquisition, allowing landowners to agree to sell their land to the government directly, thus bypassing some of the more stringent provisions of the original Act. This approach aims to facilitate smoother and faster land acquisition while ensuring fair compensation and resettlement for affected individuals.

In Tamil Nadu, when the LARR Act was notified, the separate and existing Tamil Nadu Acquisition of Land for Industrial Purposes Act, 1997 was made applicable under the LARR Act. The state is, therefore, not bound by the LARR Act and can continue to employ the other legislation.

In this way many states, particularly those with a strong industrial foundation, have found ways to bypass the LARR Act.

Similarly, in 2016 the Government of Gujarat passed the "Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement (Gujarat Amendment) Bill, 2016" in the Assembly. This bill aims to streamline and simplify the land acquisition process. It grants the state government the authority to exempt certain projects—such as those essential to national security or defence, affordable housing for the poor, state government industrial corridors (allowing land acquisition up to one kilometre on both sides of designated railways or roads), and infrastructure projects under public-private partnerships where land ownership remains with the government—from specific provisions of the original Act. These exempted provisions include those related to the social impact assessment and social provision to safeguard food security.

This outcome aligns with what was anticipated following the central government's attempts to reform land laws in 2013 and 2015. While the LARR Act was enacted in 2013, a 2015 ordinance aimed at curbing

certain provisions of the Act failed to pass in Parliament. As a result, the responsibility for land law reforms has shifted to the states, prompting proactive measures from states like Maharashtra and Andhra Pradesh.

2.3 Prolonged Land Acquisition Delays and Cost Overruns in the Mumbai-Ahmedabad Bullet Train Project

The foundation stone for the Mumbai-Ahmedabad Bullet Train project was laid on 14 September 2017, with an initial completion target of 2023. In fact, the deadline was later advanced, with hopes of having the bullet train's first run by 15 August 2022. However, the project suffered severe delays due to prolonged land acquisition.

By December 2018, only 21.02 hectares—around 1.46% of the total land required for the project—had been acquired. By June 2019, only 39% of the required land had been secured (471 hectares in Gujarat and 66 hectares in Maharashtra). By January 2020, 47% of the land had been acquired, but no land had yet been secured in Mumbai.

Maharashtra, in particular, faced significant delays. By February 2021, only 101.04 hectares of the 432 hectares needed in Maharashtra had been acquired, with no land acquired in Mumbai. By December 2021, 78% of the land had been secured, and by March 2022, 89% of the land was acquired: 98% in Gujarat and 68% in Maharashtra. It wasn’t until January 2024, after more than 5.5 years from the first notification, that 100% of the required land was finally acquired.

These delays significantly impacted the project’s costs and timeline. The original estimated cost of INR 1.08 lakh crore was expected to surpass INR 1.6 lakh crore in 2022. By 2024, the cost was estimated to exceed INR 2 lakh crore. Civil construction, originally scheduled to begin by June 2018, only started in February 2021. Now, a 50 km stretch from Surat to Bilimora is expected to be completed by 2026, with a larger 352 km section through Gujarat anticipated to open by 2027. The entire project is now expected to be completed by the end of 2028, a full 11 years after the foundation stone was laid.

3. NAVIGATING LAND ACQUISITION BARRIERS IN TRANSPORT INFRASTRUCTURE WITH NON-TICKETING REVENUE

Reforming India's land acquisition laws, particularly the Land Acquisition, Rehabilitation, and Resettlement Act (LARR) 2013, presents a complex and multifaceted challenge. The process is not only lengthy but also demands significant political will. Efforts to reform land laws at both the central and state levels require coordination across multiple stakeholders, and this journey is often hindered by bureaucratic obstacles and political considerations. One such effort to reform the 2013 Act failed in 2015.

One of the major roadblocks is the political hesitation to amend or dilute the provisions of LARR 2013. Many political parties, especially those in power, may be reluctant to enact changes that could be perceived as reducing the protections and benefits afforded to landowners. Such reforms, particularly those aimed at making the laws more industry-friendly, might involve reducing the compensation or diluting provisions related to Social Impact Assessments, potentially triggering public backlash. Thus, reforming land acquisition laws is not just a legal and administrative exercise but a highly sensitive political endeavour.

Given the time-consuming nature of reforming these laws, infrastructure projects—especially those in the transport sector—are forced to navigate the high costs of land acquisition in the interim. One of the most viable strategies to mitigate these costs is for infrastructure projects to enhance their revenue streams through non-core operations. By diversifying into activities beyond their primary purpose, these projects can generate additional income to offset the financial burden imposed by land acquisition.

The second part of this paper delves into the potential for transportation infrastructure projects to boost their revenues through non-core operations. This includes examining how projects like the Delhi Metro Rail Corporation (DMRC) have successfully leveraged activities such as property development, real estate ventures, consultancy services, and other commercial operations to enhance their financial stability. A detailed case study of DMRC will illustrate how these non-core revenue streams have contributed significantly to its financial model, providing valuable insights for other infrastructure projects grappling with high land acquisition costs. This paper also includes a comparison between Delhi metro and Hong Kong Mass Transit Railway (MTR)

Moreover, this section also explores how private airport operators have adopted similar strategies to bolster their revenues. By expanding their commercial operations—through retail spaces, real estate development, and property management—airport operators have effectively capitalized on the commercial potential of the land and infrastructure they control, thereby mitigating the high costs associated with acquiring that land.

By examining these cases, this paper aims to highlight how transportation infrastructure projects can not only survive but thrive by tapping into non-core operations as an essential component of their revenue-generation strategies. These examples offer a roadmap for current and future projects, providing an alternative solution to the financial constraints posed by delayed or expensive land acquisition processes.

3.1. IMPACT OF THE LAND ACQUISITION ACT ON DMRC RESOURCE MOBILISATION AND INVESTMENT

3.1.1 Land Acquisition Challenges

A significant challenge encountered in Phase III was land acquisition. The introduction of the new Land Acquisition Act in 2013 introduced more stringent procedures and higher compensation requirements, thereby complicating the process. As a result, DMRC had to resort to direct negotiations with individual landowners, which proved to be time-consuming and often contentious.

For instance, the construction of the Okhla NSIC Metro Station was delayed by two years due to protracted land acquisition negotiations. The area housed several small-scale industries and businesses, making it difficult to acquire the necessary land for the project.

3.1.2. NOC Delays

Obtaining NOCs from various government agencies and stakeholders was another hurdle that contributed to project delays. These approvals were essential for construction work to proceed smoothly, and any delays in obtaining them could have cascading effects on the project timeline.

3.1.3. Heritage Sites and Tunnelling Challenges

The Phase III expansion included several stretches that passed through heritage sites and densely populated areas. Tunnelling in these areas posed significant technical challenges and safety concerns. For example, the Central Secretariat-Kashmere Gate Corridor, which passed through several historical monuments, required careful planning and mitigation measures to protect these heritage sites.

Tunnelling beneath busy areas like the Janpath market also presented challenges due to the potential for ground subsidence and disturbances to nearby buildings. DMRC had to employ specialized techniques and monitoring systems to minimize these risks.

3.1.4. Specific Examples

Okhla NSIC Metro Station: The acquisition of land for this station was delayed by two years due to negotiations with local businesses and residents.

Central Secretariat-Kashmere Gate Corridor: The corridor passed through several heritage sites, including Jantar Mantar and the Red Fort. Tunnelling in these areas required careful planning and monitoring to avoid damage to these historical landmarks.

Janpath Market: Tunnelling beneath this busy market posed challenges due to the potential for ground subsidence and disturbances to nearby buildings. DMRC employed specialized techniques and monitoring systems to mitigate these risks.

The challenges faced by DMRC during the third phase of Delhi Metro expansion highlight the complexities of large-scale infrastructure projects in urban areas. Land acquisition, obtaining NOCs, and navigating heritage sites and densely populated areas are common hurdles that must be addressed effectively to ensure timely project completion. By understanding these challenges and implementing appropriate strategies, future infrastructure projects can be executed more efficiently and with minimal disruptions to the public.

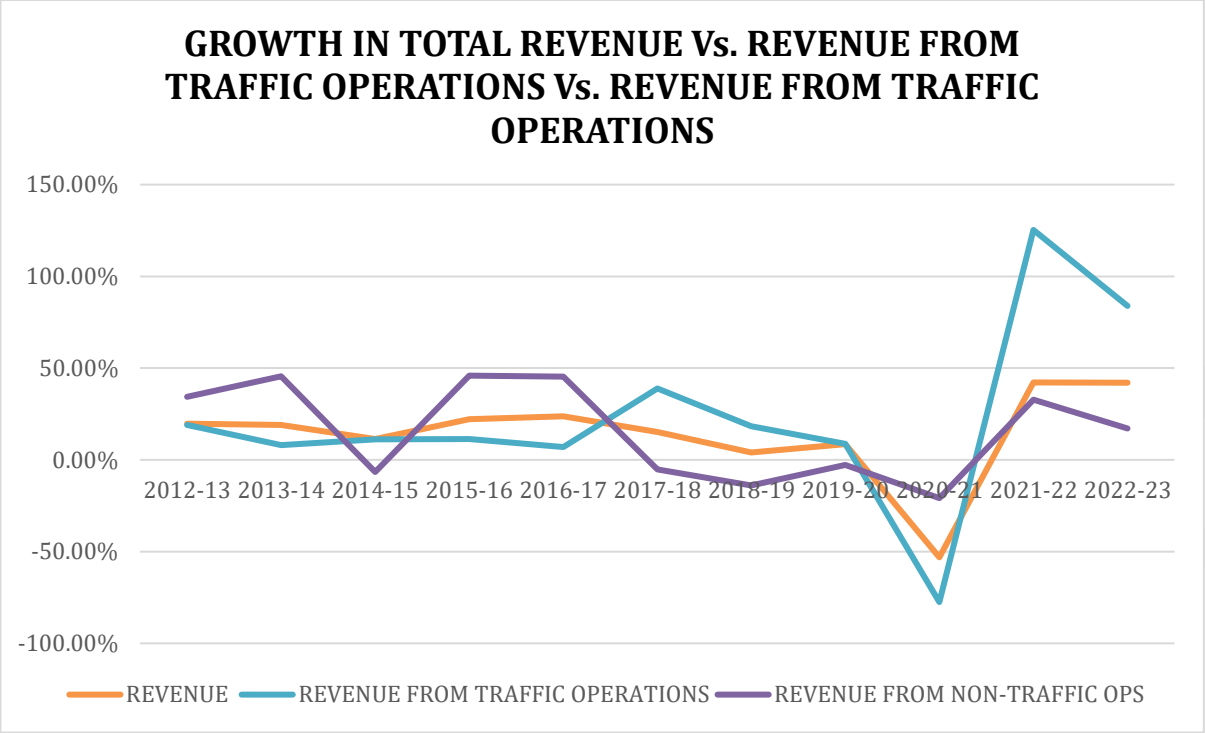
In May 2024, the Supreme Court (SC) upheld the Delhi Metro Rail Corporation's (DMRC) acquisition of land between 1957 and 2006 for public infrastructure projects. The SC also extended the time limit for starting new acquisition proceedings under the 2013 Land Acquisition Act by one year, starting August 1, 2024. This extension allows for compensation to affected landowners to be paid in accordance with the law.

In Delhi, most of the elevated metro corridors are provided along existing roads or the medians of the roads which are mostly owned by the government/government agencies so that the various impacts related to land/property acquisition are the minimum.

3.2. NON-TRANSPORT REVENUE GENERATION UNDER DMRC

With escalating costs of construction and operation of metro rail corridor projects, coupled with reducing financial support from the government and other international agencies, property development and commercial use of property is the only resource by which the metro rail projects and their operations can be sustained in the long run without compromising the main objective of providing a safe, economical and comfortable mode of public transportation with less dependence on the government for financial help.

Phase-I of the Delhi metro had provided 7 per cent of the project cost upfront and 30 percent of the recurring income.



3.2.1 Revenue through Property Development and Commercial Operations

Planning of property development work by DMRC was taken up under different types of arrangements including 6-to-12-year license for spaces within station buildings for commuter related vendors, a 30 years' concession for commercial developments on vacant land pockets adjacent to metro stations, long-term lease (50-90 years) on land pockets, and in depots, etc, not immediately needed for operational structures and advertisement through agencies

One of the first major projects undertaken by the DMRC for property development was the Information Technology (IT) Hub at Shastri Park. This project was approved by the Government of India as a sector specific special economic zone (SEZ). The total plot area was 12 hectares. One block of the 30,000 square meter floor area was completed in 2005 and another one of similar size was completed in 2011. These are being rented out to information technology enabled services (ITES) operators.

A media report in 2006 published details of the areas in the city where the DMRC was planning to develop residential and commercial property on different routes of Phase-I of the DMR. This included residential property in six different locations on 2,12,026 sqm of land and commercial property in nine different locations on 66,464 sqm of land. The localities for residential purposes include Khyber Pass, Rithala, Vishwavidyalaya, Dwarka, Netaji Subash Nagar and Najafgarh. The localities for commercial purposes include Shahdara, Inderlok, Inderlok Annexe, Pratap Nagar, Tis Hazari, Seelampur, Welcome, Kashmiri Gate.

It should be noted here that the Delhi Master Plan 2021, which was notified in 2007, but drafted in the early 2000s, specifically discusses the role of the metro in densifying the city, leading to the formation of high-density and high rise commercial development. It thus provided different building by-laws and land use norms for all segments of land within 500 meters of any metro line, specifically increasing the Floor Area Ratio (FAR) and allowing denser and higher buildings to be constructed

Income under real estate has increased from Rs 1.7 crore in 2003 to Rs 296.2 crore in 2006 and Rs 244.1 crore in 2009. However it has fallen to Rs. 155 crore in 2022-23.

In May 2012, DMRC proposed the procurement of Unattended Train Operation based Rolling Stock on Line-7 and Line-8, besides suggesting the installation of Platform Screen Doors on all the stations of Line-7 and Line-8. The proposal of Platform Screen Doors was placed (July 2012) in the 91st meeting of the Board of Directors. The Board of Directors appointed sub-committee deliberated that since the initial cost of Platform Screen Doors is high, earning from advertisement has been estimated to explore the method of funding. The sub-committee recommended (August 2012) for installation of Platform Screen Doors on 63 stations on Line-7 and Line-8 with the facility to use space for advertisement and after considering 15 square meter area per station available for advertisement, the potential earning from advertisement on Platform Screen Doors on 63 stations of Line-7 and Line-8 for 30 years was assessed to be ₹225 crore.

An advertisement posted by DMRC on 12.04.2022 sheds some light on the rental landscape of build-in shops at different metro stations. The monthly rental for a 95 sqm shop at Rajiv Chok went up to Rs. 12 lakh per month. Similarly, the monthly rental for a 14 sqm shop at Vidhan Sabha was 15000, 229 sqm shop at Janpath was 2.4 lakhs. In contrast, at the less busy stations the prices tend to be at a lower side. A 72 sqm shop at Pratapgarh cost 41000 pm, and a 32 sqm shop at Subhash Nagar was available at less than 10000 per month.

3.2.1.1. Lease Agreements and Outsourcing Property Development Projects

Of late, DMRC has been releasing tenders to invite bidders i.e. construction companies, developers or concessionaires to provide unutilised, quality tested land on lease under the corporation for development of commercial activity zones or any other viable and permitted usage of the land. These tenders have been released and acquired by notable developers, these include but are not limited to, Pacific group at Dwarka Sector 21, New Delhi and Netaji Subhash Place, respectively

Realty firm Pacific India had bagged the project from Delhi Metro Rail Corporation (DMRC) to develop a shopping mall and multi-level car parking at Dwarka in the national capital with an investment of about Rs 100 crore, as claimed by an official. The company developed a total of 4.5 lakh sq ft area, including a shopping mall of 3 lakh sq ft of leasable area and a multi-level parking, having capacity of 600-700 cars, he added. The then estimated total project cost of this metro mall was to be Rs 90-100 crore, funded through internal accruals of the company.

At the time of development, the company expected a rent of over Rs 40 crore annually from this project. The company has to pay Rs 15 crore annually to DMRC during the 25-year lease period.

Through these tenders, DMRC intends to select a "Lessee" to take up on „Lease basis", the land parcel available for MRTS Property Development. It is envisaged to transfer Lease RFP for Property Development rights to a selected developer /Bidder with requisite financial, managerial and technical expertise for a period of 50 (Fifty) years from the "Commencement Date" to utilize the land parcel for permitted development as per control norms.

As per Government of India guidelines, residential development is not normally allowed on government land. The lessee is free to develop the plot for activity other than constructing purely residential units (any permissible uses given under Sl. No. v) to xii) of Sub-Clause 8(2) of Chapter 17 given on page 277 of MPD-2021 modified up to 31/08/2022) such as Short Term Accommodation1 , etc. or Local Shopping Complex as permitted under MPD-2021, making use of available ground coverage and floor area as permitted under Master Plan of Delhi 2021 (MOD 2021). The development of purely residential units for long term lease such as Plotted Housing, Group housing, Studio Apartments and Residence cum work plot is not permitted. DMRC will not have any objection if the lessee gets the land use changed with the approval of concerned local authorities as per the due process.

3.2.2. Underutilization of Land and Infrastructure Resources under DMRC Operations

The audit report on the Delhi Metro Rail Corporation (DMRC) reveals a concerning pattern of gross underutilization of resources and substantial shortfalls in revenue generation from property development under Phase-III of the project. Below is an expanded analysis of the key points from the audit:

3.2.2.1.Significant Revenue Shortfall from Property Development

Target vs Actual Earnings: As per the directive from the Ministry of Housing and Urban Affairs (MoHUA), DMRC was required to fund 4.5% of the Phase-III project cost through revenue generated from property development. The total revenue target for this was set at ₹2,505 crore, which included a shortfall of ₹751 crore from Phase-II. However, as of March 31, 2020, DMRC had only earned ₹657.13 crore — a mere 26.23% of the target, leaving a shortfall of ₹1,847.87 crore (73.77%). This substantial gap underscores the failure to leverage property development as a critical source of funding for the project.

Implication of Shortfall: The shortfall of ₹1,847.87 crore not only affects the funding of Phase-III but also places an additional financial burden on the government and other stakeholders, forcing them to look for alternative sources of funding or incur further debt. The delayed revenue generation also means that DMRC's ability to reinvest in expansion, infrastructure, and operational improvements is compromised.

3.2.2.2. Underutilization of High-Potential Sites

Vasant Vihar Site: The audit highlights that the Vasant Vihar site alone has the potential to generate ₹2,292 crore through property development, which could almost entirely cover the Phase-III target. Despite this immense potential, DMRC has failed to explore any possibility of development at this site. This represents a severe underutilization of one of DMRC's most valuable assets. Had the site been properly utilized, it could have significantly reduced the overall revenue shortfall.

Bhikaji Cama Place: Another glaring missed opportunity is at Bhikaji Cama Place, where 14,000 sqm of land has been identified for property development, but no tender has been finalized as of March 2020. With such prime real estate lying idle in one of Delhi's busiest commercial areas, the failure to finalize tenders reflects a lack of strategic foresight and an inability to capitalize on high-value assets in a timely manner.

Anand Vihar: At Anand Vihar, only 1,358 sqm of land out of the proposed 1.5 hectares has been identified for property development, and no proposals have been initiated for the remaining land. This site, being a

major transit hub, presents a significant opportunity for commercial development, but it remains largely unutilized, further contributing to the shortfall.

3.2.2.3. Unutilized Infrastructure at Faridabad

Idle Commercial Spaces: In Faridabad, two government-owned plots were identified in the Detailed Project Report (DPR) for property development, which was expected to generate ₹234.22 crore. However, 44,751 sqm of constructed area, including three additional floors each at Sarai and Raja Nahar Singh metro stations (at a cost of ₹151.49 crore), remains unused as DMRC has been unable to lease them out. Despite the construction of this infrastructure, the lack of leasing activity means that these commercial spaces have been lying idle for years, representing not just a loss of potential revenue but also wastage of significant capital investment.

Faridabad Sector 5 and Sector 20: Similarly, two plots of land handed over by the Haryana Urban Development Authority for property development have not been leased out to date. This further highlights DMRC's inability to make use of prime land assets, which could have contributed to the ₹234.22 crore revenue target.

3.2.2.4. Shortfall in Non-Fare Box Revenue

Non-Fare Revenue Goals Unmet: During the 87th Board of Directors meeting in March 2012, it was recognized that DMRC's non-fare revenue (i.e., revenue from sources other than passenger fares, such as property development) constituted only 21.6% of the total revenue. The goal was to increase this to 30% within the next five years. However, DMRC failed to meet this goal. The audit notes that DMRC had no Standard Operating Procedure (SOP) or approved plan for generating this non-fare revenue, further demonstrating the lack of a cohesive strategy to exploit non-operational assets.

Missed Revenue from Semi-Naming Rights: The DPR for Phase-III had estimated non-fare revenue of ₹1,917.25 crore for the period 2016-17 to 2019-20, with a significant portion expected from semi-naming rights and co-branding rights at Phase-III stations. However, DMRC earned only ₹76.06 crore, a mere 3.97% of the target, leaving a shortfall of ₹1,841.19 crore. The failure to capitalize on this new concept of semi-naming rights reflects not only a missed opportunity but also a lack of preparedness to implement innovative revenue streams.

3.2.2.5. Lack of Strategic Planning

Absence of SOP for Property Development: The audit reveals a systemic issue with DMRC's property business division, which lacked any approved plans, strategies, or Standard Operating Procedures (SOPs) for generating revenue through property development. The absence of such a framework hindered decision-making and led to the underperformance of key revenue-generating initiatives. As a result, several potential income streams remained unexplored or severely delayed, contributing to the overall revenue shortfall.

YEARS	NON TRAFFIC RENENUE GROWTH	AVG DAILY RIDERSHIP GROWTH	AVERAGE DAILY RIDERSHIP	OPERATIONAL NETWORK	OPERATIONAL NETWORK GROWTH
2012-13	34.39%	16.02%	1926000	167.33	0.00%
2013-14	45.55%	14.49%	2205000	188.05	12.38%
2014-15	-6.55%	8.98%	2403000	191.12	1.63%
2015-16	45.90%	8.82%	2615000	209.97	9.86%
2016-17	45.41%	7.11%	2801000	209.97	0.00%
2017-18	-5.21%	-7.64%	2587000	249.46	18.81%
2018-19	-14.01%	0.23%	2593000	342.07	37.12%
2019-20	-2.73%	7.21%	2780000	359.23	5.02%
2020-21	-20.86%	-68.42%	878000	359.23	0.00%
2021-22	32.77%	186.56%	2516000	360.975	0.49%
2022-23	17.19%	83.90%	4627000	390	8.04%

3.2.2.6. Discussion

The audit paints a picture of widespread underutilization of valuable land and infrastructure assets by DMRC. High-potential sites such as Vasant Vihar, Bhikaji Cama Place, and Anand Vihar have remained undeveloped, while major investments like the additional floors at Sarai and Raja Nahar Singh stations in Faridabad are yet to generate any return. This gross underutilization had led to severe shortfalls in projected revenues, hindering DMRC's ability to meet its funding obligations for the Phase-III project. Without a well-structured plan or strategy in place, DMRC has missed out on substantial non-fare box revenue opportunities, failing to capitalize on innovative revenue streams like semi-naming rights.

HONGKONG MTR SYSTEM: A CASE STUDY IN OVERCOMING UNDERUTILISATION AND LAND DEFICITS TO FOSTER A PROFITABLE AND SUSTAINABLE COMMERCIAL, NON TRANSPORTATIONAL REVENUE MODEL
Hong Kong's unique urban landscape, characterized by extremely high density and limited land for expansion, has driven the city to make efficient use of land resources and adopt a highly effective mass transit system to support both mobility and economic growth. This

relationship between land scarcity and efficient transit planning has shaped not only Hong Kong's urban form but also its economy, real estate market, and fiscal structure.

1. Efficient Use of Land and Transit Infrastructure:

Due to Hong Kong's land constraints, efficient land use is essential. The city has embraced a model of compact development, which has been largely supported by its mass transit system. The MTR Corporation (MTRC) has played a critical role in shaping urban areas, promoting dense construction and development along key transport corridors. The success of this model lies in its ability to concentrate both residential and commercial properties around transit hubs, reducing the need for sprawling development and enhancing the effectiveness of public transportation.

High density has not only demanded efficient land use but has also been essential in making the mass transit system financially sustainable. The high concentration of people and businesses around transit lines ensures a consistent and heavy flow of passengers, enabling the MTRC to operate efficiently and with minimal government subsidies.

2. Impact of Land Scarcity on Real Estate and Revenue:

Land scarcity in Hong Kong has translated into high property prices and a thriving real estate market. The high demand for limited space near transit hubs has driven property values up, creating significant opportunities for both the government and the private sector to generate revenue through land sales, leases, and real estate transactions. The revenue from land sales alone has historically accounted for over three-quarters of all funds for capital works, demonstrating the critical role that land management plays in funding urban infrastructure.

In addition to land sales, property taxes, rental income, and transaction fees contribute about 20% of the inland revenue, further underscoring the importance of the real estate market to Hong Kong's economy. This robust income from land and property allows the government to maintain relatively low tax rates, ensuring that the city remains an attractive place for businesses and residents alike.

3. Public Land Ownership and its Role in Urban Development:

A unique aspect of Hong Kong's system is that all land is publicly owned (except for St. John's Cathedral). This arrangement gives the government considerable control over how land is allocated, used, and developed. The government can lease land to public entities like the MTRC, facilitating the integration of transit infrastructure and urban development. This has been instrumental in supporting compact development around high-density transit corridors from an early stage of urban planning.

The government's ability to strategically lease or grant land to the MTRC has allowed the corporation to carry out its Rail + Property (R+P) model, where property development around transit stations not only funds infrastructure investment but also drives urban growth. This has fostered high-density, mixed-use development along transit lines, ensuring that the city's limited land is used to its maximum potential.

4. MTRC's Role in Shaping Urban Form:

The MTRC's involvement in land development has significantly influenced the urban layout of Hong Kong. By facilitating the construction of residential, commercial, and office buildings along its railway corridors, the MTRC has promoted transit-oriented development that reduces reliance on cars, encourages public transit usage, and ensures that the city's growth remains compact and efficient.

This strategy of densification along transit lines ensures that key areas of the city are well-served by public transportation, while also maximizing the economic return on land. The MTRC's ability to capture the increase in land value as a result of transit investments provides a continuous source of revenue, which can be reinvested in further infrastructure development.

5. Economic and Fiscal Benefits of the Land-Transit Nexus:

The combination of high-density development, efficient transit systems, and a thriving real estate market has had far-reaching economic and fiscal benefits for Hong Kong. The revenue generated from land sales and property development has allowed the city to fund large-scale

infrastructure projects without relying heavily on debt or international funding. This self-sustaining model has not only supported the expansion of the transit system but also enabled Hong Kong to maintain a competitive fiscal regime with relatively low tax rates.

The integration of transit and land use planning has also contributed to Hong Kong's global competitiveness. The city's efficient transport system and high land values attract businesses and international investment, reinforcing its role as a leading global financial center.

The LVC Model

The financing of extensive railway investments in cities like Singapore, Tokyo, and Hong Kong through land value capture (LVC) mechanisms presents a highly effective model for sustainable urban transport development. These cities have managed to transform urban growth and improve economic performance by leveraging the rising value of land around transit hubs to finance public transport infrastructure. This method has set benchmarks for local governments in Asia, as they look for innovative ways to fund transportation projects while reducing reliance on international donors.

Hong Kong's Rail + Property (R+P) Model:

One of the most successful applications of the LVC model is Hong Kong's Rail + Property (R+P) scheme, managed by the MTR Corporation (MTRC). This approach has been in use for several decades, allowing the city to not only finance its extensive transit infrastructure but also foster urban growth around rail stations.

1. LVC Through Transit and Land Development:

The R+P model allows the MTRC to develop and sell or lease land around railway stations, capturing the increase in land value that results from improved accessibility due to the transit network. By engaging in private sector land development, the MTRC effectively covers a significant portion of the infrastructure investment costs, thereby creating a self-sustaining revenue stream for funding further expansion.

2. Extensive Transit Network:

As a result of this model, the MTR network spans 240.6 kilometers (excluding high-speed rail), with 97 MTR stations and an additional 68 light rail stops. The R+P model has enabled the continuous expansion and modernization of Hong Kong's metro system without significant reliance on government subsidies or external funding.

3. Urban Transformation:

The R+P model has led to the creation of rail villages, where stations serve as the nucleus of urban clusters. The impact is profound:

42% of households, 43% of the employed population, and 75% of commercial and office floor areas are located within a 500-meter radius of a station. This proximity not only encourages high public transport usage but also spurs commercial and residential development around stations.

These developments are attractive to both commercial interests and transit users, reinforcing a synergistic relationship between transport infrastructure and land use. The walkability of the areas around the stations, with distances within 500 meters or a 10-minute walk, encourages healthier, more sustainable urban living patterns.

Implications for Urban Growth and Economic Performance:

Hong Kong's R+P model showcases how transit-oriented development can drive urban transformation and economic growth. By making railway stations the heart of commercial, residential, and office clusters, the MTRC has not only financed its infrastructure but also contributed to the creation of thriving, highly accessible urban communities. The compact development around transit hubs has reduced dependency on private vehicles, encouraging sustainable urban mobility and reducing congestion.

Lessons for Other Cities:

The success of Hong Kong's model has made it a reference point for other Asian cities looking to fund their metro systems without heavy government subsidies or loans from international donors. The integration of land development with transit planning ensures that

the value generated by transit improvements is captured and reinvested in further infrastructure development, thus creating a virtuous cycle of urban growth.

Hong Kong's model of high-density development, combined with the efficient use of land and transit infrastructure, offers a compelling example of how cities can navigate land scarcity while supporting both economic growth and urban mobility. The city's ability to capture land value increases through public ownership and strategic development around transit stations has not only allowed it to finance extensive infrastructure but also shaped its urban form in a way that promotes sustainability and efficiency.

By fostering compact, transit-oriented development, Hong Kong has ensured that its limited land resources are used to their maximum potential, driving economic growth while keeping the city connected through an expansive, efficient transport network. The success of this model provides valuable lessons for other cities facing similar challenges of land scarcity and rapid urbanization.

By adapting elements of the R+P model, other cities can enhance the financial sustainability of their public transport projects, promote mixed-use development around transit hubs, and contribute to more compact, efficient urban forms. In this way, transit infrastructure becomes not only a catalyst for mobility but also a powerful tool for shaping urban landscapes and supporting long-term economic growth.

Consolidated Profit or Loss (in HK$ million)	Years									
	2023	2022	2021	2020	2019	2018	2017	2016	2015	2014
Total revenue Hong Kong transport services										
— Hong Kong transport operations	20131	13404	13177	11896	19938	19490	18201	17655	16916	16223
— Hong Kong station commercial businesses	5117	3077	3208	3269	6799	6458	5975	54544	5380	4963
— Total Hong Kong transport services	25248	16481	16385	15165	26737	25948	24376	23199	22296	21186
— Hong Kong property rental and management businesses	5079	4779	5036	5054	5137	5055	4900	4741	4533	44190
— Mainland China and international railway, property renal and management subsidiaries	25955	26016	25045	21428	21085	20877	17194	13562	12582	12627
— Other businesses	700	363	383	894	1545	1990	2174	2339	2290	2153
— Recurrent businesses	56982	47639	46849	42541	54504	53870	48444	43841	41701	40156
— Mainland China property development	—	173	353	—	—	60	6996	1348	—	—
— Total	56982	47812	47202	42541	54504	53930	55.44	45189	41701	40156
Total EBITDA										
— Recurrent businesses	15323	7852	8019	5194	15351	18843	17677	16947	16260	15478
— Hong Kong properv development	2329	11589	1 1,097	6491	4496	2574	1097	228	2891	4216
— Mainland China property development	13	59	129	13	25	25	2314	366	(14T	55
— Total	17639	19500	19245	11672	19822	21 442	21088	17541	19011	19639
Depreciation and amortisation	6105	5769	5430	5365	5237	4985	4855	4127	3849	3485
Provisions for onerous contracts and impairment loss	1022	962	—	—	—	—	—	—	—	—
Variable annual payment	2355	323	260	238	2583	2305	1933	1787	1649	1472

Source: https://www.mtr.com.hk/archive/corporate/en/investor/10yr_stat_en.pdf

3.3. COMMERCIAL AIRPORTS: DUTY FREE AND ALLIED COMMERCIAL SERVICES AS AN EXHAUSTIVE CASE STUDY OF IMPORTANCE ON NON-CORE OPERATION SERVICES IN THE TRANSPORT SECTOR

The focus on non-aeronautical revenues for airport operators in India represents a strategic shift that capitalizes on underutilized resources to enhance profitability. This shift is particularly important as aeronautical revenues—which include landing fees, aircraft parking charges, and user development fees—are heavily regulated, limiting the potential for growth. Non-aero revenues, on the other hand, are unregulated, allowing airport operators to fully leverage their existing resources to maximize profits.

3.3.1. Significance of Non-Aeronautical Revenue in Enhancing Profitability

Maximizing Underutilized Resources: Airports are more than just transit hubs for passengers and airlines; they are also commercial centers with enormous potential for generating revenue from non-aeronautical services such as retail, duty-free shops, advertising, car parking, real estate leasing, and cargo services. By tapping into these resources, airports can make better use of the space and infrastructure that might otherwise remain underutilized. For example, large commercial areas within terminals, parking lots, and unused land parcels surrounding the airport can be developed for retail and real estate purposes.

Higher Profit Margins: Non-aeronautical services tend to have higher profit margins than regulated aeronautical services. For instance, Rs 100 earned from non-aeronautical services can result in Rs 70-80 of net profit, compared to a much lower return from aeronautical services. This is because non-aero services often have lower operational costs and benefit from higher consumer spending, particularly from international travelers. Given this potential, airport operators are increasingly working to boost their non-aero revenues, which also require less capital investment than aeronautical infrastructure.

3.3.2. Current Utilization of Resources: A Global Benchmark

Indian Airports Lag in Non-Aero Yield per Passenger: As noted by Vinay Kumar G of ICRA Limited, the non-aero yield per passenger (pax) at Indian private airports is lower compared to major airports globally. This is mainly because of a lower proportion of international and transit passenger traffic in India, who tend to spend more on non-aero services like duty-free shopping, luxury goods, and premium lounges. This lower yield indicates a significant untapped potential in Indian airports' non-aero revenue streams.

Mumbai and Delhi Airports' Growth Potential: Despite the current lower yield, there are strong growth prospects. At Mumbai and Delhi international airports, non-aero revenues are expected to reach $7 per

passenger over the next four to five years. This growth will be driven by the premiumization of services such as duty-free, luxury retail, advertising, and car parking, all of which represent strategic utilization of available airport space and services that cater to higher spending travelers, especially international passengers.

3.3.3. Focus on Non-Aero Services to Bolster Financial Sustainability

Shift in Revenue Models: The aero-to-non-aero revenue ratio at Indian airports, especially those run by the Adani Group, is currently skewed, with 75% of revenues coming from aeronautical services. However, this reliance on regulated aeronautical services limits profitability due to government-imposed price controls. In contrast, Mumbai International Airport has made better use of its resources, achieving a 50-50 split between aero and non-aero revenues, placing it closer to global benchmarks. The Adani Group aims to increase the share of non-aero revenues to 75% at its airports in the next two to three years, a target that reflects the industry's broader strategic shift.

Higher Margins with Lower Capital Investment: Non-aero services offer higher profit margins with relatively lower capital investment than aeronautical services. For example, developing retail outlets, duty-free shops, and parking facilities involves using already existing terminal space or land, thus reducing the need for new, expensive infrastructure. This approach maximizes the use of the airport’s physical assets while catering to a consumer market with discretionary spending power, particularly among international travelers.

3.3.4. Unlocking Value from Infrastructure and Services

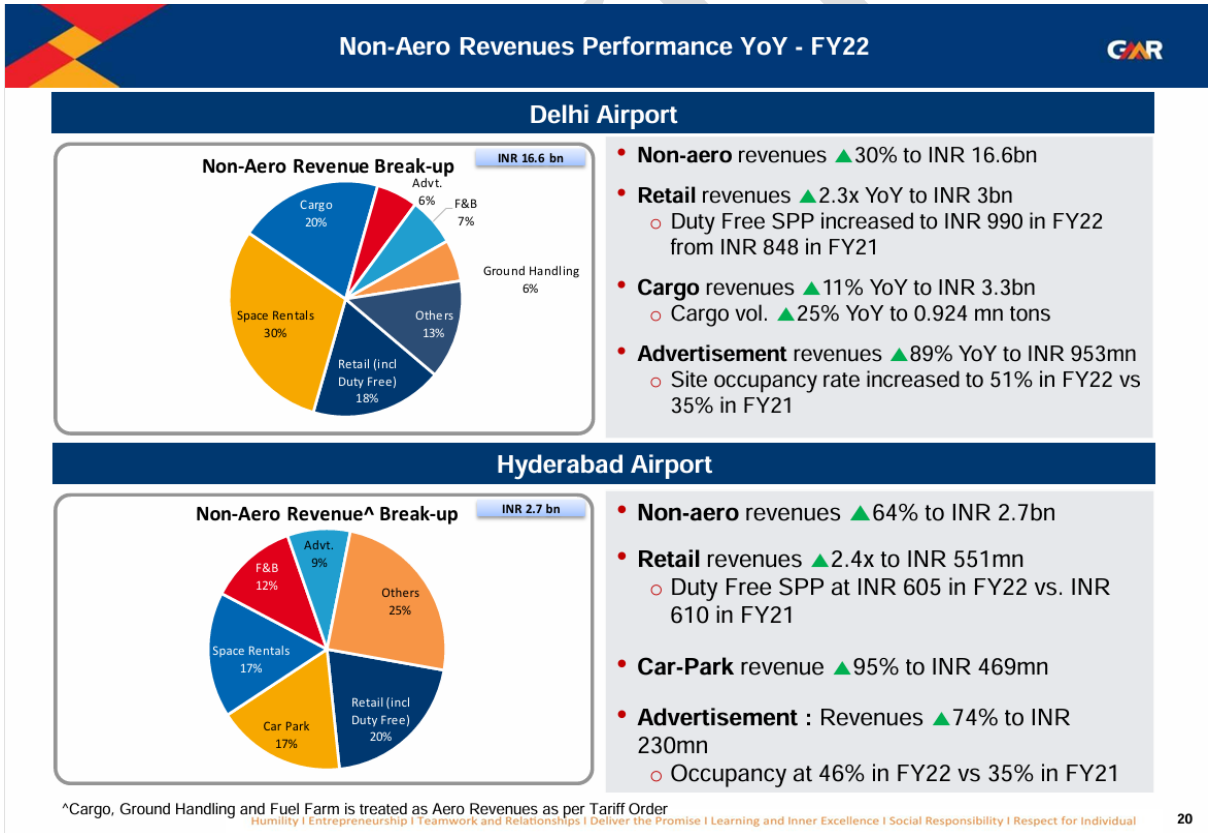
Duty-Free and Retail Opportunities: Duty-free shopping is expected to be a major contributor to non-aero revenue growth, especially at airports like Delhi and Mumbai that handle a higher share of international traffic. International passengers, with longer dwell times, are more likely to spend on luxury goods, perfumes, alcohol, and other items available at duty-free outlets. The strategic expansion and premiumization of retail services within airports can cater to this demand, significantly boosting revenue per passenger.

Real Estate and Advertising: Airport operators have large areas of underutilized real estate in and around airports that can be developed into commercial spaces, hotels, or business parks. Additionally, advertising space inside terminals and on airport grounds presents another high-margin revenue stream. By leasing out these areas to advertisers, airports can generate a steady income without significant operational costs.

Car Parking and Rentals: Parking facilities at airports also represent a critical source of non-aero revenue. As demand for airport parking grows, especially with the increasing number of passengers and visitors, improving the yield from parking services—such as premium or valet parking—offers an easy way to increase profits. Similarly, leasing out space to car rental companies or airport lounges can add to the non-aero revenue stream.

3.3.5. Strategic Moves by Major Operators

GMR Airports' Strong Non-Aero Focus: GMR Airports Infrastructure, which operates major airports like Delhi International Airport, has made strides in increasing its non-aeronautical revenue share. In FY23, GMR generated ₹3,830.97 crore (or 57.24% of total revenue) from non-aero services, a significant increase from FY22 (₹2,488.19 crore). This shows a deliberate move to utilize the airport's non-operational assets more effectively, ensuring that non-aero services contribute the largest portion of overall revenue. This shift reduces dependence on regulated aero revenues and increases profitability.



Source: Investor Report, GMR

Revenue From Non-Aeronautical Operations GMR, Indira Gandhi International Airport, New Delhi				
Particulars	(in Millions except percentages)			
	2023		2022	
Duty Free	5072.2	20%	2117.55	13%
Retail	1791.72	7%	926.7	6%
Advertisement	1665.26	7%	952.81	6%
Food and Beverages	2130.77	9%	1101.27	7%
Cargo	3360.83	14%	3314.32	20%
Ground Handling	1611.22	7%	946.22	6%
Parking	730.83	3%	347.68	2%
Land and Space Rentals	5372.1	22%	4970.3	30%
Others*	3037.51	12%	1903.02	11%
Total	24772.45	100%	16579.86	100%
*Others primarily -include revenue from IT services, -including maintenance.management, upgrades and modernization of IT resources at the IGIA received from one of the joint ventures, income from foreign exchange rcounters and flight catering charges.				

Source: Annual Report FY 2022-23, Delhi Airport as Published by GMR

Adani Group's Strategic Shift: Similarly, the Adani Group, which operates six airports including Mumbai, Ahmedabad, and Lucknow, is actively working to restructure its revenue model by focusing more on non-aero sources. With Mumbai Airport already achieving a 50-50 aero-to-non-aero revenue ratio, Adani's other airports are expected to follow suit. By investing in premium retail outlets, expanding duty-free areas, and enhancing advertising spaces, the group aims to increase the non-aero revenue share to 75% within the next few years.

3.3.6. Non-Aero Revenue as the Future of Airport Profitability

Global Benchmark for Non-Aero Revenues: Internationally, non-aeronautical revenues make up 70-80% of total profits at major airports, even if they account for only 40-50% of total revenue. Indian airports are recognizing this trend and focusing on optimizing non-aero revenue sources to stay competitive and ensure long-term financial sustainability. The move toward non-aero services is not just a necessity for higher profits but a reflection of the shift in consumer behavior at airports—where passengers increasingly expect premium experiences, shopping, and services beyond the core transport function of airports.

3.3.6. Maximizing Resources for Future Growth

The emphasis on non-aeronautical revenues in India's airport sector represents a significant opportunity to make better use of the existing infrastructure and resources. By expanding into high-margin services such as duty-free shopping, retail, advertising, and parking, airports are well-positioned to diversify their revenue streams and reduce their dependence on regulated aeronautical services. Major operators like GMR Airports and the Adani Group are already moving in this direction, with ambitious plans to increase the share of non-aero revenues to match international benchmarks. This strategic shift not only boosts profitability but also ensures the optimal utilization of airport resources, making airports hubs of commerce and services beyond their transport infrastructure roles.

4. CONCLUSION: NON-TICKETING REVENUE, EVEN WHEN OPERATED FROM SOLE PROFIT MOTIVE, CAN ANCHOR GROWTH AND DEVELOPMENT OF THE ECONOMY OF SAID REGION, SUBSEQUENTLY CONTRIBUTING TO NATIONAL GDP GROWTH

Transportation infrastructure is a critical driver of economic growth at the regional, state, and national levels, with far-reaching impacts on trade, productivity, and employment. Globally, investments in transport systems have consistently been linked to enhanced economic performance, as seen in countries like Japan, the United States, and Singapore. In India, regions like the Delhi-NCR (National Capital Region) have benefited significantly from improvements in transportation infrastructure, such as the Delhi Metro and highways. However, there are still substantial gaps that, if addressed, could further amplify the economy's growth potential.

In economic terms, transportation infrastructure lowers logistics and transportation costs, improves market access, and facilitates the movement of labor and goods. For instance, research by the World Bank shows that every dollar invested in infrastructure yields a return of $1.50 to $2 in GDP growth over time. In India, the Pradhan Mantri Gati Shakti initiative, which aims to integrate and streamline logistics infrastructure, has identified transport as a key pillar for achieving its target of a $5 trillion economy. The program focuses on enhancing multi-modal transport systems, which reduce delays, lower transportation costs, and improve the competitiveness of Indian goods in global markets. However, significant gaps remain in the utilization of publicly owned land around transportation hubs, and the underinvestment in urban transport systems is evident.

In Delhi-NCR, the Delhi Metro Rail Corporation (DMRC), despite its vast network, has faced shortfalls in generating non-fare box revenue from property development. As highlighted by the CAG audit in 2020, DMRC fell short by nearly ₹1,841.19 crore in projected revenue from property development and naming rights between 2016-2020. This underutilization of available resources contrasts with the successful examples of land value capture (LVC) models used in other global cities, such as Hong Kong, Tokyo, and Singapore.

Hong Kong's MTR Corporation (MTRC) is a prime example of leveraging transportation infrastructure for urban and economic growth through its Rail + Property (R+P) model. The MTRC developed land surrounding metro stations, creating commercial and residential hubs that not only facilitated transport but also generated significant revenue. Approximately 42% of Hong Kong's households and 75% of its commercial spaces are located within walking distance of an MTR station, reflecting the transformative impact of this integrated approach. This model allowed the MTRC to become self-sustaining and to finance

further network expansion. In India, this concept could be effectively replicated around the Delhi Metro and other metro systems, where valuable real estate near stations remains underdeveloped. As of 2020, DMRC had only generated ₹657.13 crore from property development against a target of ₹2,505 crore, pointing to significant lost potential for creating a self-financing cycle.

Non-aeronautical revenues at airports in India provide a parallel model that can be applied to metro systems. In airports like Delhi and Mumbai, non-aero revenue—derived from retail, duty-free, advertising, and parking—accounts for a large share of total income. According to ICRA, non-aero revenue per passenger at private airports in India is expected to reach $7/passenger over the next five years, with growing retail and premiumization opportunities driving this increase. GMR and Adani Airports have both recognized the high-profit potential of non-aero revenue, which contributes significantly to overall profitability despite accounting for a smaller share of total revenue. In 2023, non-aero revenues made up over 57% of GMR's revenue at Delhi International Airport, illustrating how airports are leveraging non-transportation activities for financial sustainability. Similarly, metro systems can generate substantial revenue through station area development, retail leases, and advertising rights, providing critical funds for infrastructure maintenance and expansion.

The need for these self-financing models is evident in the gaps in public transportation infrastructure investment in India. While substantial investments have been made, such as the Bharatmala and Sagarmala projects, urban transport systems continue to suffer from funding shortfalls. The economic benefits of improved transportation infrastructure are clear. For instance, McKinsey Global Institute estimates that India needs to spend $1.1 trillion on infrastructure by 2030 to meet the needs of its growing population and urbanization. However, government budgets alone cannot sustain this level of investment, which is why leveraging private sector participation through public-private partnerships (PPPs) and land monetization is essential.

By harnessing revenue from property development and non-fare services, urban transit systems can initiate a virtuous cycle of investment and growth. These funds can be used to pay off debts, refinance loans, and further invest in system upgrades, creating a self-sustaining model. This cycle not only eases the financial burden on public budgets but also stimulates broader economic growth by promoting efficient land use, fostering real estate development, and attracting commercial activity around transport hubs.

In conclusion, investment in transportation infrastructure is crucial for sustained economic growth, particularly in fast-urbanizing regions like Delhi-NCR. Through better utilization of land resources and the implementation of self-financing models like Hong Kong's R+P, India can bridge existing investment gaps,

boost non-fare revenues, and create long-term economic benefits that support national development goals. This integrated approach to infrastructure funding will not only help meet growing urban demands but also contribute significantly to India's economic transformation.

REFERENCES:

The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement (Second Amendment) Bill, 2015 (prsindia.org)

https://ncst.nic.in/sites/default/files/2017/Presentation/MRD.pdf
https://ncst.nic.in/sites/default/files/2017/Presentation/MRD.pdf

https://prsindia.org/billtrack/prs-products/prs-legislative-brief-2459

Contemporary Issues and Challenges of Land Acquisition Law in India | National Law School of India University (nls.ac.in)

https://www.indiacode.nic.in/handle/123456789/2121?sam_handle=123456789/1362

The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Bill, 2013 (prsindia.org)

https://economictimes.indiatimes.com/news/politics-and-nation/gujarat-assembly-clears-amendments-to-land-acquisition-law/articleshow/51632690.cms?from=mdr

Current Land Issues in India: Puzzles and Possible Solutions – NUS Institute of South Asian Studies (ISAS)

https://pib.gov.in/newsite/printrelease.aspx?relid=170771

https://www.thehindu.com/news/national/bullet-train-will-operate-within-gujarat-for-now/article68363908.ecem

https://www.financialexpress.com/business/railways-bullet-train-project-in-india-2024-launch-date-nhsrcl-indian-railways-3475130/

https://web.archive.org/web/20190923042744/https://mumbaimirror.indiatimes.com/mumbai/other/only-39-of-land-needed-for-ambitious-mumbai-ahmedabad-bullet-train-project-acquired/articleshow/69900940.cms

Delhi metro rail: Beyond mass transit by Pritpal Randhawa

LAND ACQUISITION IN INDIA: A CRITICAL REVIEW by Moushila De

Critical Issues Related to Metro Rail Projects in India

https://cag.gov.in/en/audit-report/details/114644

https://delhimetrorail.com/OtherDocuments/DMRC_Annual-Report-2012-2013.pdf

https://delhimetrorail.com/OtherDocuments/DMRC_Annual-Report-2012-2013.pdf

https://delhimetrorail.com/OtherDocuments/EnglishAR201314Low.pdf

https://delhimetrorail.com/OtherDocuments/Review%20Report%20(2014-15).pdf

https://delhimetrorail.com/OtherDocuments/DMRCAEnglhYear20156.pdf

https://delhimetrorail.com/OtherDocuments/Annual%20Accounts%20And%20Directors%20Report%202016-17.pdf

https://delhimetrorail.com/OtherDocuments/DMRC-English-AR-Year-2017-18.pdf
https://backend.delhimetrorail.com/documents/20/DMRC-REPORT-2018-2019-English-Web.pdf

https://backend.delhimetrorail.com/documents/18/DMRC-English-Annual-Report-2019-20.pdf

https://backend.delhimetrorail.com/documents/1749/DMRC-AR-2020-21-14022022.PDF

https://backend.delhimetrorail.com/documents/3502/DMRC_Annaul_Report_2021-22_Lowres.pdf

https://backend.delhimetrorail.com/documents/3502/DMRC_Annaul_Report_2021-22_Lowres.pdf

https://www.theguardian.com/cities/2019/mar/19/how-public-transport-actually-turns-a-profit-in-hong-kong

Land value capture and transit oriented development as a way of funding railway systems: The case of Hong Kong Rail + Property Model by Franco Jauregui-Fung

https://www.mtr.com.hk/archive/corporate/en/investor/10yr_stat_en.pdf

TABLE OF CONTENTS

1. INTRODUCTION

Digital infrastructure is the backbone of modern economies, facilitating communication, financial transactions, and the efficient functioning of businesses and governments. In the context of India, the development of digital infrastructure has been pivotal in transforming the country's economic landscape, fostering inclusivity, and creating a robust foundation for future growth. The Indian government's initiatives, such as Digital India, aim to provide seamless internet connectivity and digital services to all citizens, thus democratizing access to information and resources.

India's digital infrastructure has evolved significantly over the past decade, driven by the rapid expansion of mobile broadband, fiber-optic networks, and digital payment platforms. This growth has had far-reaching implications, enabling more efficient service delivery, enhancing business competitiveness, and contributing to the overall economic development of the nation. The rise of mobile phone penetration and internet connectivity has not only facilitated the emergence of a vibrant digital economy but also brought millions of individuals and small businesses into the formal financial system through digital payments.

The role of digital infrastructure in economic development is multifaceted. It drives productivity by improving the efficiency of businesses and reducing transaction costs. For instance, the adoption of digital payment systems, like the Unified Payments Interface (UPI), has transformed how businesses conduct transactions, allowing for faster, more secure, and transparent operations. Digital infrastructure has also been crucial in improving governance through the implementation of e-governance initiatives, which have streamlined public service delivery and reduced bureaucratic inefficiencies.

Moreover, digital infrastructure plays a key role in fostering financial inclusion, as demonstrated by the Pradhan Mantri Jan Dhan Yojana, which brought millions of unbanked individuals into the financial system. This has empowered marginalized communities by giving them access to banking services, digital payments, and government subsidies, which were previously out of their reach. The availability of affordable mobile internet has further accelerated this inclusion, as mobile phones have become a primary means of accessing financial services.

India's burgeoning IT and software services sector also owes much of its success to the robust digital infrastructure. The industry has become a major contributor to GDP growth, job creation, and exports,

positioning India as a global leader in IT-enabled services. With the rise of emerging technologies like 5G, artificial intelligence, and cloud computing, India's digital infrastructure will continue to be a critical enabler of innovation, economic competitiveness, and sustainable development.

2. LITERATURE REVIEW

India's journey into the digital age has been one of remarkable transformation, reshaping its economy and society in ways unimaginable a decade ago. The widespread adoption of digital infrastructure, especially mobile broadband and payment platforms, has played a pivotal role in driving this change. What was once a largely cash-dependent economy now boasts a robust digital payments ecosystem, with UPI leading the charge. From humble beginnings, UPI transactions surged from 92 crore in FY 2017-18 to over 8,375 crores in FY 2022-23, highlighting how technology has embedded itself into the everyday lives of millions. This growth wasn't in isolation; it was part of a broader effort, driven by the government's initiatives like the Aadhaar Payment Bridge and DigiLocker, which brought essential services to citizens in even the most remote areas.

But as with any story of progress, there are obstacles. The vast and diverse landscape of India presents challenges, none more pressing than the digital divide that continues to plague rural regions. As urban centers surged ahead, leveraging the latest in broadband and fintech innovations, rural areas struggled to keep pace. In 2022, only about 52% of India's population had access to the internet, and a stark gender divide further complicated the picture, with men significantly more likely to be online than women. While the country has made impressive strides, these gaps threaten to leave large sections of the population behind.

Amidst this transformation, another powerful force is emerging: artificial intelligence. AI is poised to be a game-changer, offering possibilities that stretch the imagination, from revolutionizing healthcare to transforming cities into smart, data driven urban spaces. Yet, as Mhlanga noted in 2021, AI is a double-edged sword. It offers unprecedented opportunities but comes with risks, such as job displacement and biases within its algorithms. If deployed responsibly, however, AI could further drive the nation's digital infrastructure, but it will require a balance of innovation and ethics.

The government's vision for a digitally empowered India took form through initiatives like Digital India, launched in 2015. This program sought to provide seamless internet connectivity and digital services to all

citizens, democratizing access to information and resources. By 2022, the impact was clear: internet penetration had nearly doubled since 2015, creating a digitally connected society. Yet, as impressive as these numbers are, rural areas remain a blind spot, where infrastructure is often underdeveloped, and digital literacy remains a hurdle.

Public infrastructure, too, saw the influence of India's digital revolution. The creation of Digital Public Infrastructure (DPI) set the stage for improved governance and service delivery. With projects like Aadhaar and the Jan Dhan Yojana bringing millions into the formal economy, India created systems that bridged long-standing gaps. The Aadhaar Payment Bridge, for example, facilitated secure transfers of government benefits, helping to empower marginalized communities. DigiLocker, another innovation, allowed citizens to store vital documents digitally, eliminating many bureaucratic hurdles.

As India's digital landscape evolved, so did its entrepreneurial spirit. Startups began to flourish, especially in the IT services, fintech, and e-commerce sectors, all buoyed by government support and improved infrastructure. These digital entrepreneurs represented the future, with the potential to create jobs and drive innovation. However, the contribution to employment remains modest, reminding us that while technology drives change, it doesn't always ensure widespread job creation.

Looking ahead, the future of India's digital journey will likely be shaped by the continued integration of advanced technologies like AI and 5G. The introduction of 5G has already begun to reshape connectivity, increasing data consumption and enabling next-generation services like autonomous transportation and telemedicine. However, ensuring that these advances reach beyond urban centers will be a critical challenge. The promise of AI and 5G lies not just in their technological potential but in their ability to transform industries and lives across the country.

In the end, India's digital transformation is far from complete. The journey continues, with progress marked by both incredible advancements and persistent challenges. The digital divide, ethical deployment of AI, and the need for rural inclusion remain issues that need addressing. However, with continued investment and thoughtful policies, the potential for a fully connected, digitally inclusive India remains within reach.

3. RESEARCH METHODOLOGY AND SCOPE

Research Design

This study employs a comprehensive mixed-method approach to analyze trends and developments in India's digital infrastructure. The research design is based on systematic secondary research methodology, focusing on collecting and analyzing existing data and literature to ensure robust and reliable conclusions.

Methodological Framework

The study primarily utilizes extensive secondary research methods through a systematic review process. This includes a comprehensive examination of government publications, official documents, industry reports, market research studies, academic literature, scholarly publications, and international organization reports. The methodology emphasizes thorough verification and cross-referencing of information to maintain accuracy and reliability.

Analytical Approach

The analytical framework combines both quantitative and qualitative methods. The quantitative analysis encompasses statistical examination of growth metrics, comparative analysis of sector-wise developments, and economic impact assessment through various indicators. Time-series analysis is employed to understand developmental patterns and trends in digital infrastructure growth.

The qualitative component focuses on policy framework evaluation, assessment of implementation challenges, stakeholder perspective analysis, and examination of best practices in the field. This dual approach ensures a comprehensive understanding of both measurable outcomes and contextual factors affecting digital infrastructure development.

Research Process

The research process follows a structured approach beginning with systematic data collection from verified sources. This is followed by a rigorous analysis phase where information is classified, categorized, and examined for patterns and trends. The process emphasizes the chronological organization of information to track developmental trajectories effectively.

The synthesis phase integrates findings from various sectors and aspects of digital infrastructure development. This integration allows for the development of coherent narratives and a comprehensive understanding of the interconnections between different elements of digital infrastructure growth.

Quality Assurance

Quality assurance measures are integral to the research methodology. The process includes continuous validation of data through multiple source verification and cross validation of findings. Expert consultation is sought for the interpretation of complex trends and patterns. The methodology acknowledges temporal limitations and considers the rapidly evolving nature of the digital landscape.

Research Ethics

The study maintains strict adherence to academic integrity guidelines throughout the research process. This includes proper attribution of information, transparent reporting of findings, and objective analysis of data. The methodology ensures an unbiased interpretation of results while maintaining academic rigor.

Limitations

The research methodology acknowledges inherent limitations in secondary research approaches. These include potential gaps in available data, temporal limitations in rapidly evolving digital scenarios, and variations in regional coverage. These limitations are carefully considered in the analysis and interpretation of findings. In conclusion, this comprehensive methodology has been designed to ensure a thorough examination of India's digital infrastructure development. The approach facilitates evidence-based conclusions and recommendations while maintaining academic standards and analytical depth. The framework allows for systematic analysis of trends, challenges, and opportunities in the digital infrastructure landscape, supporting the development of meaningful insights and practical recommendations.

Scope of the Report

This report comprehensively analyses India's digital infrastructure, focusing on its trends, sectoral and regional growth, and integration into the private and public sectors. It explores the development of digital infrastructure in key areas, offering state-wise and sector-wise assessments to highlight regional disparities and sectoral performance. The report also delves into the rapid growth of artificial intelligence (AI) in India

and its profound impact on the economy, including its influence on innovation, productivity, and employment. Furthermore, it examines the role of digital infrastructure in the public sector, evaluating its integration into governance and service delivery and its contributions to improved efficiency and inclusivity. Through these lenses, the report aims to provide a holistic understanding of India's evolving digital ecosystem and its critical role in shaping its economic and social development.

Research Objectives:

1. **Examine the Trends in Digital Infrastructure Development in India over the last decade**

Analyze the growth and evolution of digital infrastructure across the country, with a focus on key indicators for the year.

2. **Assess Sector-Wise and State-Wise Growth of Digital Infrastructure**

Investigate the development and expansion of digital infrastructure across various sectors and states, highlighting regional disparities and sectoral advancements.

3. **Explore the Integration of Digital Infrastructure in the Public Sector**

Assess the adoption and integration of digital technologies within the public sector, with a focus on governance, service delivery, and public administration efficiency.

4. Trends in Digital Infrastructure Development in India

4.1 Digital Infrastructure Growth

Digital infrastructure has emerged as an essential component of modern society, comparable to traditional basic needs such as roads, electricity, and water. The COVID-19 pandemic has significantly accelerated the demand for resilient digital systems, prompting governments worldwide to enhance their digital capabilities. This infrastructure encompasses the physical resources and systems required to process and utilize data effectively, playing a pivotal role in supporting contemporary economies.

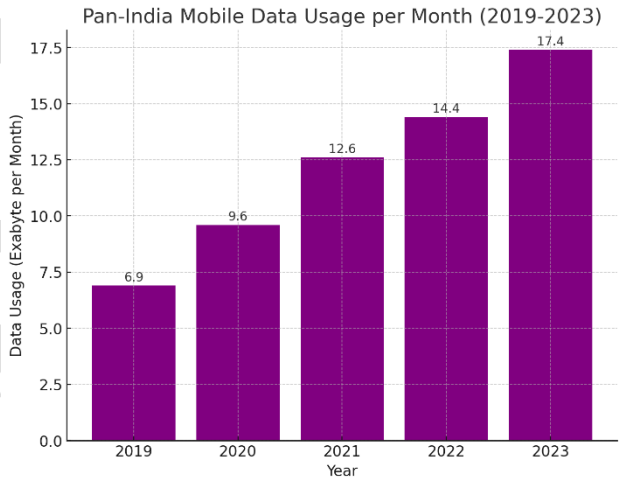
Countries are increasingly focused on building agile and resilient digital frameworks to adapt to the rapidly evolving technological landscape. The Indian government, for instance, has set an ambitious goal of achieving a $5 trillion economy within five years, with digital transformation as a key foundation. The Digital India Mission prioritizes security, reliability, and the seamless provision of digital services. With an internet user base nearing 500 million, India is well-positioned to harness significant economic gains

through digital transformation. Projections suggest that this user base could expand five-fold by 2025, offering lucrative opportunities for both domestic and international companies to invest in advanced technologies tailored to India's unique needs.

The rapid adoption of new technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), and blockchain, alongside the pressures introduced by the pandemic, has further highlighted the necessity of robust digital infrastructure. As India accelerates its progress toward smart cities and improves its healthcare system, reinforcing its digital backbone is essential for unlocking the full potential of these technologies. This is not only vital for economic growth but also for ensuring long-term social development.

Growth of Mobile Broadband in India

The expansion of mobile broadband in India has been nothing short of transformative. Mobile data traffic has witnessed exponential growth over the past five years, increasing from 6.9 Exabytes (EB) per month in 2019 to 17.4 EB per month by the end of 2023, reflecting a compound annual growth rate (CAGR) of 26%. This surge has been driven by the widespread adoption of 4G networks, the early deployment of 5G, and the increasing penetration of smartphones in both urban and rural areas. Notably, early 5G adopters have contributed significantly to this growth, as they tend to consume much more data compared to 4G users.



Source: Nokia Analysis, Operator Quarterly Reports, TRAI

Additionally, the average monthly data consumption per user mirrors this upward trend, growing at a CAGR of 21.1%. Monthly data usage has increased from 11.2 GB per user in 2019 to 24.1 GB in 2023,

primarily due to the rising demand for high-definition video streaming, online gaming, and other bandwidth-intensive applications. This growth is further evidenced by a 24% year-on-year increase in personal data usage, underscoring the growing significance of mobile broadband in users' daily activities.

The momentum of this growth is projected to continue. Forecasts indicate that average monthly data consumption could rise to 28-30 GB per user by the end of 2024. The expansion of 5G services, coupled with the introduction of new mobile solutions such as Fixed Wireless Access (FWA) and enhanced enterprise offerings, is expected to drive this increase. With 5G enabling up to 3.6 times more data consumption than 4G, India's digital landscape is set for further transformation, unlocking vast opportunities for innovation and connectivity.

Smartphone Adoption: Trends Over the Years

India's smartphone market is experiencing robust growth, with projections estimating that it could reach a staggering $90 billion by 2032. This growth is largely fuelled by economic development, demographic shifts, and increasing consumer demand for digital connectivity.

- **Economic and Demographic Drivers**

By the end of the decade, India is expected to emerge as the world's third-largest economy, with its GDP projected to more than double to $7.5 trillion, at an annual growth rate of 6.6%. As the economy develops, the number of high-income households is anticipated to increase five-fold by 2031, thereby boosting consumer purchasing power and driving smartphone adoption. Currently, smartphone penetration in India stands at around 40%, which is considerably lower than the global average of 60%, indicating significant room for growth.

- **Market Growth Forecast**

The Indian smartphone market is projected to grow at a CAGR of 11% over the next decade, driven primarily by urbanization and infrastructure development. By 2032, India is expected to account for 15% of the global smartphone market value, up from the current 6%, positioning itself as a major growth engine for the global smartphone industry, accounting for 20% of global shipments.

- **Changing Consumer Preferences**

Recent surveys highlight a strong desire among Indian consumers to upgrade their smartphones, with three-quarters of respondents planning to purchase a new device within the next year. Moreover, consumers are willing to spend 20% more on their next smartphone, with younger consumers (aged 18-25) willing to pay up to 30% more. This shift indicates a growing demand for premium features, such as 5G capability, enhanced camera quality, and increased storage capacity.

- **The Shift to Premium Devices**

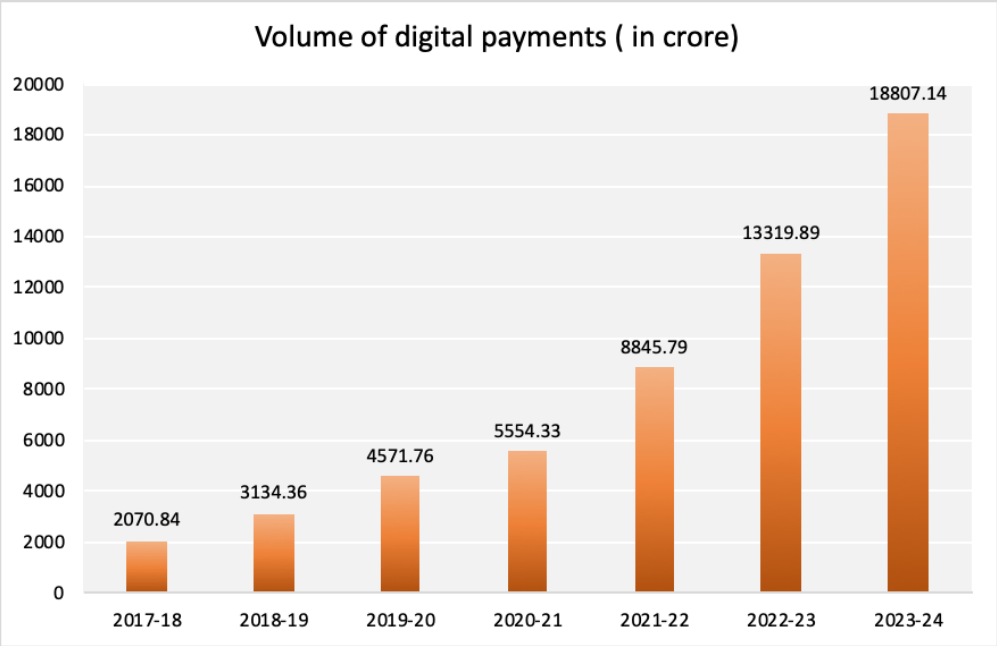
Future growth in India's smartphone market is expected to be driven primarily by demand for higher-end devices, with 80% of this growth coming from smartphones priced above $250. This marks a significant shift from the previous five years, during which the market was dominated by lower-end, budget devices. Smartphones have become a central part of daily life in India, with consumers prioritizing smartphone purchases over other household items, reflecting changing attitudes and the increasing importance of digital technology.

In conclusion, the combined forces of economic growth, demographic shifts, and evolving consumer preferences have positioned India as a key player in the global smartphone market, with substantial growth expected in the coming years.

4.2 Digital Payments Ecosystem in India

India's digital payments ecosystem has expanded significantly in recent years, driven by a combination of government initiatives, increased internet and smartphone penetration, and the rapid growth of e-commerce. The bar chart in Fig. 1 showcases the impressive growth in digital payment volumes across India over seven consecutive fiscal years, from 2017-18 to 2023-24. This period represents a pivotal shift in both consumer behaviour and business practices, as India increasingly transitions from traditional cash-based transactions to digital payment systems. The data, measured in crores, underscores the vast scale of digital payment adoption nationwide.

Fig. 1 Volume of Digital Payments in India from 2017-18 to 2023-24



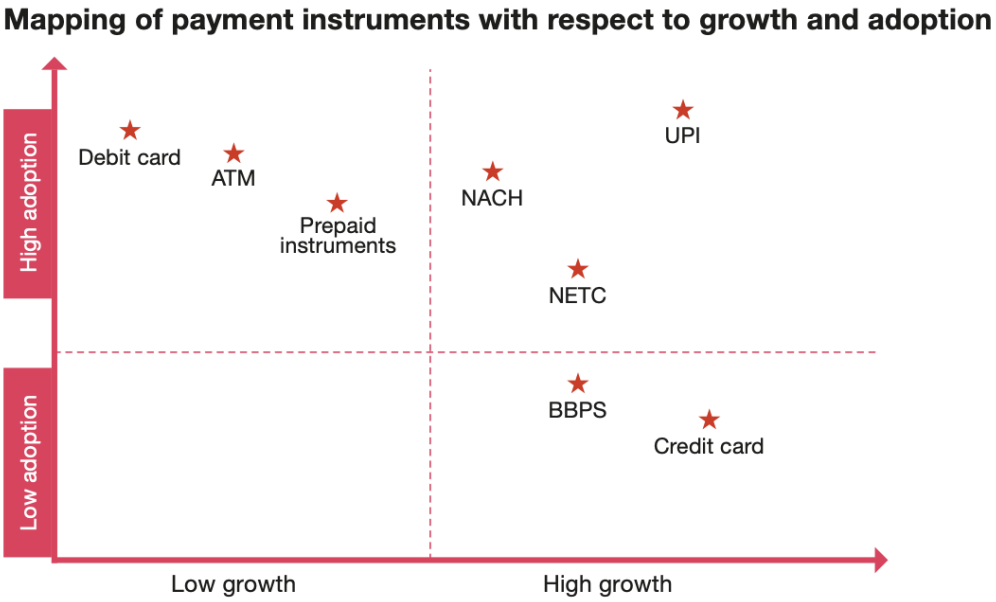
In the fiscal year 2017-18, the volume of digital payments stood at 2,070.84 crore, establishing a baseline for subsequent years. By 2018-19, this figure had surged to 3,134.36 crore, reflecting a growing preference for digital transactions across the country. The upward trend continued in 2019-20, with digital payment volumes reaching 4,571.76 crore, solidifying the nation's shift toward digital payment platforms. The fiscal year 2020-21 saw a marked increase in digital payments, rising to 5,554.33 crore. This growth can be largely attributed to the effects of the COVID-19 pandemic, which accelerated the adoption of contactless, digital payment methods as people sought safer alternatives to physical transactions. By 2021-22, the volume of digital payments had surged further to 8,845.79 crore, signalling a broader acceptance of digital payment systems across both urban and rural sectors of India. The fiscal year 2022-23 witnessed an even more dramatic rise, with digital payment volumes reaching 13,319.89 crore. This exceptional growth highlights the increasing integration of digital payments into various sectors, from retail to services. By 2023-24, digital payment volumes had reached an all-time high of 18,807.14 crore, marking the culmination of consistent, year-on-year increases and reinforcing India's ongoing movement toward a cashless economy.

Notably, the highest year-on-year growth occurred between 2021-22 and 2022-23, with digital payment volumes increasing by approximately 4,474.1 crore during this period. This substantial jump reflects the rapid scaling of digital payment solutions, driven by technological advancements, the proliferation of

smartphones, government policies promoting digital transactions, and a fundamental shift in consumer preferences toward convenience, speed, and efficiency.

Over time, the Indian government, in consultation with the Ministry of Finance and the Reserve Bank of India, has introduced over 16 different digital payment modes to facilitate this transition. These include AEPS, BHIM Aadhar, BHIM UPI, Closed Loop Wallet, Credit Card, Debit Card, IMPS, Internet Banking, Mobile Banking, NACH, NEFT, PPI, RTGS, and USSD, providing a broad range of options for consumers and businesses alike to engage in digital transactions.

Fig. 2 Mapping of Payment Instruments with respect to Growth and Volume



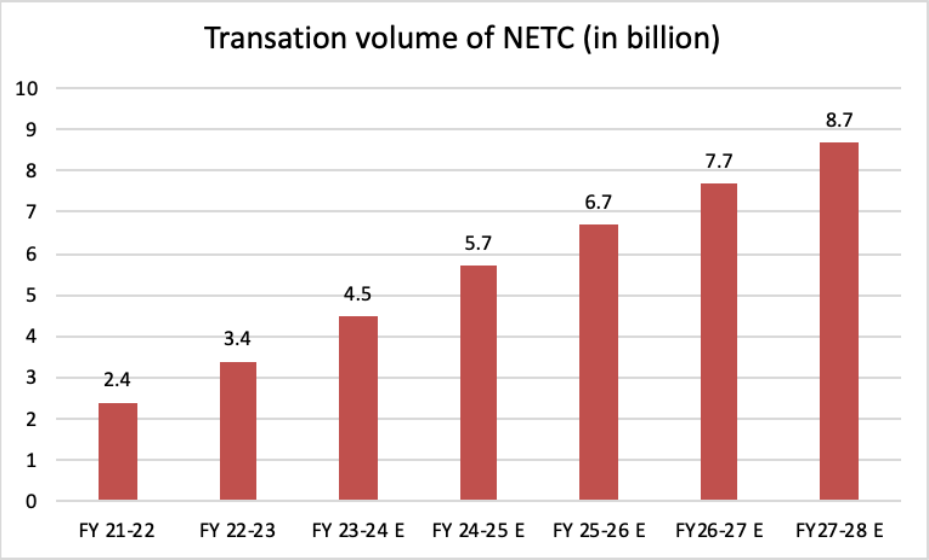
With respect to the growth and volume of digital payment instruments, Debit cards and ATMs demonstrate a high level of adoption; however, their growth rate remains relatively stagnant. Conversely, the Unified Payments Interface (UPI) occupies a position in the high adoption and high growth category, signifying not only its broad acceptance across users but also its rapid increase in usage. Payment instruments such as credit cards, the Bharat Bill Payment System (BBPS), and the National Electronic Toll Collection (NETC) exhibit differing patterns of adoption and growth. Notably, emerging digital payment systems like UPI are characterized by both significant growth and widespread adoption, while more traditional methods, such as

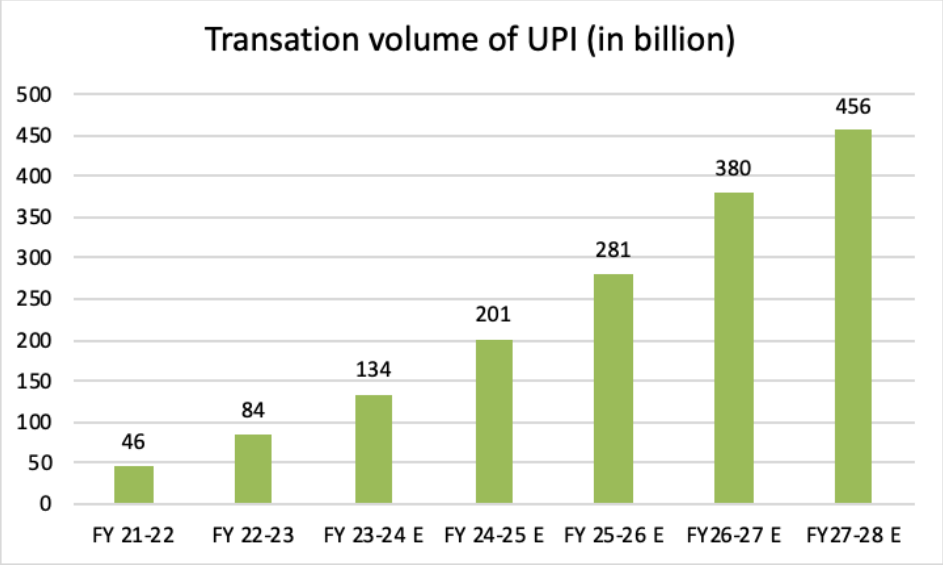
debit cards and ATMs, maintain high user penetration but exhibit much slower growth trajectories. This disparity highlights the evolving consumer preference towards newer, more efficient payment technologies.

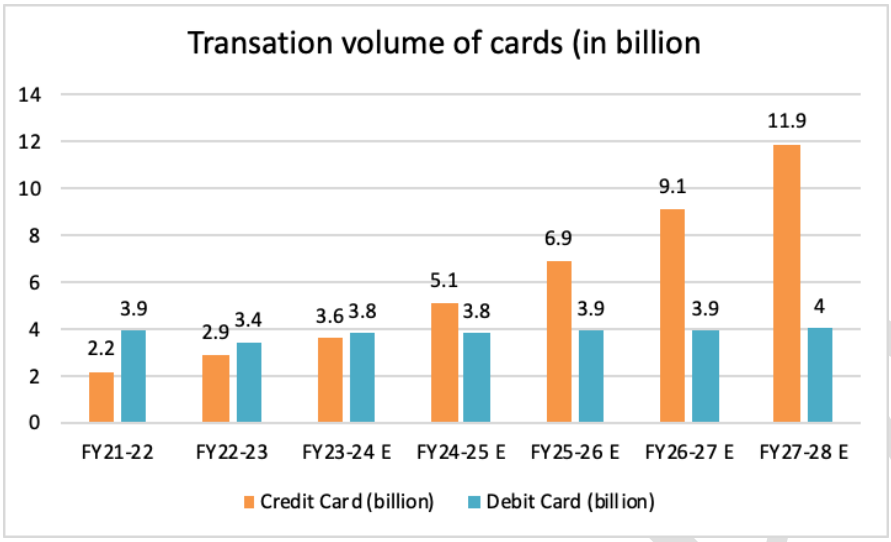
Growth Trends in Digital Payment Instruments

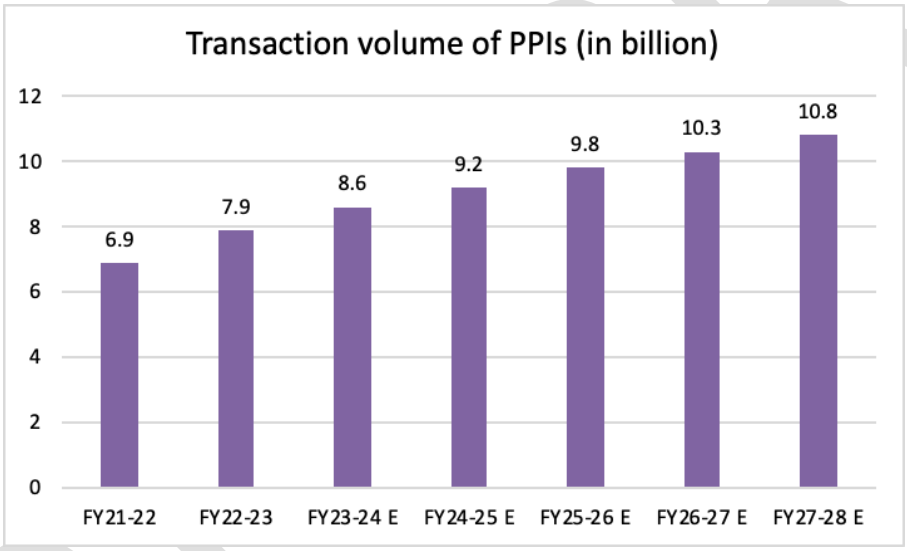
The transaction volumes of various digital payment instruments, including NETC (National Electronic Toll Collection), Prepaid Instruments (PPIs), credit cards, and UPI, have shown significant growth and are projected to increase further in the coming years. As of May 2023, UPI accounted for more than 78% of all retail digital payments in India, and according to PwC estimates, it is expected to contribute approximately 90% by FY 2026–2027. Month-over-month data from FY 2023-24 indicates that credit card transaction volumes surpassed those of debit cards in January, maintaining this lead throughout the fiscal year. This shift is largely due to the attractive features offered by credit cards, such as a 30–45-day interest-free credit period, along with additional incentives like cashback, reward points, and various savings options.

Fig. 3 Transaction volumes of NETC, PPIs, Cards, and UPI (in billions)


Transation volume of NETC (in billion)
10
9
8
7
6
5
4
3
2
1
0
2.4
3.4
4.5
5.7
6.7
7.7
8.7
FY 21-22
FY 22-23
FY 23-24 E
FY 24-25 E
FY 25-26 E
FY26-27 E
FY27-28 E


Transation volume of UPI (in billion)
500
450
400
350
300
250
200
150
100
50
0
46
84
134
201
281
380
456
FY 21-22
FY 22-23
FY 23-24 E
FY 24-25 E
FY 25-26 E
FY26-27 E
FY27-28 E





Technological advancements have played a critical role in driving this growth. Features such as contactless payment options, the integration of UPI with credit cards, and the broadening acceptance of credit cards across merchants have significantly boosted transaction volumes and customer adoption. Furthermore, the transaction volumes of PPIs are expected to grow at a compound annual growth rate (CAGR) of 7%, while NETC transactions are forecasted to expand at a remarkable 23% CAGR over the next five years. These trends highlight the evolving landscape of digital payments in India, driven by consumer preferences for convenience, technology integration, and financial benefits.

4.2 Internet Penetration

India has experienced rapid growth in mobile internet connectivity, marked by a substantial increase in active mobile broadband subscriptions over the last decade. Since 2010, the country has shown remarkable progress, surpassing many other G20 nations and nearing global averages in subscriber numbers. India now ranks as the second-largest market for mobile and internet users worldwide, with one of the highest growth rates globally. This expansion underscores India's strategic emphasis on information and communication technology (ICT) services, solidifying its role as a major player in offshore business services and digital innovation. Smartphone adoption in India is projected to rise from 77% in 2022 to 95% by 2030, driven by factors such as rising disposable incomes and increased internet penetration. Consequently, India has emerged as one of the largest smartphone markets globally.

Fig. 4 Number of Active Mobile Broadband Subscriptions (Source: ITU and TRAI)

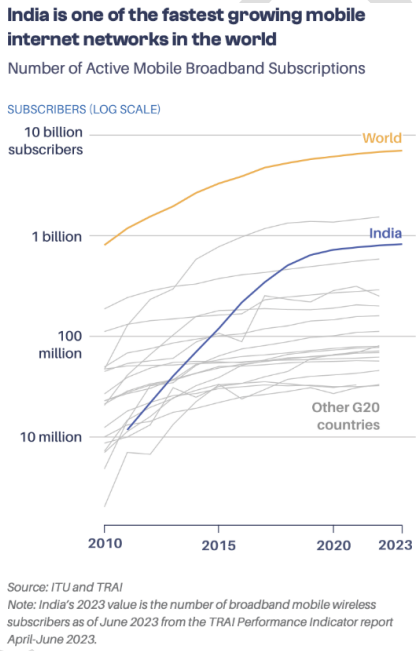
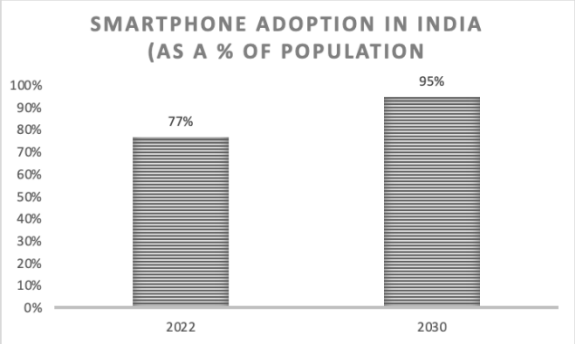


Fig. 5 Smartphone Adoption in India (as % share of population)



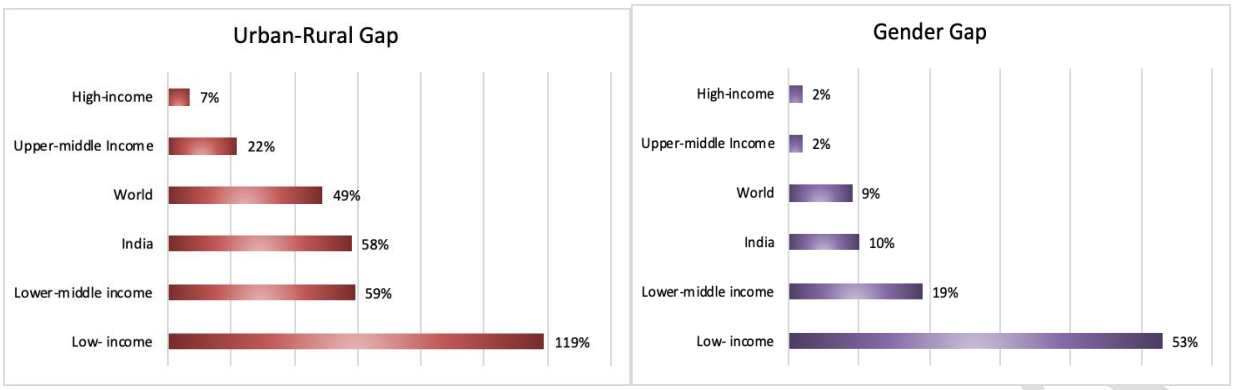
Internet connectivity for businesses in India is relatively widespread, though global indices may not fully reflect this due to missing data from certain countries. The market is further bolstered by the widespread availability of affordable smartphones and low-cost data plans, making India the most cost-effective among G20 countries. These factors have significantly improved internet access across different income groups. However, challenges persist, including low average revenue per user (ARPU) for telecom companies and the affordability of internet-enabled devices, potentially constraining future infrastructure investments. Despite these hurdles, India's mobile internet sector remains robust, playing a crucial role in the country's growing digital economy.

As of March 2023, India has deployed approximately 750,000 telecom towers, with plans to nearly double this figure to 1.5 million by 2024-25. Currently, about 38.44% of these towers are fiberized, with a target to double the fiberization rate by 2024-25. Broadband access now reaches 885 million people, accounting for 60% of the population. However, a significant disparity exists between rural and urban areas in terms of internet penetration. In 2023, urban internet penetration stood at 107%, while rural penetration lagged behind at 40%.

4.4 Digital Divide in India

The digital divide* describes the gap between individuals who have access to modern information and communication technologies (ICT), like the Internet, and those who do not. This divide often correlates with disparities in income, education, and geographic location.

Fig. 6 Digital Divides in India (Urban-Rural Gap and Gender Gap)

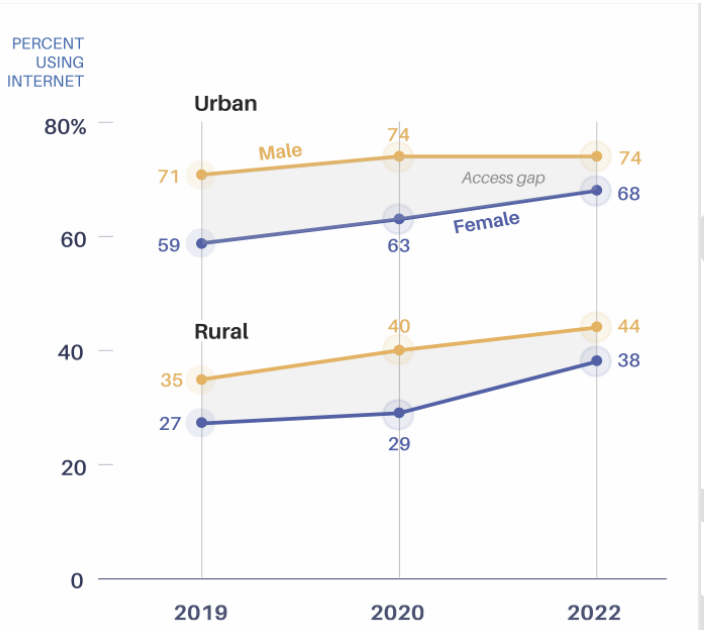


Source: ITU, IMRB Kantur ICube

The graph above highlights the digital divide in India, with a focus on urban-rural disparities and gender gaps in internet access. On the left, it illustrates the substantial difference in internet penetration between urban and rural areas, particularly pronounced among low-income groups. Here, the divide reaches 119%, underscoring significantly lower internet access in rural regions compared to urban centres. As income levels increase, this gap narrows, with lower-middle-income groups showing a 59% disparity and the overall national divide standing at 58%, which is notably higher than the global average of 49%. For upper-middle-income and high-income groups, the urban-rural gap is significantly smaller, at 22% and 7%, respectively, indicating that higher income levels are associated with reduced disparities in internet access between urban and rural areas.

On the right, the graph emphasizes the gender gap in internet access. In India, the overall gender gap stands at 10%, slightly exceeding the global average of 9%. The gender divide is especially stark among low-income groups, where the gap reaches 53%, reflecting significantly lower internet access for women compared to men in this income bracket. As income levels rise, this divide diminishes, with lower-middle-income groups showing a 19% gap, and upper-middle-income and high-income groups showing a minimal gap of just 2%.

Fig. 7 Urban-Rural Gap and Gender Gap from 2019 to 2022



Source: IPCIDE Research and Kantar IMRB ICube Survey

Between 2020 and 2022, the gender gap in internet access in India showed signs of narrowing, with significant improvements in rural women's access. The most notable progress occurred among women aged 35 and above, particularly in northern and eastern regions. This improvement is partly attributable to the increased sharing of internet-enabled devices within households, where men are typically the primary users. However, the reduction in the rural gender gap was uneven across regions. While states like Uttar Pradesh and Madhya Pradesh, which initially had low internet access rates for rural women, saw significant reductions in the gender gap, other states, such as Jharkhand, experienced an increase.

These findings underscore the deep socio-economic and gender-related disparities in internet access in India. The particularly wide gaps among low-income and rural populations highlight the challenges in ensuring equitable digital access. Bridging these divides is critical for inclusive growth and broader socio-economic development. This emphasizes the urgent need for targeted policies aimed at underserved communities to address these digital inequities.

4.5 Government Initiatives

India has emerged as a global leader in digital payments and financial technology, largely due to proactive government policies and initiatives. Over the past decade, the Indian government has implemented a series of transformative policies that have revolutionized the country's digital payment landscape and supporting infrastructure. This section evaluates the key government policies that have been instrumental in this digital transformation.

One of the most impactful initiatives has been the Unified Payments Interface (UPI), launched in 2016 by the National Payments Corporation of India (NPCI). UPI has been a game-changer for digital payments in India, recording over 9.36 billion transactions in May 2023, a 58% year-over-year increase. The total value of these transactions reached ₹14.3 trillion (approximately $172 billion), demonstrating a 48% year-over-year increase. By 2022, UPI had amassed over 300 million active users. The success of UPI can be attributed to its interoperability across banks and fintech platforms, real-time transaction processing, simple and user-friendly interface, and zero-cost framework for basic transactions.

The Digital India program, launched in 2015, has been another cornerstone of India's digital transformation. This comprehensive initiative aims to transform India into a digitally empowered society and knowledge economy. The impact of this program has been substantial, with internet penetration increasing from 27% in 2015 to 47% in 2022. The volume of digital payments grew at a compound annual growth rate (CAGR) of 55% from 2015-16 to 2020-21. A key component of Digital India is the Aadhaar program, which has become the world's largest biometric ID system, covering over 99% of India's adult population. Other crucial elements include BharatNet, which aims to provide broadband connectivity to all 250,000+ gram panchayats (village councils), DigiLocker for digital document verification, and UMANG, a unified platform for new-age governance.

The Jan Dhan-Aadhaar-Mobile (JAM) Trinity has been pivotal in creating a robust foundation for digital financial inclusion. This initiative combines three separate programs to create a powerful platform for financial services delivery. As of May 2023, over 462 million Jan Dhan accounts have been opened, significantly expanding financial inclusion. The impact is evident in the increase of adults with a bank account, rising from 53% in 2014 to 80% in 2021. The JAM Trinity has also facilitated efficient direct benefit transfers, with ₹25.16 trillion ($303 billion) transferred directly to beneficiaries' accounts since 2013.

To foster innovation in financial services, the Reserve Bank of India (RBI) introduced a regulatory sandbox in 2019. This initiative allows fintech companies to test their products in a controlled environment with real customers, albeit on a limited scale. By 2023, 26 entities had tested their products in four cohorts, focusing on areas such as retail payments, cross-border payments, MSME lending, and prevention of financial fraud. The regulatory sandbox provides relaxed regulatory requirements for the testing period, allowing for innovation while maintaining oversight.

The India Stack, a set of open APIs and digital public goods, has been instrumental in creating a unique digital infrastructure that governments, businesses, startups, and developers can utilize. Key components of India Stack include the presence-less layer (Aadhaar authentication, eKYC), paperless layer (digital records, eSign), cashless layer (UPI, Aadhaar Enabled Payment System), and consent layer (Data Empowerment and Protection Architecture). The impact of India Stack is evident in the over 9 billion eKYC transactions performed and more than 1.3 billion documents signed electronically.

The success of India's digital payment policies can be attributed to several factors. These include a holistic approach combining identity, financial inclusion, and technology; strong public-private partnerships in developing and implementing solutions; a focus on interoperability and open standards; continuous innovation and adaptation to emerging technologies; and robust regulatory support and guidance.

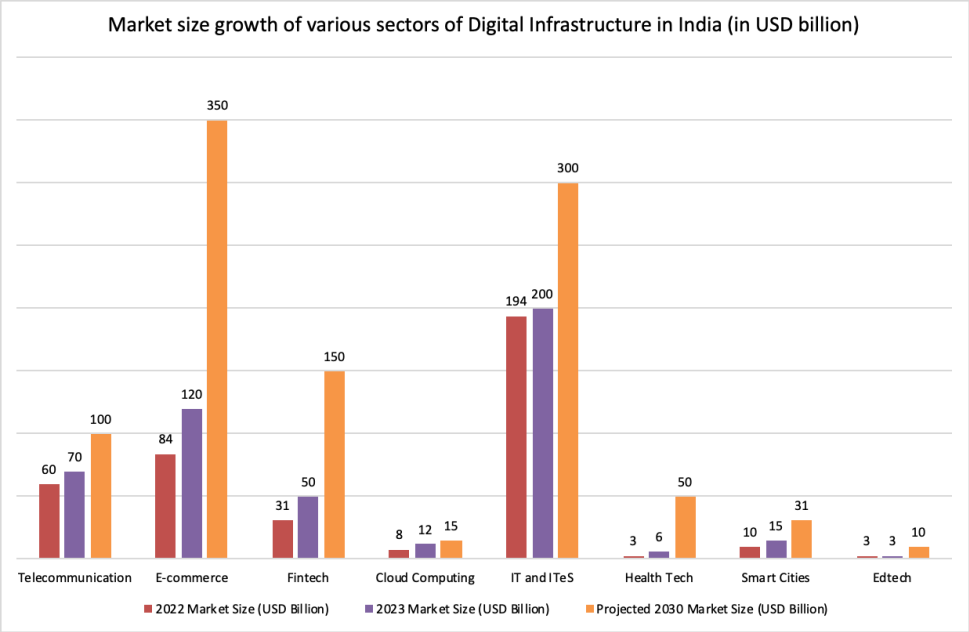
While these policies have transformed India's payment landscape and set a global benchmark for digital financial inclusion, challenges remain. These include ensuring robust cybersecurity and data protection, bridging the digital divide to include the last mile, balancing innovation with financial stability, and achieving cross-border interoperability. As India continues to evolve its digital payment ecosystem, addressing these challenges while maintaining the momentum of innovation will be crucial for sustained success.

In conclusion, India's government policies have been pivotal in driving digital payments and infrastructure development. The combination of UPI, Digital India, JAM Trinity, the regulatory sandbox, and India Stack has created a robust ecosystem that has not only transformed India's financial landscape but also positioned the country as a global leader in digital payments and financial technology. As India moves forward, the continued evolution of these policies and the development of new initiatives will be crucial in addressing emerging challenges and maintaining the country's trajectory of digital financial innovation and inclusion.

5. Sectoral Growth of Digital Infrastructure in India

5.1 Analysis of Sector-Wise Growth of Digital Infrastructure

Fig. 8 Market size growth of various sectors of Digital Infrastructure in India (in USD billion)



India's digital infrastructure is currently undergoing a remarkable transformation driven by technological advancements, increasing internet access, and comprehensive government initiatives to foster a robust digital economy. This analysis explores growth trends across multiple sectors and highlights their critical role in shaping the country's digital framework, backed by specific market size figures and growth rates.

The telecommunications sector is central to India's digital advancement. Its market is expected to grow from $60 billion in 2022 to $70 billion in 2023. It is expected to reach $100 billion by 2030, at a compound annual growth rate (CAGR) of 7%. This growth is primarily driven by the proliferation of mobile networks and increasing demand for high-speed internet services. Government initiatives like the National Broadband Mission are playing a key role in improving connectivity across the country.

E-commerce has seen phenomenal growth in India. The market size is expected to grow from $84 billion in 2022 to $120 billion in 2023 and could reach $350 billion by 2030, indicating a staggering compound annual growth rate of 20%. This growth is driven by increasing digital adoption, changing consumer preferences towards online shopping, and favourable policies under the Digital India initiative, all aimed at

strengthening the digital economy. Another area to watch is the fintech sector. The market size is expected to grow from $31 billion in 2022 to $50 billion in 2023, reaching $150 billion by 2030. This rapid growth represents a robust annual growth rate of 18%. The increase is mainly due to the widespread adoption of digital payment methods through platforms such as the Unified Payments Interface (UPI), which is central to the government's vision of promoting a cashless society and improving financial inclusion.

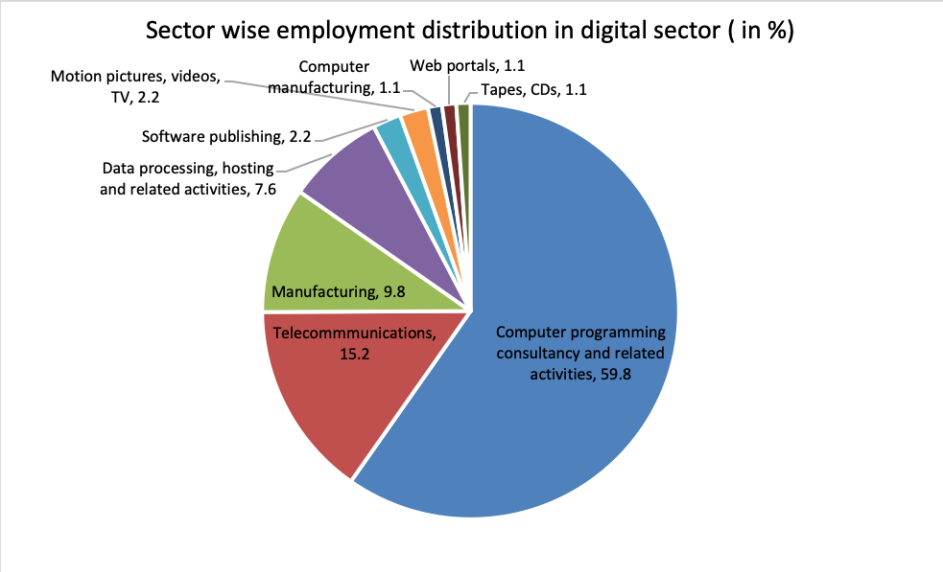
Significant growth is expected in cloud computing. Forecasts suggest that it will grow from $8 billion in 2022 to $12 billion in 2023, eventually reaching around $15 billion by 2030, with an annual growth rate of 10%. The growing trend of businesses moving to cloud-based solutions to improve scalability and operational efficiency is a major growth driver in this sector. This is supported by government initiatives such as the "Cloud Vision for India 2022" to help companies digitally transform. The IT and IT-enabled services (ITeS) sector remains an integral part of India's economic framework. With a market size of $200 billion in 2023 (up from $194 billion in 2022), the sector is expected to grow to $300 billion by 2030, achieving a compound annual growth rate of 8%. The success of the sector is underpinned by a highly skilled workforce, robust digital infrastructure, and ongoing efforts to foster innovation and global service delivery.

The health technology sector is also poised for significant growth. Market size estimates are expected to grow from $3 billion in 2022 to $6 billion in 2023 and reach $50 billion by 2030, a staggering annual growth rate of 40%. This growth is driven by the increasing use of telemedicine, digitization of health records, and integration of artificial intelligence in health diagnostics, supported by initiatives such as the Ayushman Bharat Digital Mission.

Finally, smart city initiatives represent a key aspect of digital infrastructure development, with a market value estimated at $10 billion in 2022 and projected to grow to $15 billion in 2023, making the sector worth US$203 billion, at a compound annual growth rate of 11%. The government's investments in urban modernization are aimed at leveraging technologies such as IoT and big data analytics to improve urban services while enabling effective governance, thus improving the quality of life for citizens.

5.2 Employment Generation and Trends in the Digital Sector

Fig. 9 Sector-wise employment distribution in the digital sector (%)



Source: RBI, December, 2022

The employment distribution within the digital sector, as reported by the Reserve Bank of India in December 2022, reveals a strong concentration in a few key areas. Computer Programming, Consultancy, and Related Activities dominate the sector, accounting for nearly 60% of the total employment. This underscores the central role of software development, IT consulting, and related services in driving the digital economy.

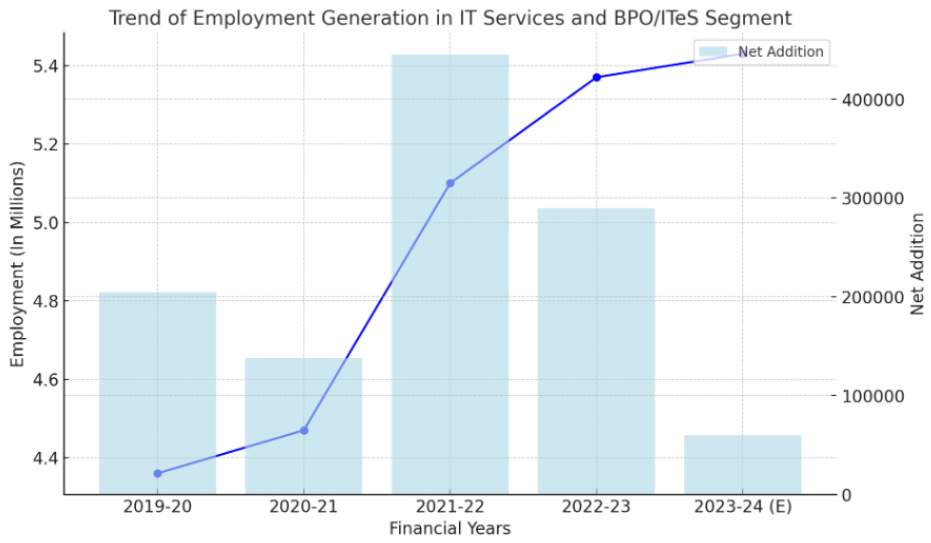
Telecommunications is the second largest contributor to employment, with a 15.2% share. This sector's significant role highlights the ongoing need for robust infrastructure that supports digital connectivity. Meanwhile, Manufacturing represents 9.8% of the workforce, indicating the importance of electronics and hardware production, as well as recycling, in sustaining digital infrastructure.

Other sectors such as Data Processing, Hosting, and Related Activities and Software Publishing account for 7.6% and 2.2% of employment, respectively. These areas reflect the growing demand for data management services and the continued importance of software development. Although sectors like computer manufacturing, web portals, motion pictures, videos, and TV contribute smaller shares, they remain integral to the overall functioning and growth of the digital industry.

Overall, this distribution illustrates a concentrated yet diverse employment landscape in the digital sector, with a clear emphasis on programming and telecommunications. These areas are pivotal for innovation and infrastructure, supporting the broader growth of the digital economy.

Employment Trend of Digital Infrastructure from 2019-20 to 2023-24

Fig. 10: Employment Generation Trend in IT Services and BPO/ITeS Segment in India (2019-20 to 2023-24)



The trend line graph offers an insightful examination of employment trends in the IT services and BPO/ITeS segment in India, covering the period from 2019-20 to the projected figures for 2023-24. This analysis focuses on two critical metrics:

1. Total Employment (in millions), visualized by the blue line.
2. Net Addition of Jobs Each Year, represented by the light blue bars.

These indicators collectively highlight the sector's substantial impact on employment generation and its direct influence on related industries such as transportation, real estate, catering, security, and housekeeping. The trends illustrated in the graph reflect broader economic patterns and the evolving landscape of the IT sector in India.

1. **Growth in Employment (2019-20 to 2023-24)**

Steady Increase in Employment: From 2019-20 to 2023-24 (E), there has been a steady increase in employment within the IT services and BPO/ITeS sector. The workforce has expanded from 4.36 million in 2019-20 to an estimated 5.43 million by 2023-24. This consistent growth is indicative of several underlying factors:

- **Digital Transformation**: India has been undergoing a significant digital transformation, driven by both public and private sector initiatives. This transformation has created a surge in demand for IT services, ranging from software development to customer support, fuelling job creation.
- **Global Outsourcing Hub**: India remains a global leader in outsourcing, particularly in the IT and ITeS sectors. The country's competitive advantage, built on a skilled and cost-effective workforce, continues to attract international businesses seeking to outsource their operations. This demand directly translates into employment opportunities.
- **Government Initiatives**: Programs like Digital India and policies promoting the IT sector have created a favourable environment for growth. Government incentives and investments in infrastructure have bolstered the sector, leading to an increase in job opportunities.

2. Significant Job Creation in the Year 2021-22

The net addition of jobs each year reveals a pattern of fluctuation, reflecting the sector's ability to navigate economic challenges while maintaining its role as a significant employment generator. The 2021-22 fiscal year experienced the highest net addition of jobs, with **445,000 new positions** created. This spike in job creation can be attributed to several factors:

- **Post-Pandemic Recovery**: The year marked a significant recovery following the economic disruptions caused by the COVID-19 pandemic. As businesses adapted to the new normal, there was a rapid acceleration in digital adoption, leading to increased demand for IT services. Companies expanded their IT and customer support teams to manage the growing digital infrastructure and online services.
- **Remote Work Adoption**: The pandemic also accelerated the shift towards remote work. This transition opened up opportunities for IT service providers to offer new solutions and support systems, further driving job creation in the sector.

- **Expansion of Services**: The IT and BPO sectors expanded their service offerings to include more advanced technologies like *artificial intelligence, machine learning, and cloud computing*. The need for specialized skills in these areas contributed to the creation of new jobs.

3. **Slowdown in Job Creation in the Year 2023-24 (Projection)**

However, the projected data for 2023-24 indicates a noticeable slowdown in job creation, with only 60,000 new jobs expected to be added. This deceleration could be due to several factors:

- **Market Saturation**: As the sector matures, the rapid growth experienced in previous years may have led to a point of market saturation. The demand for basic IT services might be reaching its peak, leading to fewer new job opportunities.
- **Increased Automation**: The adoption of automation and AI technologies within the IT and BPO sectors could reduce the need for human labour. Routine tasks that were once performed by large teams are increasingly being handled by automated systems, leading to a slower rate of job creation.
- **Economic Uncertainty**: Global economic factors, including inflation, geopolitical tensions, and shifts in global trade, may contribute to businesses' cautious approach to expanding their workforce. This uncertainty could be causing companies to optimize existing resources rather than aggressively hiring new talent.

Despite the expected slowdown in job creation, the IT services and BPO/ITeS sector continues to be a vital employment generator in India. The sector is characterized by its large and diverse workforce, with approximately 36% of employees being women, highlighting its role in promoting gender diversity in the workplace.

The evolution of this sector will remain a key indicator of broader economic and employment trends in India. As the country continues to advance in digital transformation and adopt new technological innovations, the IT services and BPO/ITeS sector is likely to evolve in response to these changes. This evolution could include a shift towards more high-skilled jobs in emerging areas such as data analytics, cybersecurity, and AI-driven solutions. In conclusion, while the growth rate of employment in this sector may slow down, its importance as a pillar of India's economy is unlikely to diminish. The sector's ability to adapt to technological changes and market demands will determine its future trajectory and its ongoing contribution to employment generation in the country.

The Impact of AI on Employment: Job Displacement and Creation Across Sectors

Sector	Current Jobs (Millions)	% of Jobs That Will Be New	% of Jobs That Will Be Changed
IT-BPM	-3.9	10-20	60-65
Automotive OEM	2.04	10-15	55-60
Automotive Components	5.99	10-15	55-60
Retail: Food and Grocery	21.4	5-10	20-25
Textile: Weaving	7.7	5-10	30-35
Textile: Garmenting	19.3	10-15	35-40
Banking	1.24	15-20	55-60

Source: NASSCOM-FICCI-EY (2017)

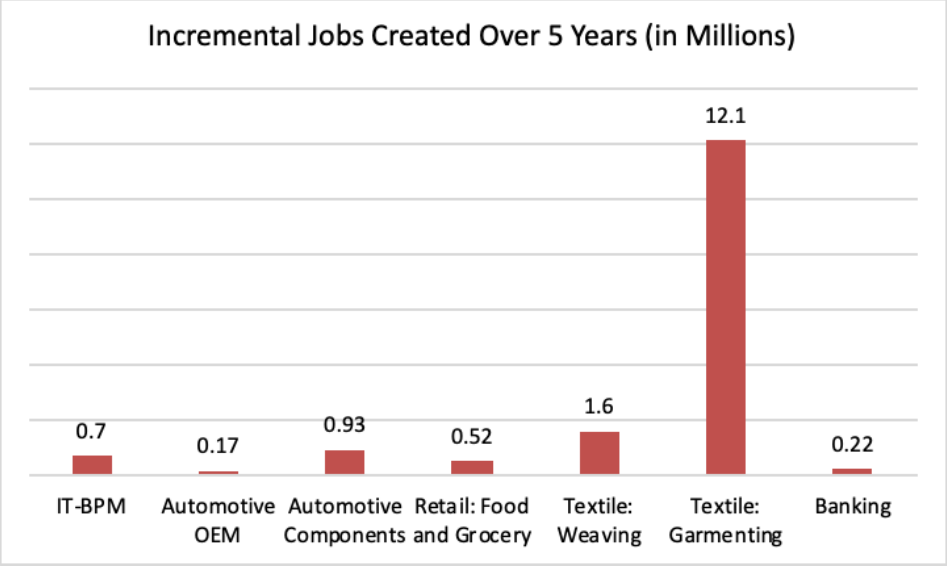


Fig. 11: Incremental jobs created over 5 years

Artificial Intelligence (AI) is reshaping the employment landscape by automating routine tasks and enabling personalized services, resulting in both job displacement and creation across various sectors. As industries increasingly integrate AI, the nature of work and the skills required to thrive are evolving. A report by MeitY (2019) highlights that digital interventions, including AI, could reskill and upskill 40 to 45 million workers in India by 2025, creating approximately 20 million new jobs. This transformation is already evident in sectors like IT-BPM, manufacturing, agriculture, and transport, and logistics, where AI technologies are redefining traditional roles and operations.

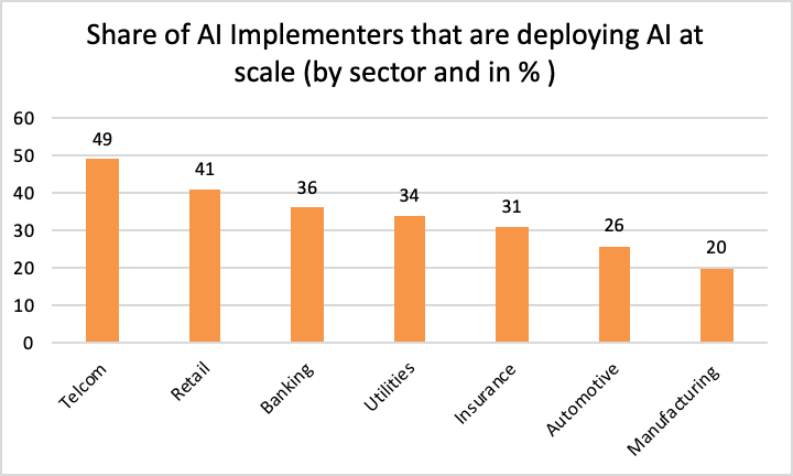


Fig 12. Share of AI Implementers that are deploying AI at scale (by sector and in %) (Source: Capegemini, 2017)

AI adoption, however, varies across industries. According to Capgemini (2017), the telecom sector leads with an AI adoption rate of 49%, followed by retail (41%), banking (36%), utilities (34%), and insurance (31%). This trend underscores AI's role in driving operational efficiency, enhancing customer experience, and optimizing resource utilization. As AI adoption grows, industries will face significant shifts in job roles, fostering innovation-driven employment while also disrupting established functions.

Despite the benefits, the shift to AI-driven processes poses challenges. A NASSCOM-FICCI-EY report (2017) indicates that in the IT-BPM sector, 20-35% of current jobs are at risk of automation, potentially leading to job losses if reskilling efforts do not keep pace with technological advances. Similarly, the automotive OEM and parts sector faces a 15-20% risk of job automation, necessitating a workforce equipped with specialized digital skills. The retail, textile, and banking sectors are also undergoing transformations due to AI, which increases efficiency but demands proficiency in new-age technologies.

This creates a complex environment where job displacement coincides with new opportunities, emphasizing the need for strategic workforce development.

A shift in consumer preferences towards AI-driven services, such as travel bookings, tax preparation, and administrative support, is further altering the employment landscape. Growing trust in AI's capabilities is driving demand for AI-centric roles, such as data architects, machine learning engineers, AI product managers, and robotic process automation (RPA) developers. However, the rapid pace of AI development has led to a significant skills gap, as there is a shortage of qualified professionals to fill these emerging positions. This underscores the urgent need for comprehensive reskilling programs that emphasize both technical AI skills and strategic decision-making, alongside ethical considerations for AI implementation. Moreover, AI is creating new job opportunities in areas like data creation, consulting, and healthcare improvement. For instance, data creation centres offer employment to individuals with basic digital skills, contributing to the development of training datasets critical for AI learning. AI-driven advisory services are expanding into agriculture, rural healthcare, and finance, enhancing access to expertise in these fields. In healthcare, AI's ability to handle routine tasks allows professionals to focus on more complex cases, ultimately improving the overall quality of care.

This evolving landscape demonstrates AI's transformative effect on employment, requiring a proactive approach to reskilling and upskilling the workforce. By investing in workforce development and embracing AI-enabled roles, industries can mitigate job displacement risks while maximizing AI's potential to fuel economic growth and innovation.

5.3 Recent IT Sector Growth and Export Trends

India's IT and BPO Sector: A Global Leader and Catalyst for Transformation

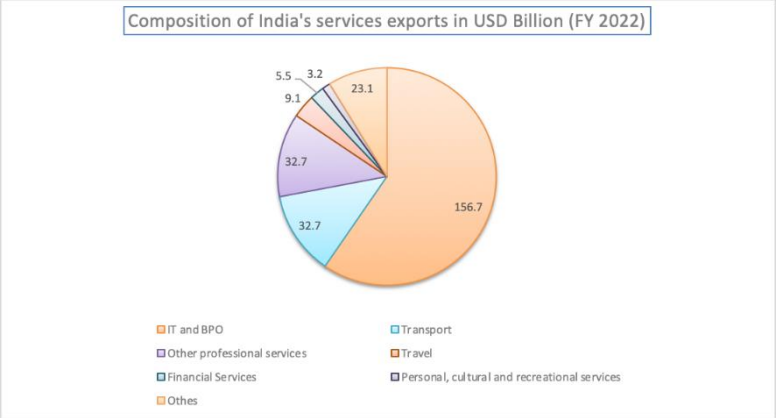
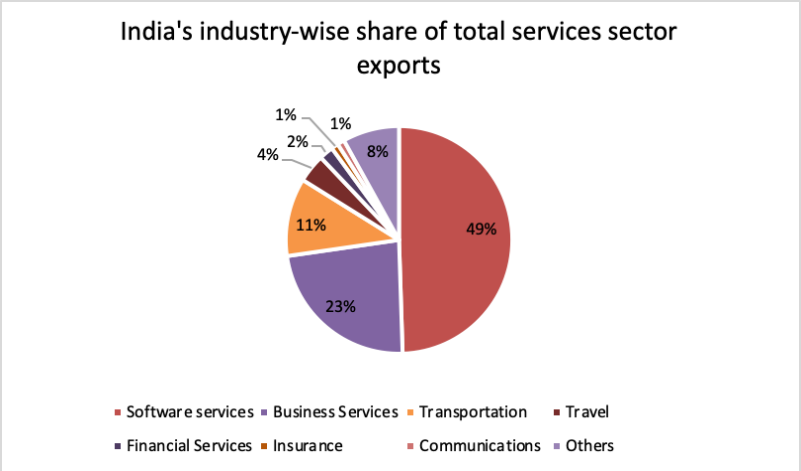


Fig. 13 Composition of India's services exports in US$bn (FY2022)

Source: RBI

India has firmly positioned itself as a global leader in Information Technology (IT) and Business Process Outsourcing (BPO) services, generating estimated revenues of approximately $157 billion in FY 2021-22. Of this, $106 billion was attributed to IT services, while BPO services contributed $51 billion. Beyond its substantial economic impact, the industry has emerged as a major source of employment, directly providing jobs for around 5.1 million individuals and indirectly creating over 12 million additional positions. Over the next two decades, India's IT sector is poised for rapid expansion, with an increasing focus on delivering complex, transformational services that require specialized expertise. As Indian professionals assume more advanced roles, they will help global organizations manage end-to-end digital operations, transitioning India from a technology back-office hub to a strategic leader in digital transformation for some of the world's largest corporations.

Fig. 14: Industry-wise share of total services sector exports (FY 2023)



Source: RBI

In 2023, Software Services accounted for 49% of India's total services exports, marking it as the leading export sector and underscoring the dominance of IT-related services in the country's export portfolio. This significant share reflects India's well-established reputation as a global hub for IT services, including software development and business process outsourcing. With its strong foundation in digital engineering and a growing emphasis on cutting-edge technologies, the Indian IT industry continues to shape the global digital landscape.

The future of India's IT industry is also closely linked to advancements in emerging technologies such as robotics and artificial intelligence. The industry is aiming to develop a hybrid workforce of robots and engineers capable of delivering round-the-clock services. This shift from traditional operational services to higher-value roles—such as consulting, digital innovation, and product development—is fuelling the evolution of new business models and processes critical to modern enterprises. Indian IT firms are increasingly focusing on areas like the Metaverse, 5G technologies, cybersecurity, and automation, positioning themselves to provide end-to-end solutions that go beyond operational support to include strategic guidance, design, and full-scale implementation. These advances are expected to further strengthen India's status as a global technology leader.

5.4 The Role of AI and its Impact on Digital Infrastructure

Generative AI (GenAI) refers to a class of artificial intelligence technologies capable of creating new content, such as text, images, music, or even code, by learning from vast datasets. Unlike traditional AI, which primarily analyses and predicts, GenAI can produce original outputs that mimic human creativity and decision-making. This emerging technology has the potential to revolutionize various industries by automating complex tasks, enhancing productivity, and driving innovation.

GenAI is projected to be a game-changer for India's economic landscape, with estimates indicating that it could contribute between $1.2 trillion and $1.5 trillion to the country's GDP over the next seven years. By fully integrating GenAI into its economic framework, India stands to gain an additional $359 billion to $438 billion by FY 2029-30, which could account for a 5.9% to 7.2% increase above baseline GDP projections. The impact of AI, however, extends beyond economic gains. It plays a crucial role in advancing the United Nations' Sustainable Development Goals (SDGs), with research suggesting that AI could contribute to the achievement of 79% of the SDGs and address 134 out of the 169 targets that may otherwise remain unmet by 2030. AI's potential is particularly pronounced in areas such as poverty reduction, affordable clean energy, industrial innovation, and sustainable urban development.

India's AI landscape has seen substantial growth, with significant strides in research, adoption, and cross-sector applications. Initiatives such as the development of an English-Hindi machine translation system, the national AI strategy, and the #AIForAll program launched by NITI Aayog in June 2018 emphasize India's focus on AI-driven advancements in key sectors, including healthcare, agriculture, education, smart cities, and infrastructure. These efforts underscore the nation's dedication to advancing AI and semiconductor technologies, which are critical to its long-term development goals. Furthermore, recent regulatory and policy measures, such as the **Data Protection Act 2023**, the **New National Policy 2023**—which proposes new PhD and Master's programs in Machine Learning and AI at universities—and the **Digital India Bill**, demonstrate India’s commitment to fostering a robust AI ecosystem.

To support this vision, the Government of India has allocated Rs 1,040 crore to the **India AI Mission**, aimed at building a comprehensive AI infrastructure and ecosystem. Key objectives of this mission include developing a state-of-the-art computing infrastructure with more than 10,000 GPUs through public-private partnerships, as well as providing Indian startups and researchers with access to high-quality non-personal datasets to drive AI innovation. India's AI capabilities are now well above the global average, with the

prevalence of AI-related skills increasing nearly three-fold between 2015 and 2023. This highlights the country's growing expertise and leadership in AI technologies, positioning it to be a global leader in the field.

The Role of AI Across Key Economic Sectors

- **Public Services**

Artificial intelligence (AI) is transforming public services by enhancing the efficiency and accessibility of essential systems, including transportation, environmental monitoring, disaster response, and public safety. AI is also playing a crucial role in promoting women's empowerment and advancing financial inclusion, demonstrating a commitment to making public institutions more responsive to societal needs. These applications of AI are helping to address key social challenges while improving the overall functionality of public services.

- **Agriculture**

In agriculture, AI is driving significant advancements through precision farming techniques, yield prediction, and early detection of diseases and pests. It is instrumental in optimizing soil analysis, irrigation management, livestock care, and supply chain processes, resulting in more efficient and sustainable farming practices. Furthermore, AI enhances the performance of agricultural machinery and improves overall farm productivity, contributing to a more resilient and modernized agricultural sector.

- **Healthcare Management**

AI is revolutionizing healthcare by facilitating remote consultations, telemedicine, and patient monitoring, expanding access to healthcare services, especially in underserved areas. It also supports critical functions such as drug discovery, medical imaging, and predictive analytics, enabling early diagnosis and prevention of diseases. AI-powered virtual assistants and the generation of synthetic data further enhance patient care and medical research, leading to more effective and efficient healthcare delivery systems.

- **Education**

AI is reshaping education by offering personalized learning experiences, supporting multilingual education, and incorporating augmented and virtual reality (AR/VR) technologies for immersive learning. It also

streamlines administrative processes, facilitates intelligent content creation, and enables adaptive tutoring systems, resulting in a more personalized and efficient educational environment. Additionally, AI helps in continuous learning support, adaptive assessments, and early interventions to provide comprehensive student assistance.

- **Energy**

In the energy sector, AI is widely applied for demand forecasting, price prediction, and demand-side management at both the residential and commercial levels. Research is being conducted on advanced techniques such as efficiency-focused ontologies and natural language generation to reduce energy consumption. While AI's contributions are most evident in power generation, particularly in renewable energy applications, its potential extends to robotics in oil, gas, and nuclear energy operations. AI is also used for weather forecasting and sun tracking in renewable energy, as well as inspecting the structural integrity of renewable energy facilities.

- **Water and Wastewater**

AI is being integrated into various stages of water management, from initial treatment processes to distribution and consumer services. Research in this field is focused on improving water quality and contaminant removal in standard and wastewater treatment systems. Machine learning is being applied in desalination to optimize plant design, while techniques like artificial neural networks, random forests, and deep belief networks are used to predict water demand and pricing at different geographical levels.

- **Telecommunications**

AI and machine learning are essential to the development of next-generation wireless networks, including cellular, software-defined, optical, 5G, and cloud-based systems. These technologies assist in traffic forecasting, demand prediction, and network optimization to reduce latency and improve the customer experience. AI also plays a key role in network security, with applications in anomaly detection, denial-of-service prevention, and intrusion detection. The use of unmanned aerial vehicles (UAVs) as mobile base stations is an emerging field of research, with efforts underway to enhance their effectiveness.

- **Transportation**

AI is transforming the transportation sector by developing intelligent systems for traffic control, accident prediction, and navigation. In road transportation, machine learning is applied to forecast demand, manage traffic flow, and optimize taxi services. AI also plays a critical role in road network mapping and infrastructure monitoring through computer vision. The development of autonomous vehicles is heavily reliant on deep learning technologies. In rail transportation, UAVs are used for asset monitoring, while deep learning supports fault diagnosis in high-speed trains. Public transport research primarily focuses on traffic flow optimization and bus network management, ensuring efficient and sustainable urban mobility solutions.

Future Prospects: AI's Advancement and Inclusive Deployment in India

India's AI-driven growth is poised to transform key sectors such as healthcare, agriculture, and education. Strategic investments in infrastructure, open data ecosystems, and AI research, alongside ethical frameworks and public awareness, are essential to harness AI's full potential and position India as a global leader in innovation.

- **Reinvigorating Investments in Communications Infrastructure**

To effectively support AI-driven technologies, it is crucial to prioritize revitalized investments in communications infrastructure. Key recommendations include the rationalization of telecommunication taxes, lowering right-of-way charges, and offering subsidies for fibre optic cable investments through existing mechanisms such as the Universal Service Obligation Fund. A collaborative approach involving partnerships with rural cable operators can help accelerate the expansion of fibre-to-the-home (FTTH) services in underserved rural areas. Additionally, strategies must be devised to address risks linked to mobile financing, ensuring a more resilient and widespread communication network that is critical for AI advancement.

- **Building an Open Data Ecosystem**

Access to high-quality, diverse data is essential for the development of robust AI models. To facilitate this, the establishment of a data trust—a legal entity that securely manages and shares data on behalf of various stakeholders—is recommended. Sector-specific open data ecosystems, particularly in agriculture and healthcare, are also vital for accelerating AI-driven innovation. Furthermore, governments should focus on

digitizing public data in regional languages to create inclusive and diverse datasets that can support the development of large-scale language models (LLMs) and other AI solutions. This open data ecosystem will be the foundation for fostering AI research and applications across critical sectors.

- **Funding AI Research and Competence Centres**

The expansion of AI Centres of Excellence at the state level is a key strategy to strengthen research in cutting-edge areas such as generative AI and computer vision. These centres should focus on fostering innovation in vital sectors like agriculture, education, and public services. Additionally, strengthening international collaboration and reducing barriers to partnerships will enhance research outputs and ensure that India's AI ecosystem remains competitive on a global scale. Targeted investments in AI research will drive advancements that benefit both national development and international competitiveness.

- **Implementing an Ethical AI Framework**

Developing an ethical AI framework is essential to address issues such as algorithmic bias and to promote fairness, accountability, and transparency in AI systems. Key measures include fostering diversity in AI development, creating open-source AI testing tools, and establishing independent review processes to evaluate AI systems. These steps are crucial for building societal trust in AI technologies and ensuring that AI is used responsibly and ethically. Significant progress has already been made, including aligning AI governance with constitutional rights, issuing responsible AI guidelines by NITI Aayog, and setting up an "AI Task Force" by the Union Ministry of Commerce and Industry. Additionally, efforts to combat AI-related threats and misinformation, led by the Security Council Committee on Counter-Terrorism, are strengthening the overall ethical framework for AI deployment in India.

- **Promoting Public Awareness and AI Literacy**

To bridge the gap between AI developers and end-users, AI education must be integrated into post-secondary curricula. This integration should cover both the fundamentals of AI and its social, ethical, and political implications. Public awareness campaigns and active stakeholder engagement are necessary to build trust and understanding of AI technologies across sectors. A well-informed public is critical for ensuring that AI is adopted in a responsible and transparent manner, further facilitating its widespread acceptance and application.

- **Building AI Clusters**

Establishing AI clusters, akin to bio incubators, is crucial for driving AI innovation and creating a dynamic ecosystem where startups and researchers can collaborate effectively. These clusters should be supported through targeted funding for AI startups, which will foster local innovation and balanced growth. AI clusters will play a pivotal role in research, manufacturing, and the development of AI-powered solutions across the country, positioning India as a global leader in AI innovation. This ecosystem will serve as a key driver of the AI industry, accelerating the nation's progress in the field.

5.5 Digital Entrepreneurship in India

The digital entrepreneurship ecosystem in India is multifaceted and not easily delineated, making it challenging to measure its overall scale. This study zeroes in on software development, agency work, content creation, and e-commerce, as these categories form the largest segments of internet-driven entrepreneurship that are predominantly mediated through digital platforms. Digital start-ups, a prominent subset of this ecosystem, have garnered considerable attention as a metric of India's digitalization success.

As of 2020, there were **41,317 start-ups in India** recognized by the Department for Promotion of Industry and Internal Trade (DPIIT). These start-ups span **54 industrial sectors**, are generally within five years of incorporation or registration, and have a turnover of less than INR 25 crores (USD 3.3 million). Although these start-ups have created nearly 500,000 jobs, representing just **0.1% of the labour force**, their impact on employment remains relatively modest. Notably, 41% of these start-ups are in technology-related sectors, classifying them as digital start-ups. Despite their small share in the overall labour market, digital start-ups are frequently heralded as a symbol of the successful digitalization of the Indian economy.

Fig. 15: Sector concentration of technology start-ups in India as of 2020

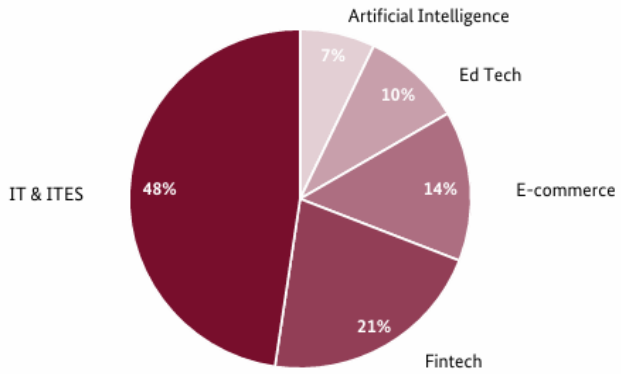


Figure 8: Sector concentration of technology start-ups in India as of 2020

Source: DPIIT, 2020

Source: DPIIT, 2020

The sector concentration of these technology start-ups is heavily skewed, with 48% of them rooted in IT & ITES (Information Technology Enabled Services), as depicted in the accompanying figure. Fintech follows with a 21% share, reflecting the rapid growth of financial technology solutions in the country. E-commerce and Ed Tech sectors account for 14% and 10% of start-ups, respectively, while Artificial Intelligence (AI), though a smaller segment, comprises 7%. This concentration highlights the sectors where digital entrepreneurship is most vibrant, driven by technological advancements and market demands.

In addition to start-ups, a significant portion of digital entrepreneurs comprises freelance workers engaged in agency work and content creation. While comprehensive data on freelancers is sparse, it is known that in 2020, nearly 35% of the labour supply on English-language freelancing platforms was based in India. Freelancers, especially those aiming to scale their services into full-fledged businesses, represent a critical yet underexplored segment of digital entrepreneurship. The growth of India's e-commerce sector, estimated to reach over USD 350 billion by 2030, further underscores the expanding opportunities within the digital economy, driven by increased digitalization and the pandemic-induced surge in online commerce.

Analysing the Integration of 5G and AI: Spotlight on India's Tech Advancements

The introduction of 5G technology in India has significantly reshaped the country’s digital landscape, marking a pivotal shift in connectivity and driving a considerable increase in data usage. By 2023, 5G users in India are consuming data at a rate 3.6 times higher than that of 4G users, with total monthly mobile data

usage reaching 17.4 exabytes, a 20.8% year-on-year increase. This surge reflects the rapid adoption of 5G, particularly in major cities where, by December 2023, 5G is projected to account for 20% of all mobile data traffic. The transition from 4G to 5G is especially pronounced in densely populated urban areas, driving demand for next-generation applications that require higher data bandwidth.

The 5G revolution has also triggered a substantial increase in the subscriber base. The number of 5G subscribers is projected to reach 131 million by the end of 2023, up from just 12 million in 2022, with a forecast of 575 million users by 2026. This growth in users has been accompanied by a 21.1% compound annual growth rate (CAGR) in average monthly data consumption over the past five years, fuelled largely by the rising popularity of data-heavy services such as high-definition streaming, online gaming, and AI-powered applications.

Furthermore, the introduction of 5G has greatly enhanced AI-driven services, particularly in industries reliant on large-scale data processing and real-time analytics. Homes and businesses using 5G fixed wireless access (FWA) consume 2.5 times more data than mobile users, underscoring the greater data demands of cloud-based AI applications, video conferencing, and remote work environments. Additionally, the increasing availability of affordable 5G devices and improved network performance is accelerating the adoption of AI-powered Internet of Things (IoT) solutions, smart city infrastructure, and autonomous systems, further driving data consumption. By 2030, the integration of 5G and AI is expected to transform key industries such as autonomous driving, telemedicine, intelligent manufacturing, and immersive entertainment, all of which will benefit from 5G's low-latency, high-speed capabilities. As data demands continue to rise, 5G data usage is anticipated to reach 310 exabytes annually by 2026. AI-driven services, including predictive modelling and machine learning, will become increasingly efficient, leveraging the vast data processing capabilities made possible by 5G networks.

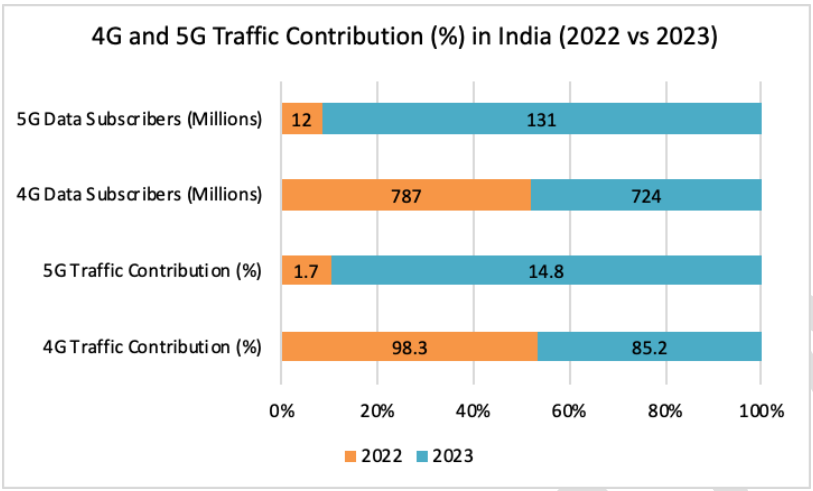


Fig. 16 4G and 5G Traffic Contribution (%) in India (2022 vs 2023)

Source: Nokia Analysis, Operator Quarterly Reports, TRAI

However, despite the immense potential of 5G and AI integration, several challenges persist. Ensuring equitable access to the benefits of 5G will require a concerted effort to accelerate infrastructure development in non-metro areas, which currently contribute only 12-14% of 5G traffic compared to 20% in metropolitan regions. While expanding 5G availability and enhancing network performance are critical, strategic investments in supporting the AI ecosystem—such as edge computing and robust data management frameworks—will be essential to unlocking the full potential of 5G and AI integration across India.

6. Public Sector Integration of Digital Infrastructure

6.1 Digital Public Infrastructure (DPI) in India

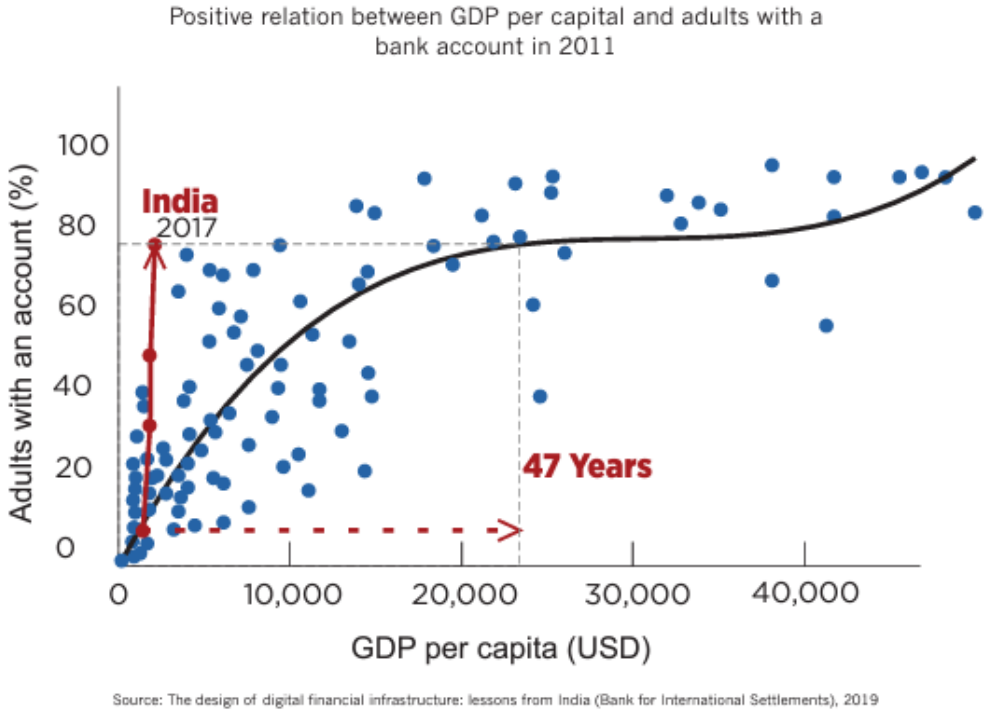
Until recently, the concept of Digital Public Infrastructure (DPI) was not widely recognized on a global scale. Under India's leadership, drawing on both international examples and domestic experiences, DPI has been redefined as an infrastructure-centric approach that harnesses technology to achieve societal objectives through an ecosystem of technology, markets, and governance designed in the public interest. This approach encourages private sector innovation within established regulatory frameworks. DPI fundamentally differs from the traditional understanding of digital infrastructure, such as internet connectivity or mobile networks, in several key aspects. (G20 DPI REPORT)

India's Outcomes From DPI

India has achieved remarkable digital progress over the last decade by implementing DPI - a unique approach to digital projects tailored to India's context.

India's Accelerated Progress in Financial Inclusion

India has achieved an unexpected leapfrog over the last decade. In 2009, only 17% of adults in India had bank accounts, 15% used digital payments, one in twenty-five had a unique ID document, and about 37% had mobile phones. In the eight years to 2017, these numbers saw unprecedented growth: tele density was up to 93%; over a billion people had a digital ID document, 80+% had bank accounts, and over 2 billion digital payment transactions were completed per month. The Bank of International Settlements (BIS) estimated that progress which would have otherwise taken almost half a century was achieved in India in 8 years (see figure below).



Source: The design of digital financial infrastructure: lessons from India (Bank for International Settlements), 2019

This progress was made possible by India's world-class digital public infrastructure for financial inclusion, including:

1. Unified Payments Interface (UPI): UPI transactions have grown from 92 crore in FY 2017-18 to 8,375 crore in FY 2022-23. Moreover, the system has expanded internationally, with countries like UAE, Singapore, and France adopting or considering UPI. Recent developments include the integration of UPI with credit cards and the launch of UPI Lite for offline transactions. These advancements have not only enhanced financial inclusion but also positioned India as a leader in digital payments globally.

2. Aadhaar Payment Bridge: Rs. 3.81 lakh crore cash transfers sent directly to beneficiaries' bank accounts in 2019-20.

3. Aadhaar & eKYC: Digital ID for over a billion adults with over 33B authentications.44.7 million new bank accounts opened bringing up banking penetration to 80%, and allowing ease of SIM card registration.

4. Adhaar Enabled Payments System (AEPS): an interoperable network of biometric-based cash withdrawals & deposits enabled by agents for 150 million people in small towns to complement physical ATMs.

5. DigiLocker: An eLocker for verifiable credentials, used by over 211 million people to store over 6 billion individual and business identity documents, educational credentials, vaccination certificates, and beyond.

6. Bharat Bill Payments System: APIs for bill fetch & pay allowing any bill to be paid using any app, processing over 23M bills per month.

7. FastTag: streamlined toll charges and parking collections platform.

8. Account Aggregator: A cross-sectoral framework for consented financial data sharing (sometimes referred to as 'open finance') to drive access to credit, insurance, and other services that have scaled to 1.9 billion financial accounts capable of sharing data.

9. Public Tech Platform for Frictionless Credit: a set of protocols that allow for access to information to the lenders which can be utilized for frictionless credit to the borrowers allowing for inclusive growth.

Market adoption and scale-up of many of these DPI Building Blocks were orchestrated through targeted Mission Mode programs and schemes of the Government. For instance, the **Pradhan Mantri Jan Dhan Yojana (PMJDY)**, or **"National Mission for Financial Inclusion"** was a financial inclusion program in India aimed at providing access to banking services for all, especially those in rural and underprivileged areas, and encouraged the opening of no-frills accounts using Aadhaar authentication and eKYC.

It played a critical role in driving progress; since its launch, the number of Bank accounts opened tripled from 147.2 million in March 2015 to 508.7 million by November 2023 in which women own 55 percent of these accounts, more than 282 million. In addition, the **Direct Benefit Transfer program (DBT)** was launched to accelerate the usage of the Aadhaar Payment Bridge to deliver benefits directly to individuals such as the **JanDhan Yojana**. The **BHIM UPI** app was launched by the Prime Minister in **December 2016** as a campaign to drive up UPI adoption and usage.

6.2 Major Challenges to India's Digital Public Infrastructure

- **Digital Divide Dilemma**:
    - **Access Disparities**: As of 2022, only about 52% of India's population had internet access, leaving nearly half offline. Rural areas lag significantly behind urban centres in digital adoption, with many residents still relying on cash while urban counterparts rapidly adopt digital payment systems like UPI.
    - **Gender Gap**: The National Family Health Survey 2019-21 found that only 33% of Indian women used the internet compared to 57% of men, highlighting a significant gender-based digital divide.

- **Digital Literacy Lag**:
    - **Limited Digital Literacy**: Despite efforts like the Pradhan Mantri Gramin Digital Saksharta Abhiyan, a large portion of the population remains digitally illiterate, hindering the effective use of digital services such as UPI and e-governance platforms.

- **Vulnerability to External Shocks**:

- **Overdependence on Technology**: Recent global IT disruptions, such as the CrowdStrike software update failure, revealed the fragility of India's digital infrastructure, underscoring the need for robust fail-safe mechanisms.
- **Cybersecurity Risks**: With over 3,000 cyberattacks per week targeting Indian businesses, the sector faces significant cybersecurity challenges, as demonstrated by the 2023 ransomware attack on AIIMS Delhi.

- **Vernacular Issues**:
  - **Language Barriers**: India's linguistic diversity, with 22 official languages and numerous dialects, poses a significant challenge to digital adoption. Although initiatives like BHASHINI aim to address this, many government apps and websites remain predominantly in English or Hindi, limiting their accessibility.

- **Digital Sovereignty Struggles:**
  - **Data Localization Challenges**: India's push for data localization, as seen in the RBI's mandate on payment data storage, creates compliance complexities for global tech companies and may impact cross-border data flows.
  - **Personal Data Protection Concerns**: The Digital Personal Data Protection Act, of 2023, while allowing the transfer of personal data outside India, may not sufficiently evaluate data protection standards in other countries.

- **Personal Data Privacy Paradox**:
  - **Privacy Concerns**: As digital services expand, issues surrounding data privacy and security have intensified. The Digital Personal Data Protection Act, of 2023 is yet to be fully implemented, with past incidents like the Aadhaar data breaches in 2018 raising public concerns.

6.3 Steps to Enhance the Resilience of India's Digital Public Infrastructure

- **Enhanced Cybersecurity Measures**:
  - **Increased Budget Allocation**: India should significantly boost its cybersecurity budget to reflect the growing importance of digital security.

- **Mandatory Audits and National Response Plans**: Implementing mandatory cybersecurity audits and developing a robust national cyber incident response plan, complete with regular drills, would strengthen defences.

- **Interoperability Standards**:
  - **National Standards and Open APIs**: Developing national interoperability standards and an Open API policy for government services would ensure seamless integration and promote innovation.
  - **Regulatory Sandbox and IndEA Framework**: Establishing a regulatory sandbox for financial services and adopting the IndEA (India Enterprise Architecture) framework would provide a unified approach to digital transformation.

- **Inclusive Digital Literacy Programs**:
  - **Digital Saksharta Abhiyan 2.0**: Launching a nationwide initiative focused on practical digital skills, with partnerships across NGOs and tech companies, would enhance digital literacy, especially in remote areas.
  - **Targeted Programs**: Developing programs specifically for women, the elderly, and marginalized communities would help bridge the digital divide.

- **Cyber Security Board**:
  - **Establishment and Implementation**: Creating a Cyber Security Board with members from both the government and private sectors, along with implementing a zero-trust architecture and standardized incident response playbooks, would modernize and secure state networks.

- **Agile Regulatory Framework**:
  - **Multi-Stakeholder Digital Economy Task Force**: Establishing this task force would enable adaptive policymaking that keeps pace with technological advancements.
  - **Principle-Based Regulations**: Developing technology-neutral, future-proof regulations would ensure flexibility while maintaining necessary oversight.

- **Infrastructure Expansion**:

- **Accelerating BharatNet and 5G Rollout**: Connecting all 600,000 villages with high-speed internet and developing a national strategy for 5G deployment would bridge the digital divide and position India at the forefront of wireless technology.

- **Vernacular Digital Content**:
  - **Multi-Lingual Support and AI-Powered Translation**: Mandating multi-lingual support for all government services and developing real-time translation tools would ensure wider accessibility and inclusivity.
  - **Voice-Based Interfaces**: Implementing voice-based digital services would overcome literacy barriers, making technology more accessible.

- **Green Digital Infrastructure**:
  - **Energy Efficiency and Renewable Energy**: Setting energy efficiency standards for data centres and promoting the use of renewable energy in digital infrastructure would align India's digital growth with sustainability goals.
  - **Incentivizing Green Technology**: Encouraging green technology adoption in the IT sector would reduce the carbon footprint and support environmental sustainability.

Conclusion

In conclusion, this report provides an in-depth analysis of India's rapid strides in digital infrastructure across various sectors. The growth in mobile broadband has significantly increased data consumption, driven by rising smartphone usage and initiatives like the National Broadband Mission. The digital payments landscape has also seen significant evolution, with the Unified Payments Interface (UPI) facilitating over 18 billion transactions in the fiscal year 2023-24. These developments have elevated India as a global leader in fintech, advancing financial inclusion, especially in previously underserved rural areas. However, a substantial gap persists between urban and rural populations, as rural internet penetration continues to lag, limiting equal access to digital technologies.

The report highlights notable sectoral growth, particularly in IT services, cloud computing, and fintech, while acknowledging the growing influence of emerging technologies like Artificial Intelligence (AI) and 5G in transforming industries. The telecommunications sector, for example, is forecasted to grow from $70 billion in 2023 to $100 billion by 2030, driven by rising demand for faster internet and advanced mobile solutions. AI is playing an increasingly prominent role in fields such as healthcare, agriculture, and smart cities, driving innovation and efficiency. However, the rise of AI and automation brings challenges, particularly in employment, where job displacement may occur. Although the IT sector is expected to employ 5.43 million people by 2023-24, the pace of job creation is likely to slow due to automation, highlighting the need for focused reskilling and upskilling initiatives.

Digital integration in the public sector has been critical, with programs such as Aadhaar and DigiLocker facilitating seamless access to government services and financial platforms. Aadhaar-enabled services and direct benefit transfers have also enhanced financial inclusion by providing millions with access to essential services and subsidies. The development of smart cities, leveraging technologies like AI, IoT, and big data, marks another significant step forward, improving governance, service delivery, and the quality of urban life.

To maintain the inclusivity and sustainability of these advancements, the report recommends addressing the challenges of digital infrastructure integration, especially in rural areas. Expanding communication infrastructure in non-urban regions, investing in AI research, and fostering public-private collaborations

will be crucial for maintaining momentum. Additionally, creating a robust ethical and regulatory framework for emerging technologies is necessary to ensure responsible AI deployment, mitigating risks such as job loss and algorithmic bias.

In the long term, India's digital infrastructure will continue to be a key driver of economic growth and technological leadership. With appropriate policies, continuous investments, and efforts to bridge the digital divide, India can capitalize on its digital transformation to promote sustainable development, foster innovation, and ensure that the benefits of this transformation reach all corners of the country.

References

Research Papers and Reports:

- The Impact of Infrastructure on Development Outcomes- Policy Research Working Paper 10343, World Bank Group
- Infrastructure Development in India: An Appraisal- Research Gate Article
- Infrastructure Development in India: De, P. (2008), 'Infrastructure Development in India', in Kumar, N. (ed.), International Infrastructure Development in East Asia – Towards Balanced Regional Development and Integration, ERIA Research Project Report 2007-2, Chiba: IDE-JETRO, pp.105-130.
- Mhlanga, D. Artificial Intelligence in the Industry 4.0, and Its Impact on Poverty, Innovation, Infrastructure Development, and the Sustainable Development Goals: Lessons from Emerging Economies? Sustainability 2021, 13, 5788. https://doi.org/10.3390/su13115788
- Survey paper: A review of the use of artificial intelligence methods in infrastructure systems
- ADVANCING INFRASTRUCTURE IN DEVELOPING NATIONS: A SYNTHESIS OF AI INTEGRATION STRATEGIES FOR SMART PAVEMENT ENGINEERING Eche Samuel Okem1, Emmanuel Adikwu Ukpoju2, Abayomi B. David3, & Joy Otibhor Olurin4 1Department of Civil Engineering, University of KwaZulu-Natal, South Africa 2 Independent Researcher, South Africa 3Civil Engineering Department, Stellenbosch University, South Africa 4Hopewell Company Limited, Ibadan Oyo State Nigeria
- REPORT OF INDIA'S G20 TASK FORCE ON DIGITAL PUBLIC INFRASTRUCTURE
- Impact of Digitalization on Employment Pattern in India- Dr. Disha Pandey (IJFMR)
- EY Report: Economy Watch Monitoring India's macro-fiscal performance April 2023
- Digitalisation and the Indian Labour Market Trends, Challenges, and Opportunities- Published by GIZ
- Niti Aayog- The Role of Digital Infrastructure in Socio-economic Development
- https://www.pwc.in/assets/pdfs/consulting/financial-services/fintech/payments-transformation/the-indian-payments-handbook-2023-2028.pdf
- https://assets.ey.com/content/dam/ey-sites/ey-com/en_in/topics/india-at-100/2023/01/ey-india-at-100-full-version.pdf
- https://www.ey.com/en_in/insights/tax/how-digital-transformation-will-help-india-accelerate-its-growth-in-the-coming-years
- https://icrier.org/pdf/State_of_India_Digital_Economy_Report_2024.pdf
- https://assets.ey.com/content/dam/ey-sites/ey-com/en_in/news/2024/05/ey-realizing-ai-for-all-in-india-report.pdf

- https://www.morganstanley.com/ideas/india-smartphone-market-growth
- https://www.nokia.com/sites/default/files/2024-03/mbit-2024.pdf
- https://www.ris.org.in/sites/default/files/Publication/Policy%20brief-104_Amit%20Kumar.pdf

Open Data Sources:

- India's Digital Public Infrastructure- Drishti IAS
- Invest India- Digital India: Revolutionising the Tech Landscape
- https://www.nic.in/blogs/digital-payments-driving-the-growth-of-digital-economy/
- https://pib.gov.in/PressReleasePage.aspx?PRID=1988370
- https://digipay.gov.in/dashboard/default.aspx
- https://www.ibef.org/exports/services-industry-india

TABLE OF CONTENTS

1. **Overview**

On October 2, 2014, the day of the nation's father, Mahatma Gandhi, the Indian government announced the "Swatch Bharat Mission" (SBM). This was transformed into a large-scale movement, spearheaded by Prime Minister Mr. Narendra Modi. There were two sections to the mission: urban and rural. Currently, approximately 1,115 MT of rubbish are produced daily in Indore, and all of it is collected from the source, which might be a home or business. In two of the city's 84 wards, the door-to-door service was launched as a test experiment in January 2016. Reaching 100% door-to-door rubbish pickup took nearly a year. The Municipal Corporation was effective in raising public awareness of the need of recycling waste at its source and avoiding open-air disposal sites in just a single year. Through community involvement, Indore's Swachhata narrative demonstrates true transformation.

2. **Awareness-Building Program for Modified Behaviour**

The first stage of execution was raising awareness among the populace and the community via meetings, public involvement, loudspeakers, brochures, and community rallies. They were informed of the advantages of separating wet and dry trash, as well as the effects it has on the environment and public health. The Swachh Bharat Mission's effectiveness depends on behaviour change, which can only be achieved via Information, Education, and Communication (IEC). A variety of IEC activities, including as print, electronic, social/digital, audiovisual, and traditional media, were embraced and carried out by IMC.

Below is a summary of some of the innovative IEC actions that IMC has used to encourage behavioural change in Indore:

Indigenous inventions Street dramas, wall paintings, and FM radio all continuously updated their programming by adding fresh themes to convey and coming up with inventive methods to do so. Events like Gandhi Jayanti, Dussehra, and the Ganesh festival were used to promote the swachhata message. The incorporation of IEC into monitoring operations was a significant component. These actions confirmed (tracked) the state of service provision. Verification was done in a few distinct ways. Among these were: a) the 311 app for service delivery; and b) online site visits for surprise checks, c) using biometrics to track employee attendance. 311 app has evolved as a significant technique for recording concerns arising from different residential neighbourhoods. Fast response times are seen while handling concerns. The Municipal Commissioner keeps an eye on the status of complaints that are filed and handled. Through IEC, the NGOs

disseminated information on composting techniques and how they may benefit other stakeholders, in addition to recycling garbage. As a result, a cross-partnership was formed, and the garbage was transformed into a valuable product that met the requirements of others.

3. WASTE MANAGEMENT MODEL

3.1 Door-to-Door Collection Model

There are 19 zones and 85 wards in Indore. There are around 6,000 homes and 600 businesses (as part of 88 recognized commercial zones) in each ward. Waste is produced in Indore from a variety of sources, including residences, businesses, and other establishments including motels, hospitals, and RWAs. The bulk collection system covers semi-bulk and bulk generators, whereas the door-to-door collection system covers individual homes or residential complexes. Indore's door-to-door collecting method guarantees that every ward is covered 100% of the time.

3.1.1 Implementation of the D2D model:

To successfully deploy a door-to-door collection system, an identification study that determined the population and amount of waste generated at each ward had to be conducted. A thorough route plan covering every ward was created based on that information. In order to meet each ward's garbage collection requirement, a comprehensive vehicle and crew deployment strategy was put into place based on the route plan.

IMC has implemented a door-to-door collection system to gather garbage from residential generators and commercial sectors in Indore. The garbage is hauled to the garbage transfer stations for further collection by means of divided vehicles called "tippers."
These tippers deliver domestic rubbish to the transfer station, from where hook loaders take it to the trenching field. A GPS-enabled tracking system keeps an eye on every vehicle utilized in the collection and transportation operation. The GPS system is regularly checked by the monitoring cell. Drivers who deviate from the route will be fined, and repeated deviations will result in termination.

3.2 Bulk Collection system:

The Bulk Collection System is used to gather the wet trash from semi-bulk generators that produce 25 to 100 kg of garbage. The bulk collection vehicles consist of a dumper which is used

to collect wet garbage and a compactor which is used to gather dry waste. These vehicles follow a prearranged deployment strategy, moving in pairs. After finishing their collection route, these vehicles deliver the waste directly to the central processing facility.

The tippers deliver the wet waste from the door-to-door collection vehicles to one of the eight transfer stations. The tippers at the GTS empty the wet garbage into specialized compactors, which then compress and load the waste into hook loaders.

Every waste collection vehicle that arrives has its details recorded in the GTS log books. After finishing their individual collecting routes, the bulk collection vehicles head directly to the processing plant instead of the GTS.

3.3 Weighment Bridge facility:

The central processing plant is home to the Weighment Bridge facility. For all cars arriving at the plant, this is the initial point of contact. Before the wet trash can be transported to the processing plant, it must first be weighed in this computerized facility. It is collected by both the bulk collection system and door-to-door collection.

There are two locations where the wet waste is processed: central processing plants and decentralized waste processing units. The bulk generators process all of their wet waste (50 kg and above) on-site, meaning that the central processing plant does not handle this material.

The waste produced as part of the dry waste is described as follows:

- Door-to-door and bulk collection methods are used to collect the dry waste, just like with wet waste. Tippers are used to collect dry trash from residential generators, while the bulk collection system is used to collect dry waste from all bulk generators. The door-to-door collection tipper has an additional Third Bin attached to the back that is used to collect household hazardous garbage.
- Waste is collected a second time via the GTS. After being dumped into specialized compactors, the dry garbage is crushed, placed into hook loaders, and driven to the central processing plant.
- The DHW is moved into drums, which are immediately sealed and weighed. The employees of the outside organization in charge of running the Central Biomedical Waste Treatment Facility carry out this task. When weighing, the agency's employees provide the GTS employees slips on which the date, time, and weight of the collected waste are noted. After that, the waste is driven in specially designated vans to the facility.

- After that, the garbage is delivered to the Weighbridge Facility. This facility serves as the initial point of contact for all entering cars at the central waste processing plant. The door-to-door collection service's computerized system keeps track of the total weight of all the dry garbage it collects.
- At Deveguradiya, India has central facilities for processing dry waste. At these facilities, the dry trash is sorted into different components like metal, rubber, board, plastic, etc. The 343 rag pickers working at the plant's two Material Recovery Facilities carry out this segregation.

3.4 Open Defecation City

When someone chooses to relieve themselves outside of a toilet and instead uses a field, bushes, woodland, open body of water, or other open location, this is known as open defecation.

Open defecation occurs due to lack of toilets and behaviours of people. Education constituted a significant portion of the ODF's purpose, in addition to building restrooms. The IMC appointed NGOs in October 2016 on the basis of stringent turnover and experience in urban planning requirements.

In the city, 72 crucial ODF areas were found by the cleaning crew. When it came to locating ODF locations and alerting the authorities to them, NGOs were crucial. These NGOs were essential in finding critical ODF areas and bringing about public behavioural change, which was a major factor in ODF's success.

Developing an action plan and strategy for the 72 important OD spots that were identified was one of the steps taken to create the Indore ODF:

- Relocating 5,000 impoverished households within a year to vacant Basic Services for Urban Poor (BSUP) apartments.
- Strict action and oversight against defaulters by IMC authorities, with over 500 defaulters receiving spot fines.
- 400 officials and 6 NGOs participated in ODF-dedicated activities that were monitored.
- A total of 12343 IHHL have been identified as being constructed, of which 12343 have been built.
- A total of 128 community restrooms have been identified for construction, of which 128 have already been completed.
- 189 public restrooms have been designated for construction, and as of right now, 189 of those restrooms have been built.

- In areas where slums have been built on private property, disputed land, and transit settlements, modular restrooms have been installed. This made it easier to address the sanitation issues brought on by individuals residing on unpermitted property, construction workers, nomadic tribes, truck parking lots, etc., for whom building long-term restroom facilities is impractical. The modular toilets may be disassembled and utilized as needed after these slums are moved. By notification, IMC required all construction sites to provide sanitary facilities for its employees.
- IMC has created 17 portable restrooms for use at public events and gatherings, including marathons, weddings, and political gatherings. The Indore residents have had paying access to these modular restrooms.

3.5 Converting trash to fuel

Mahindra Waste to Energy Solutions Ltd. stated that about 20 tons of waste are collected daily and converted into 750–800 kg of bio-compressed natural gas (bio-CNG). The organization and IMC have a long-term agreement for the operation of the plant.
The produced gas is supplied to hotels and the Indian Institute of Management at a financed cost and used to power municipal transportation. Compost is made by blending 1-2 tons of flower business waste every day into slurry and keeping it apart.

One such project that satisfies all of the mission's emphasis areas is the current biogas project, which treats waste water, provides greener fuel for transportation, manages wet solid waste with zero discharge, and improves amenity value by lowering pollution. Indore Smart City Development Limited (IMC) and Mahindra, as a technological partner, took up this endeavour to construct a bio-methanation plant that produced BIO-CNG for public transportation. It is founded on the three Rs: reduce, reuse, and recycle. Moreover, it produces methane gas, which is transformed into CNG gas and used further. The factory produces about six tons of organic manure every day. The plant produces roughly 2000m3 / day of raw biogas. Currently, fifteen buses in Indore are powered by BIO-CNG, using over 500 kg of gas daily while covering more than 2000 km.

Kabitkhedhi Sewage Treatment facility also has a bio methanation facility with a 15 TPD capacity. The city's hotel garbage is handled by this plant. Additionally approved is a single 200 TPD bio methanation unit at Trenching Ground.

4. Revenue Generation of IMC

4.1 Carbon Credits

A carbon credit is a tradable certificate or authorization that can be used to offset one tonne of greenhouse gas emissions, such as carbon dioxide. IMC carries out initiatives to lower carbon emissions. These projects could be related to waste management, such as enhanced waste segregation, composting, or methane capture from landfills. These initiatives' reductions in emissions are measured and confirmed by impartial third parties. This method assures that the reductions are real, measurable, and additional (i.e., they wouldn't have happened without the initiative). The emission reductions are turned into carbon credits after verification. A ton of CO2 (or its equivalent) that has been kept out of the atmosphere is represented by each credit. These carbon credits can then be sold by IMC in carbon markets. Companies and governments aiming to offset their emissions in order to comply with legal obligations or voluntary sustainability goals are among the buyers of these credits.

An Indore, Madhya Pradesh, IAS official has discovered a way to make money off of green initiatives by selling the carbon credits they have accrued and making Rs 50 lakh in profit in the process. A carbon credit is a tradable certificate or authorization that can be used to offset one tonne of greenhouse gas emissions, such as carbon dioxide.

4.2 Bio-CNG plants

IMC gathers organic garbage from a range of locations, including homes, businesses, and marketplaces. The organic waste is gathered and fed into a bio-CNG facility, where anaerobic digestion takes place. In this process, organic matter is broken down by microorganisms in the absence of oxygen, creating biogas. Methane (CH4) and carbon dioxide (CO2) make up the majority of biogas, which is refined and upgraded to produce bio-CNG (compressed natural gas). Renewable fuels like bio-CNG can be sold as green energy products or used in automobiles. When utilizing bio-CNG instead of conventional fossil fuels, IMC can assert a decrease in greenhouse gas emissions. Carbon credits are a measure of and a certification for the removal of fossil fuels and the decrease in methane emissions, a strong greenhouse gas. IMC can make money from the sale of this sustainable energy by selling the bio-CNG the plant produces. They can also profit from the sale of carbon credits, which are produced as a result of the usage of bio-CNG, which lowers greenhouse gas emissions.

According to an official, the factories that turn trash into valuable products like bio-CNG bring in an annual revenue of Rs 8 crore for the IMC.

The civic body will soon earn Rs 10 crore a year from garbage treatment when a new 550-ton bio-CNG facility is put into service, according to Asad Warsi, the IMC's advisor for the Swachha Bharat Abhiyan

4.3 Green Bonds

In order to raise a substantial amount of money for the development of a 60 MW solar power station, IMC issued its first green bond in 2018. This facility seeks to encourage sustainable energy use and lessen reliance on fossil fuels. This action encourages investments through municipal bonds in addition to promoting sustainable energy. For the construction of a 60 MW ground-mounted captive solar PV power plant in Madhya Pradesh's Village Samraj & Ashukhedi, District Khargone, IMC is issuing green bonds up to Rs. 244 crores.

In terms of finances, it gives IMC access to a bigger capital pool of investors who support sustainable development. "We have chosen to go out to the people because it offers a sense of belongingness," Singh continued, adding that Indore could have easily secured finance for the solar power plant from banks or other private sources. He added that the issuance provides a newer, alternative source of funding for the municipality and creates opportunity for others to do the same.

Additionally, the Indian central bank has encouraged local governments—which are largely funded by grants or bank loans—to consider issuing municipal bonds.

5. IMC’s Structured Payment Mechanism

IMC uses a structured payment system to guarantee the security and legitimacy of its bonds. In order to comply with SPM, Indore Municipal Corporation (IMC) must establish an escrow system and first pari passu charge in the bondholders' favor on IMC's own revenues, in addition to the current 9.25% holders of Indore Municipal Corporation Series-I June 2028 bonds. The escrow revenues that have been transferred to the escrow account will be made

available in a proportionate amount (140:244) to meet the debt servicing obligations of both the current and planned bond issues.

Among the features of SPM are the following:

- The total cash collected in the escrow account during any given financial year must equal or exceed the Annual Payments cash, which includes principal and interest as appropriate.
- As stated below, the money will be sent from the escrow account to the sinking fund account (SFA) for principle repayment and the interest payment account (IPA) for interest payments.
- For every half-yearly interest payment, 20% of the interest is to be transferred to the IPA created for this bond issuance, as follows:
    - 1st half year – from 1st to 5th Month
    - 2nd half year – from 6th to 10th Month
- For STRPP A, 10 months in the first, second, and third year will see a monthly transfer of 3.33% of the principal amount to SFA in order to construct the bond issuance.
- Ten months of monthly principal transfers for STRPP B, C, and D will take place in the fourth and fifth, sixth and seventh, and eighth and ninth years, respectively.

IMC's income comparison between 2013–14, the year the Swachh Bharat Mission was implemented, and 2022–2023

Income Comparison

1. **2022-2023**:
    - **Total Income:** ₹18,29,87,863
    - **Major Income Sources:** Tax revenue, assigned revenues & compensation, rental income, and fees & user charges.
2. **2013-2014**:
    - **Total Income:** ₹8,44,88,593.50
    - **Major Income Sources:** Tax revenue, assigned revenues & compensation, rental income, and fees & user charges.

Observation:

The total income in 2022-2023 has more than doubled compared to 2013-2014. This significant increase in income could be due to:

- **Expansion in taxable properties**: In 2013-14, property and other tax revenues were lower primarily due to a smaller population base, lesser urban sprawl, and less developed systems of tax collection. At the time, the economic development of Indore hadn't yet peaked, and there were gaps in assessing and collecting taxes efficiently. By 2022-23, the economic landscape of Indore changed significantly, with rapid urbanization, commercial development, and infrastructure expansion. Improved digital tax collection systems, more stringent assessments, and enforcement measures boosted property and tax revenues. Additionally, property values in Indore increased as the city became a business hub, contributing to higher tax revenues.

- **Revenue from Municipal Services:** In 2013-14, IMC had limited income from municipal services like waste collection, water supply, and municipal properties. At this point, the municipal corporation was still grappling with basic service delivery, and user fees were minimal. By 2022-23, the situation improved dramatically with the introduction of more structured and scalable municipal services. For example, the waste management system transitioned from a traditional collection model to one that included waste-to-energy conversion and composting, which not only improved service delivery but also created new revenue streams. IMC also began charging user fees for services such as bulk waste collection and selling compost and biofuel, adding to the income.

- **Grants and Subsidies:** In 2013-14, Indore received fewer grants and subsidies from the central and state governments, as large-scale urban development programs had not yet been initiated. However, by 2022-23, Indore was a participant in various government schemes such as the **Smart Cities Mission**, **Swachh Bharat Mission**, and **AMRUT**. These programs provided significant financial assistance to IMC in the form of grants and subsidies, allowing the corporation to improve urban infrastructure, sanitation, and waste management systems, which in turn generated additional revenue.

- **4. Non-Tax Revenue:** In 2013-14, non-tax revenues such as rental income from municipal properties or interest earnings were relatively low. By 2022-23, IMC had diversified its revenue base by leasing more municipal properties, utilizing **municipal bonds**, and initiating **green bonds** to raise funds for infrastructure projects. These financial instruments allowed IMC to generate more income from investments and interest, contributing to a more stable revenue base.

Expenditure Comparison

1. **2022-2023**:
    - **Total Expenditure:** ₹16,35,45,912.95
    - **Major Expenditure Areas:** Establishment expenses, administrative expenses, operations & maintenance, and program expenses.
2. **2013-2014**:
    - **Total Expenditure:** ₹7,62,09,542.08
    - **Major Expenditure Areas:** Similar to 2022-2023, with significant spending on establishment, administrative, and operations & maintenance.

Observation:

Expenditure also shows a significant increase in 2022-2023. This can be attributed to:

- **Administrative and Salary Costs:** In 2013-14, the IMC's administrative costs were relatively low as the municipal government managed a smaller population and fewer services. With fewer personnel and smaller operational demands, salary expenditures remained within a manageable range. However, by 2022-23, the city had expanded, and so did its governance needs. The number of employees, including those involved in managing large projects like the Smart Cities initiative, increased significantly. Administrative overhead, such as salaries, grew due to the city's growing complexity and inflationary wage increases.
- **Capital Expenditure on Infrastructure:** The infrastructure needs of Indore were still modest in 2013-14, which is reflected in the lower capital expenditure on roads, sanitation, and public amenities. By 2022-23, the IMC had undertaken a series of large-scale projects under national missions like Smart Cities, requiring heavy capital investments. The city invested significantly in public infrastructure, including waste management plants, weighment bridges, and composting units. The increased expenditure in 2022-23 is largely due to the construction and maintenance of these new facilities, along with major road expansions, lighting projects, and public transport upgrades.
- **Operational and Maintenance Costs:** In 2013-14, IMC's operational expenses were lower because of less developed public infrastructure and services. The waste management system, for instance, was rudimentary, relying mainly on basic collection and disposal methods, which required minimal operational expenditure. By 2022-23, the waste management system had evolved into a complex mechanism that included waste segregation, composting, and waste-to-energy conversion. The operational and maintenance

costs for these systems naturally rose due to their sophistication and scale. Similarly, maintaining other public infrastructure, such as roads, parks, and water supply systems, became more expensive as the city expanded.

- **Inflationary Impact:** The rise in the cost of goods and services over the years also played a significant role in driving up IMC's expenses. The price of fuel, electricity, building materials, and general maintenance services increased due to inflationary pressures. By 2022-23, the cost of maintaining and operating municipal services, especially in an expanding urban environment, had risen significantly. Inflation affected not only direct costs such as fuel and materials but also contractual services for waste management, public works, and other municipal responsibilities.

Surplus Analysis

1. **2022-2023**:
    - **Net Surplus:** ₹2,29,78,07,112.04
2. **2013-2014**:
    - **Net Surplus:** ₹1,36,73,85,296.87

Observation:

The net surplus has increased significantly, reflecting improved revenue collection and possibly better financial management practices.

Potential Reasons for the Differences:

- **Economic Growth:** Between 2013 and 2023, Indore has experienced significant economic growth and urbanization. Indore is a key economic hub in Madhya Pradesh and one of the fastest-growing cities in India. The expansion of the economy naturally led to increased commercial activities, residential construction, and infrastructure development. This would have widened the tax base substantially, increasing revenue from property taxes, professional taxes, and fees from various municipal services. As urbanization intensified, the demand for municipal services such as waste collection, water supply, sanitation, and public health also increased. The municipal corporation was able to capitalize on this demand by collecting more in fees and user charges from a larger population and a growing number of businesses.
- **Government Policies:** The Indian government has launched numerous urban development programs, such as the **Swachh Bharat Mission (Clean India Campaign)** and the **Smart Cities**

Mission, during this period. These programs have not only raised public awareness but also pushed municipalities like Indore to improve their urban management, particularly in waste management and sanitation. These reforms are crucial in explaining the financial differences because they often come with grants and subsidies from the central government. In particular, Swachh Bharat's focus on sanitation likely spurred better waste collection and treatment methods, which helped generate additional revenue streams. Furthermore, Indore has consistently been ranked as the cleanest city in India, thanks to its effective solid waste management, which directly influences the increase in municipal revenues. This period also saw the introduction of **Municipal Bonds** and **Green Bonds** as funding mechanisms for urban projects, which opened up new financial avenues for municipalities.

- **Waste management as a revenue source:** One of the key differences between 2013-14 and 2022-23 could be attributed to the increased emphasis on turning waste management from a liability into an asset. Indore's waste-to-energy projects, composting initiatives, and recycling programs would have generated substantial revenue for the IMC. As waste management became a core priority under the Swachh Bharat Mission, the city likely found new ways to monetize waste. For instance, by selling compost derived from organic waste or generating energy from non-recyclable waste, Indore transformed its waste management system into a revenue-generating sector. The revenue generated from such activities likely contributes significantly to the increased surplus observed in 2022-23. The IMC's ability to treat waste not just as a public health obligation but also as a resource reflects a broader trend of innovation and sustainability in municipal governance.

Table Of Contents

OBJECTIVES

1. To quantify and analyse the direct and indirect contributions of the energy sector to the national GDP over the past years.
2. Impact of Electricity Capacity on Economic Growth, Job Creation, and Energy Access: Insights and Challenges.

INTRODUCTION

Energy infrastructure is a cornerstone of economic development, functioning as the backbone that powers industries, supports households, and sustains societal growth. This study seeks to systematically quantify both the direct and indirect contributions of the energy sector to India's GDP over the past decade, applying a robust, data-driven approach that incorporates diverse statistical methods and tools.

The research leverages data from a variety of authoritative sources, including national statistics databases, the World Bank, the International Energy Agency (IEA), and Indian government economic reports. By tapping into these data streams, the study aims to capture a detailed picture of the energy sector's evolving role in driving economic growth. Specifically, it examines how investments in energy infrastructure, energy consumption, and energy generation correlate with broader economic indicators such as GDP growth, employment, and industrial productivity.

A range of advanced statistical techniques is employed to carry out the analysis. **Correlation analysis** is used to explore the relationship between energy investments (both public and private) and GDP growth, helping to establish whether and to what extent changes in energy spending impact overall economic performance. In addition to these methods, the study uses **data visualisation** tools to present key findings in a clear and accessible manner, enabling stakeholders to readily interpret complex data and make informed decisions.

A core component of this study is its comparison of the energy sector's contributions with those of other key economic sectors, such as manufacturing, services, and agriculture. By placing the energy sector in the broader context of India's economic structure, the research highlights its relative significance and the synergies it shares with other areas of the economy. This includes an evaluation of how energy infrastructure development supports growth in industrial production, digital services, and urbanisation, among other sectors.

Furthermore, the study places a particular emphasis on the role of **renewable energy investments** and their implications for economic growth. With India’s growing focus on clean energy and sustainable development, renewable energy projects have become increasingly pivotal in shaping the energy landscape. The research includes case studies of notable renewable energy projects, such as the Jawaharlal Nehru National Solar Mission and the Koyna Hydroelectric Project, assessing their impact on job creation, regional economic development, and energy security.

The indirect contributions of energy infrastructure are also explored, such as the role energy availability plays in improving the productivity of industries, promoting rural electrification, and driving technological

innovation. By examining how energy-related investments stimulate growth across sectors, the research captures the broader multiplier effect of energy infrastructure on the economy.

This analysis culminates in recommendations for **policymakers**, **investors**, and **industry stakeholders**. Policymakers can use the findings to shape strategies that prioritise critical energy investments and promote public-private partnerships, ensuring that energy infrastructure continues to support long-term economic growth. Investors and industry leaders will benefit from insights into the most promising areas for energy-related investments, especially in renewables, where potential returns align with national development goals.

In summary, this study provides a **comprehensive, data-driven examination** of the energy sector's impact on India's GDP over the last decade, offering valuable insights for fostering sustainable economic growth and addressing key challenges related to energy security, employment, and environmental sustainability. The findings will contribute to ongoing discussions about the role of energy infrastructure in India's future development and help inform decisions that promote a resilient, diversified, and inclusive economy.

METHODOLOGY

The methodology employed in this research focuses on a comprehensive data-driven approach, leveraging various statistical and analytical techniques to quantify the relationship between the energy sector and GDP growth. Data was sourced from national databases, international organisations like the World Bank and International Energy Agency (IEA), and government economic reports.

The analysis began with the collection and consolidation of historical data on GDP, energy production, and consumption. Statistical techniques, including correlation analysis, were used to examine the relationship between energy sector investments and economic growth. Time series analysis helped to identify trends and patterns over the past decade, while data visualisation techniques, such as graphs and charts, were employed to clearly present the findings. By using these methods, the study provides a robust, evidence-based assessment of the energy sector's direct and indirect contributions to economic development.

CONTRIBUTIONS OF ENERGY SECTOR TO NATIONAL GDP

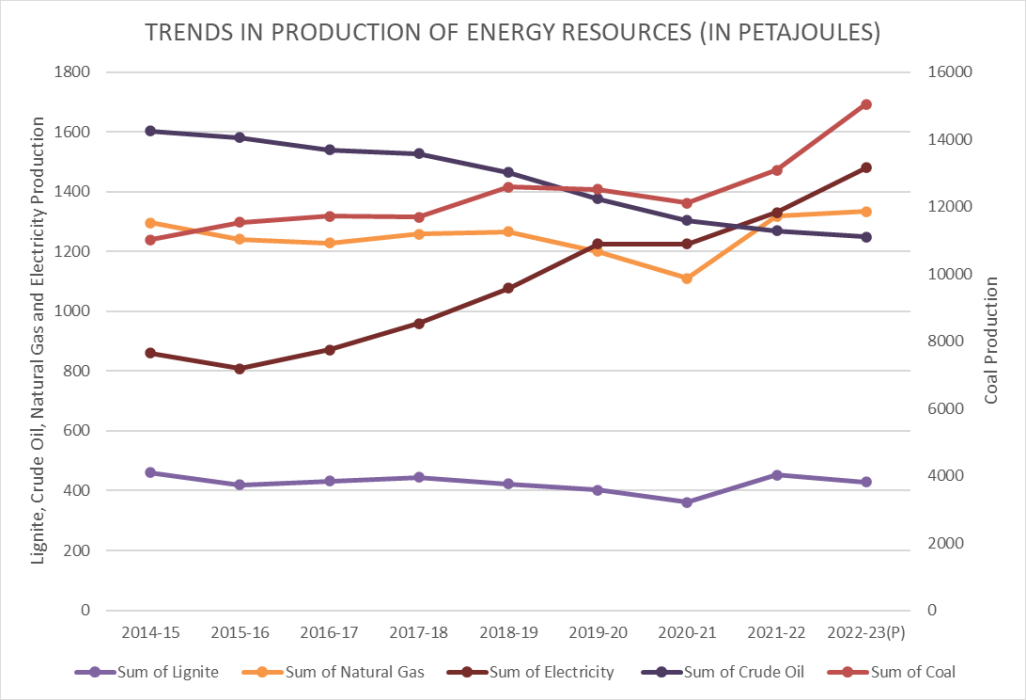
Energy production and consumption trends over the years

The trend of energy production and consumption are crucial as they directly reflect the level of economic activity and efficiency within an economy. Higher energy consumption generally correlates with increased industrial output, commercial activities, and overall economic growth, contributing significantly to GDP.

Production Trend

Year	Coal	Lignite	Crude Oil	Natural Gas	Electricity	Total	Growth Rate
2014-15	11024	461	1603	1296	860	15244	
2015-16	11539	419	1581	1242	808	15589	2.263185516
2016-17	11722	432	1541	1229	871	15794	1.315029829
2017-18	11695	445	1527	1258	959	15884	0.569836647
2018-19	12587	423	1464	1266	1078	16818	5.880130949
2019-20	12521	402	1377	1201	1226	16726	-0.547032941
2020-21	12105	362	1305	1111	1226	16109	-3.688867631
2021-22	13091	453	1270	1318	1331	17464	8.411447017
2022-23(P)	15055	429	1249	1334	1481	19549	11.93884563

Source: MOSPI



The chart represents the trends in the production (in Petajoules) of different energy sources - Coal, Lignite, Crude Oil, Natural Gas, and Electricity from 2014 - 2022.

Analysis-

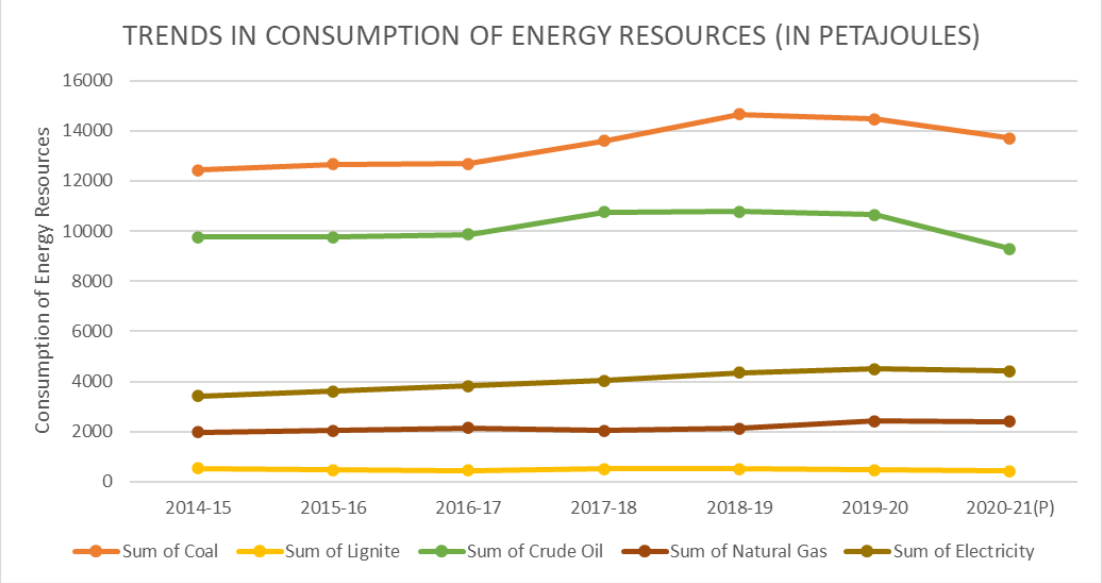
- Coal consistently shows the highest production levels among all the energy sources.
- There has been a sharp increase in its production from 2021 onwards.
- Electricity production has also shown an upward trend, with a steady increase from 2017-18 onwards. This rise has become more pronounced since 2020 - 2021.
- The decline in crude oil production reflects a shift towards other energy sources or a decrease in resource availability.
- Natural Gas and Lignite have shown stability in production, suggesting steady demand or a balanced supply.

India depends heavily on Coal as the major source of energy. During the 2022 - 23, energy generated from Coal accounted for about 77.01% of the total generation of energy followed by Electricity (from Hydro, Nuclear and other Renewable energy sources) (7.58%) and Natural Gas (6.83%).

Consumption trend

Year	Coal	Lignite	Crude Oil	Natural Gas	Electricity	Total	Growth Rate
2014-15	12439	534	9750	1976	3415	27711	
2015-16	12660	480	9753	2043	3604	28517	2.908592256
2016-17	12677	461	9867	2145	3820	29397	3.085878599
2017-18	13594	513	10750	2032	4044	30993	5.429125421
2018-19	14651	521	10769	2118	4356	32639	5.31087665
2019-20	14463	480	10651	2421	4493	32559	-0.24510555
2020-21(P)	13709	423	9286	2407	4417	30171	-7.33437759

Source: MOSPI



The chart displays the consumption patterns of various energy resources - Coal, Lignite, Crude Oil, Natural Gas, and Electricity from 2014 - 2021.

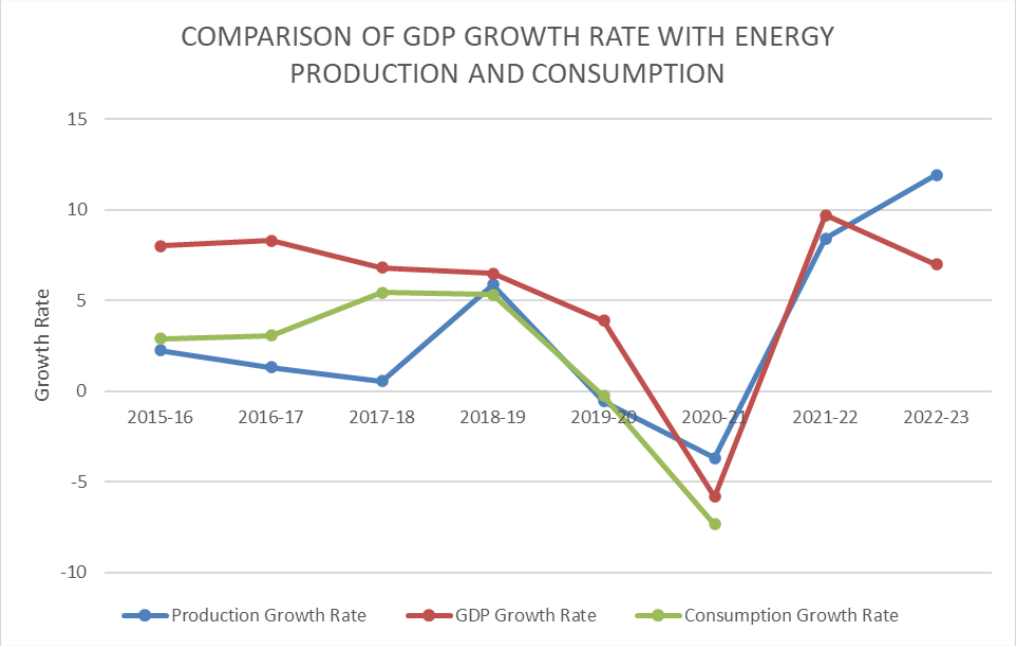
Analysis-

- Coal has consistently been the most consumed energy resource, peaking around 2018-19 and showing a slight decline afterward.
- Crude oil consumption shows a generally stable trend with slight increases until 2019-20, followed by a decline in 2020-21, which matches the reduction in production during that period.
- Natural gas and Electricity show a steady, gradual increase in consumption over the years, indicating growing reliance on these resources.
- Lignite consumption remains relatively low compared to other resources and shows minimal growth over the period.

GDP Trends and its comparison with energy production and consumption

Years	Production Growth Rate	GDP Growth Rate	Consumption Growth Rate
2015-16	2.26318552	8	2.908592
2016-17	1.31502983	8.3	3.085879
2017-18	0.56983665	6.8	5.429125
2018-19	5.88013095	6.5	5.310877
2019-20	-0.5470329	3.9	-0.24511
2020-21	-3.6888676	-5.8	-7.33438
2021-22	8.41144702	9.7	
2022-23	11.9388456	7	

Source: MOSPI



Analysis-

- Production growth rates generally trended upwards from 2015-16 to 2017-18, reaching a peak in 2017-18. Subsequently, it declined sharply in 2018-19 and 2019-20, followed by a strong recovery in 2020-21 and 2021-22, before moderating slightly in 2022-23.
- GDP growth rates followed a similar pattern to production growth, with a peak in 2017-18 and a sharp decline in 2018-19 and 2019-20. However, the recovery in GDP growth was more pronounced in 2020-21 and 2021-22 compared to production growth.
- Consumption growth rates remained relatively stable from 2015-16 to 2017-18, followed by a decline in 2018-19 and 2019-20. Consumption growth rebounded in 2020-21 but then contracted in 2021-22 and 2022-23.

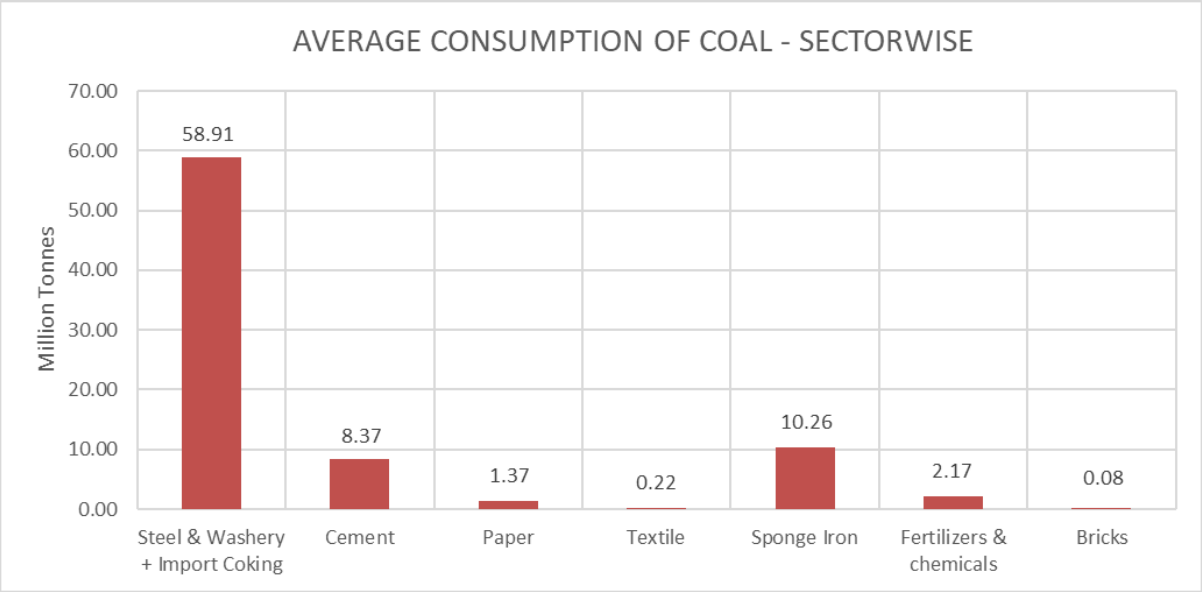
Dependence of other industries on major energy sources

COAL

Coal, a fossil fuel, has been a primary energy source for centuries. Its high energy density and relatively low cost make it a popular choice for various industries. The provided data and graph illustrate the consumption of coal in different sectors over the years.

SECTOR WISE CONSUMPTION OF COAL								
Year	Steel & Washery + Import Coking	Cement	Paper	Textile	Sponge Iron	Fertilizers &chemicals	Bricks	Total
2014-15	56.24	11.36	1.65	0.42	17.77	2.70	0.09	90.23
2015-16	57.08	8.99	1.21	0.27	7.76	2.62	0.07	78.00
2016-17	51.98	6.36	1.18	0.24	5.56	2.45	0.10	67.87
2017-18	58.45	7.71	1.51	0.24	8.53	2.16	0.12	78.72
2018-19	64.65	8.82	1.64	0.20	12.09	1.79	0.09	89.28
2019-20	63.74	8.57	1.33	0.10	10.53	1.76	0.03	86.06
2020-21 (P)	60.23	6.75	1.05	0.08	9.57	1.72	0.03	79.43
Average consumption over the years	58.91	8.37	1.37	0.22	10.26	2.17	0.08	81.37

Source: MOSPI



The graph illustrates the sector-wise average consumption of coal (in million tonnes), highlighting the dependence of different industries on coal as an energy source.

Analysis-

- The **steel industry** is by far the most reliant on coal, consuming nearly six times more than the next largest consumer (cement).
- **Sponge iron** also shows significant coal consumption, indicating that industries related to metal processing are major coal consumers.
- **Cement** and **fertiliser** industries have substantial coal needs, aligning with their energy-intensive production processes.

- **Paper**, **textile**, and **brick** industries have relatively low coal dependence, possibly indicating the use of alternative energy sources or less energy-intensive processes.

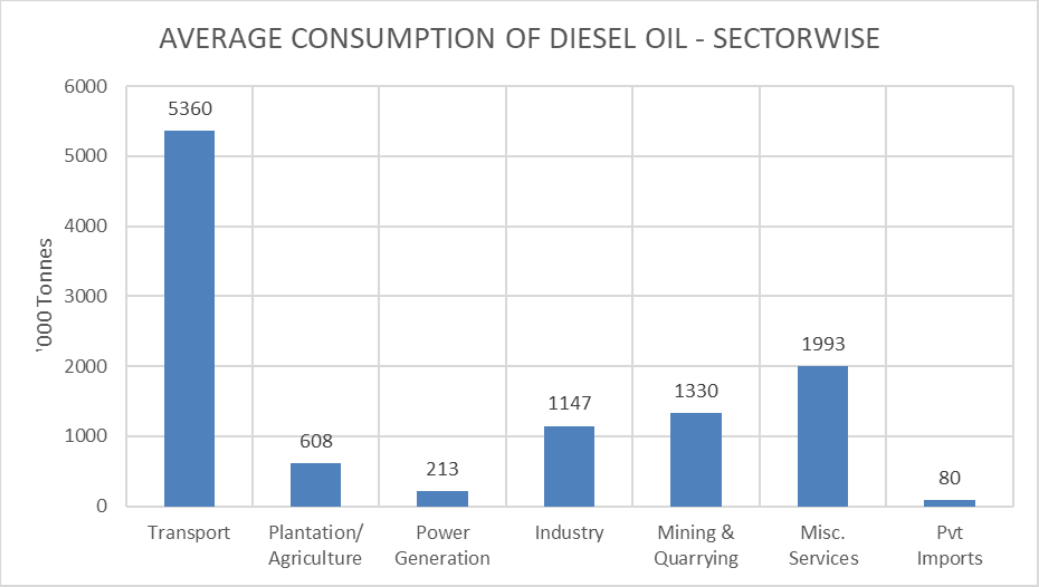
This graph effectively highlights the critical role that coal plays in energy-intensive industries like steel and cement, while other sectors either rely less on coal or utilise a mix of energy sources.

DIESEL OIL

Diesel oil, a vital liquid fuel, is widely used in various sectors due to its high energy density and efficiency. It is derived from petroleum and is a major product of oil refineries. Diesel oil is widely used in transportation, agriculture, marine transportation, and industrial applications.

SECTOR WISE CONSUMPTION OF DIESEL OIL								
Year	Transport	Plantation/ Agriculture	Power Generation	Industry	Mining & Quarrying	Misc. Services	Pvt Imports	Total
2014-15	4617	575	197	794	998	1748	83	9012
2015-16	5765	630	224	1096	1184	1922	55	10876
2016-17	5658	607	208	1033	1224	2161	46	10937
2017-18	5999	618	223	1155	1255	1887	90	11227
2018-19	6210	639	222	1264	1465	1938	93	11831
2019-20	6011	616	214	1334	1542	2064	117	11898
2020-21 (P)	3257	571	204	1355	1642	2232	79	9340
Average consumption over the years	5360	608	213	1147	1330	1993	80	10732

Source: MOSPI



This graph displays the sector-wise average consumption of diesel oil (in thousands of tonnes), illustrating the dependence of various industries on diesel oil as an energy source.

Analysis-

- **Transport** is by far the largest consumer of diesel oil, highlighting the sector's dependence on diesel for the movement of goods and people. The vast majority of heavy vehicles in freight and passenger services still run on diesel.
- **Mining & Quarrying** and **Industry** show significant diesel consumption, reflecting the energy requirements for operating large machinery and vehicles in resource extraction and industrial processes.
- **Miscellaneous services** also consume a notable amount, suggesting that various auxiliary sectors rely on diesel.
- **Agriculture** demonstrates a modest diesel use, likely due to mechanisation in farming practices.

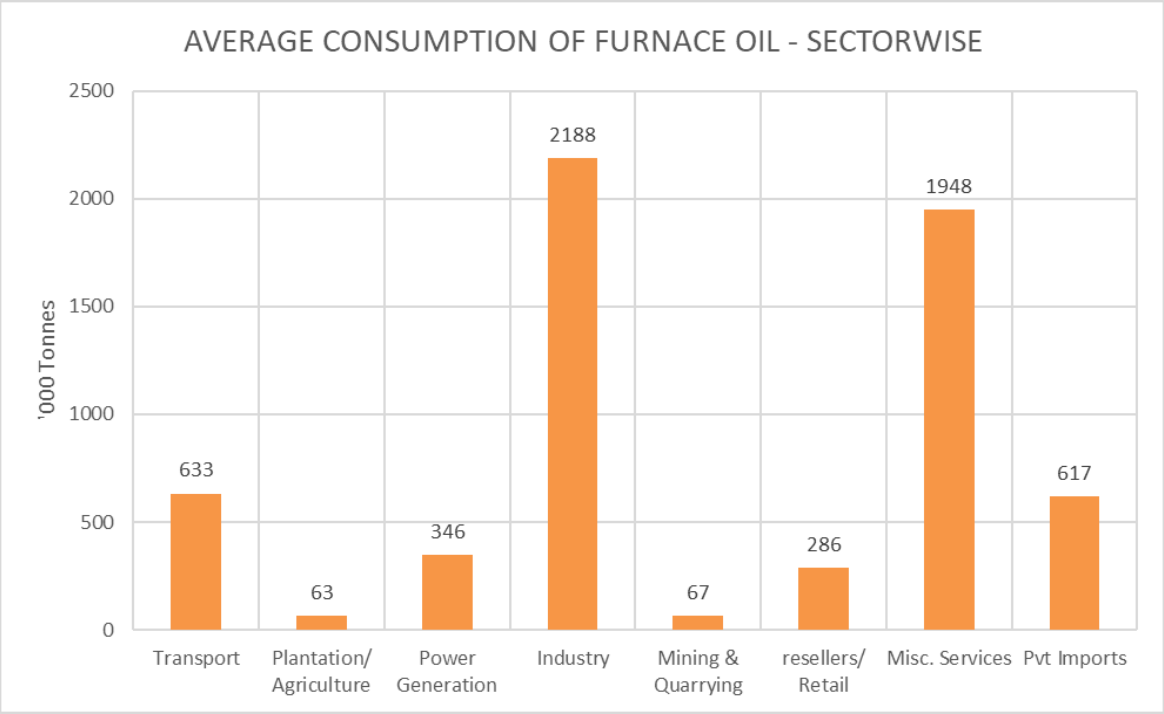
The analysis above highlights the significant dependence of major sectors on diesel oil as a critical energy source for their smooth functioning.

FURNACE OIL

Furnace oil is a liquid petroleum product used primarily for heating purposes. It is a blend of various hydrocarbons and is commonly used in residential, commercial, and industrial settings. Used in manufacturing, transport etc

SECTOR WISE CONSUMPTION OF FURNACE OIL									
Year	Transport	Plantation/ Agriculture	Power Generation	Industry	Mining & Quarrying	resellers/ Retail	Misc. Services	Pvt Imports	Total
2014-15	346	56	446	1748	45	197	2175	570	5583
2015-16	380	57	430	2136	53	270	2564	592	6482
2016-17	444	51	361	2492	71	357	2485	784	7045
2017-18	601	50	314	2346	68	321	2234	672	6606
2018-19	786	78	339	2577	54	298	1449	611	6192
2019-20	849	71	303	2143	84	290	1398	775	5913
2020-21 (P)	1022	80	226	1874	92	268	1330	316	5208
Average consumption over the years	633	63	346	2188	67	286	1948	617	6147

Source: MOSPI



The graph illustrates the sector-wise average consumption of furnace oil (in thousand tonnes), providing insight into how different sectors depend on furnace oil as an energy source.

Analysis-

- **Industries** are the largest consumers of furnace oil, indicating their reliance on it for industrial heating, machinery, and service operations.
- **Transport**, while predominantly reliant on diesel, shows moderate furnace oil use, possibly for specific segments like shipping or heavy-duty operations.
- **Power generation** uses furnace oil primarily for backup or supplemental energy needs.**Private imports** account for a considerable share, implying independent furnace oil sourcing for industrial or commercial use.
- **Mining and agriculture** show minimal reliance, suggesting the use of other fuels like diesel for most of their energy requirements.

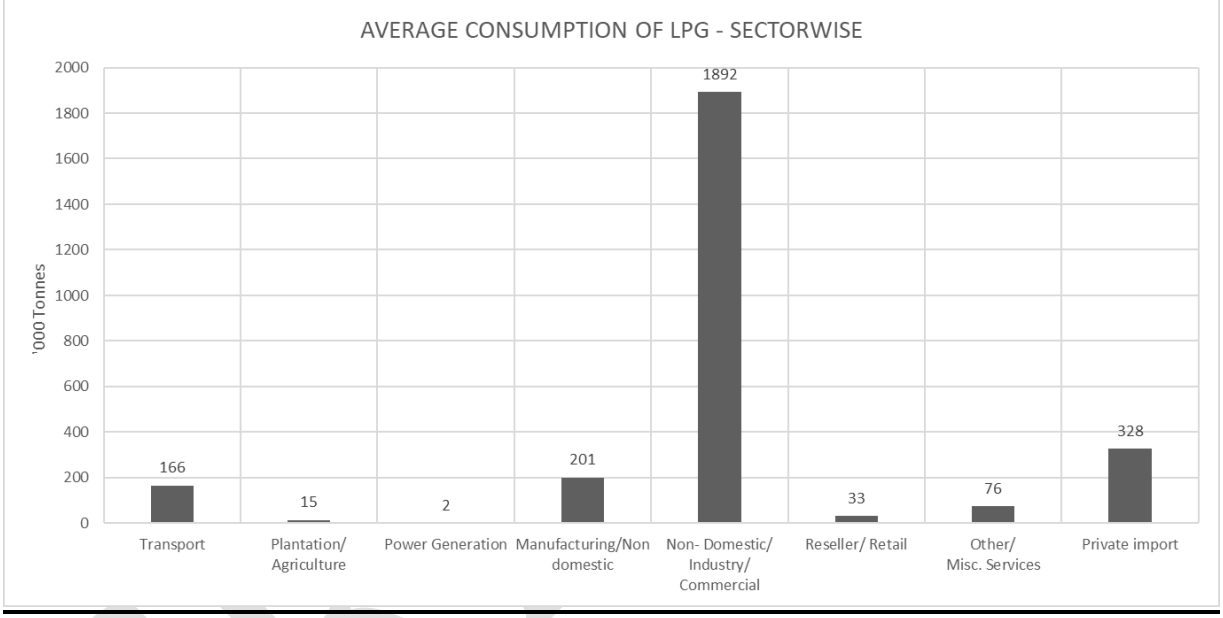
Overall, the graph reflects the continued importance of furnace oil in certain heavy industries and services, while other sectors rely less on it or use alternative energy sources.

LPG

Liquefied Petroleum Gas (LPG) is a mixture of propane and butane gases that is used for cooking, heating, and powering vehicles. It is a clean-burning and portable fuel source.

SECTOR WISE CONSUMPTION OF LPG									
Year	Transport	Plantation/ Agriculture	Power Generation	Manufacturing/ Non domestic	Non- Domestic/ Industry/ Commercial	Reseller/ Retail	Other/ Misc. Services	Private import	Total
2014-15	165	6	3	208	1,051	45	53	429	1,960
2015-16	172	7	3	202	1,464	45	60	489	2,442
2016-17	168	8	2	220	1,776	67	67	429	2,737
2017-18	185	7	1	205	2,086	74	67	364	2,989
2018-19	181	22	2	204	2,364	0	89	316	3,178
2019-20	173	26	1	153	2,614	0	82	204	3,253
2020-21 (P)	119	28	0	215	1,886	1	115	64	2,428
Average Consumption over the years	166	15	2	201	1892	33	76	328	2712

Source: MOSPI



This graph illustrates the sector-wise average consumption of LPG, showcasing how various sectors depend on energy.

Analysis-

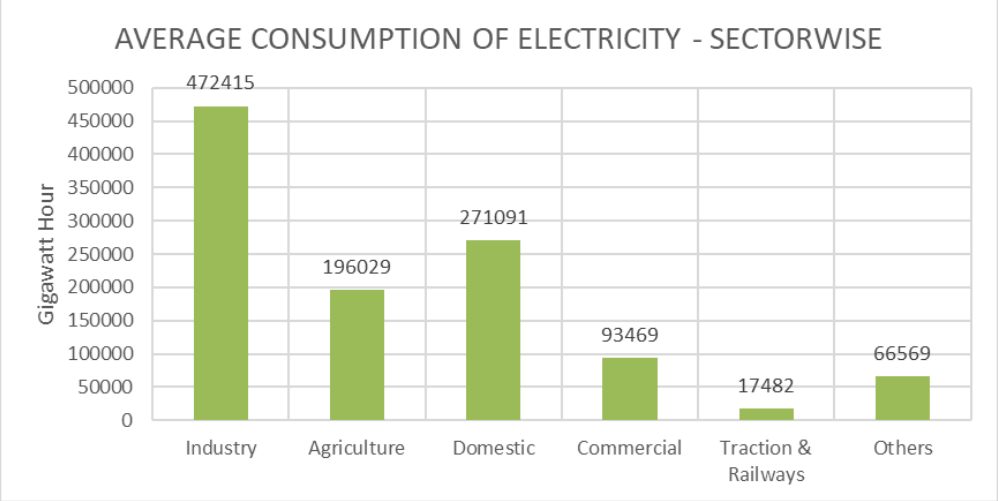
- The overwhelming dominance of the **Non-Domestic/Industry/Commercial** sector in LPG consumption highlights how integral this energy source is to economic production and commercial activities. Any disruption in the LPG supply could have severe consequences for industrial operations, commercial activities, and economic stability.
- The variety of sectors relying on LPG, from manufacturing to transport to private imports, showcases the widespread need for reliable energy sources across different industries.
- Even though some sectors (e.g., agriculture, power generation) have minimal consumption, their usage still reflects the importance of LPG in niche or supplementary roles in energy consumption.

ELECTRICITY

Electricity is a form of energy that flows through a conductor, such as a wire. It is a versatile energy source used for lighting, heating, cooling, powering appliances, and machinery. Electricity can be generated from both renewable and non-renewable sources.

SECTOR WISE CONSUMPTION OF ELECTRICITY							
Year	Industry	Agriculture	Domestic	Commercial	Traction & Railways	Others	Total Electricity Consumed
2014-15	4,18,346	1,68,913	2,17,405	78,391	16,177	49,289	9,48,521
2015-16	4,23,523	1,73,185	2,38,876	86,037	16,594	62,976	10,01,191
2016-17	4,40,206	1,91,151	2,55,826	89,825	15,683	68,493	10,61,184
2017-18	4,68,613	1,99,247	2,73,545	93,755	17,433	70,834	11,23,427
2018-19	5,19,196	2,13,409	2,88,243	98,228	18,837	72,058	12,09,971
2019-20	5,32,820	2,11,295	3,08,745	1,06,047	19,148	70,031	12,48,086
2020-21 (P)	5,04,200	2,15,000	3,15,000	1,02,000	18,500	72,300	12,27,000
Average Consumption over the years	472415	196029	271091	93469	17482	66569	1117054

Source: MOSPI



This graph depicts the sector-wise average consumption of electricity, measured in Gigawatt Hours (GWh).

Analysis-

- **Industry** is by far the largest consumer, reaffirming electricity's indispensable role in maintaining industrial productivity and economic growth. Disruptions in electricity supply to this sector could have large-scale economic ramifications.
- **The Domestic and Agriculture sectors** are also major consumers, reflecting the centrality of electricity in sustaining modern lifestyles and food production. This highlights the need for continuous and stable electricity supply to avoid disruptions in living conditions and food security.

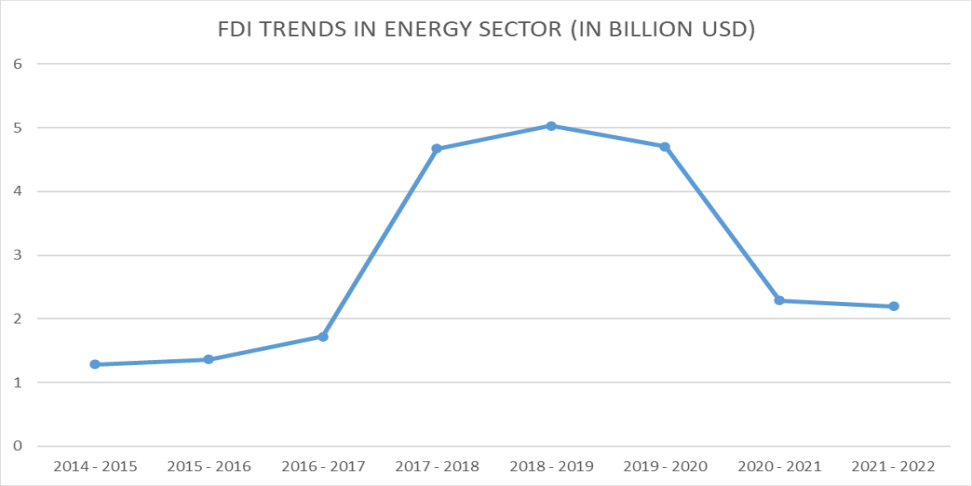
- **Commercial and Traction & Railways sectors** are smaller consumers but still crucial to the economy and public life. The steady reliance on electricity in these sectors indicates a move toward greener energy use in transportation and urban commercial centres.

The energy sector is fundamental to key industries such as transportation, manufacturing, and industrial production, all of which heavily rely on energy to operate. Whether it's powering vehicles, running manufacturing processes, or driving industrial machinery, the availability and sustainability of energy directly impacts their efficiency and growth. As these sectors transition towards renewable energy and more energy-efficient technologies, the energy sector remains crucial in supporting their operations and enabling a shift towards more sustainable practices.

FDI Trends

Year	FDI Inflow in Energy Sector (in Billion USD)
2014 - 2015	1.284
2015 - 2016	1.364
2016 - 2017	1.722
2017 - 2018	4.67
2018 - 2019	5.027
2019 - 2020	4.706
2020 - 2021	2.289
2021 - 2022	2.2

Source: NDAP



The graph depicts Foreign Direct Investment (FDI) trends in the energy sector from 2014-2015 to 2021-2022.

Analysis :

- **Initial Stability**: The first three years show a stable and low level of FDI.
- **Significant Growth**: A sharp increase occurred from 2017-2019, peaking at 5 billion USD.
- **Decline**: Post-2019, FDI started to decrease, with a notable drop after 2020, returning to pre-2017 levels.

IMPACT OF ENERGY CAPACITY ON ECONOMIC GROWTH AND ENERGY ACCESS

Year	Wind Power	Solar Power	Small Hydropower	Biomass (bagasse) Cogeneration	Biomass (Non-bagasse) Cogeneration	Waste to Power	Waste to Energy (Off-grid)	Total	GDP Real Price
2014-15	2311.77	1171.62	251.68	295.67	60.05	0	9.71	4100.5	2.03913E+12
2015-16	3423.05	3130.36	218.11	304.85	59.24	0	5.69	7141.3	2.10359E+12
2016-17	5502.37	5658.63	106.38	161.95	2.2	23.5	11.77	11466.8	2.2948E+12
2017-18	1865.23	9563.69	105.95	519.1	9.5	24.22	5.55	12093.24	2.65147E+12
2018-19	1480.97	6750.97	107.34	402.7	12	0	6.58	8760.56	2.70293E+12
2019-20	2117.79	6510.06	90.01	97	0	9.34	19.11	8843.31	2.83561E+12
2020-21	1503.3	5628.8	103.65	173.37	97.24	21	20.75	7548.11	2.67485E+12
2021-22	1110.53	12760.5	62.09	59.69	0	54.5	34.66	14081.97	3.16727E+12
2022-23	2275.55	12783.8	95.4	0	42.4	25	52.28	15274.43	3.35347E+12
2023-24	3253.38	15033.24	58.95	0	107.34	1.6	30.17	18484.68	3.54992E+12

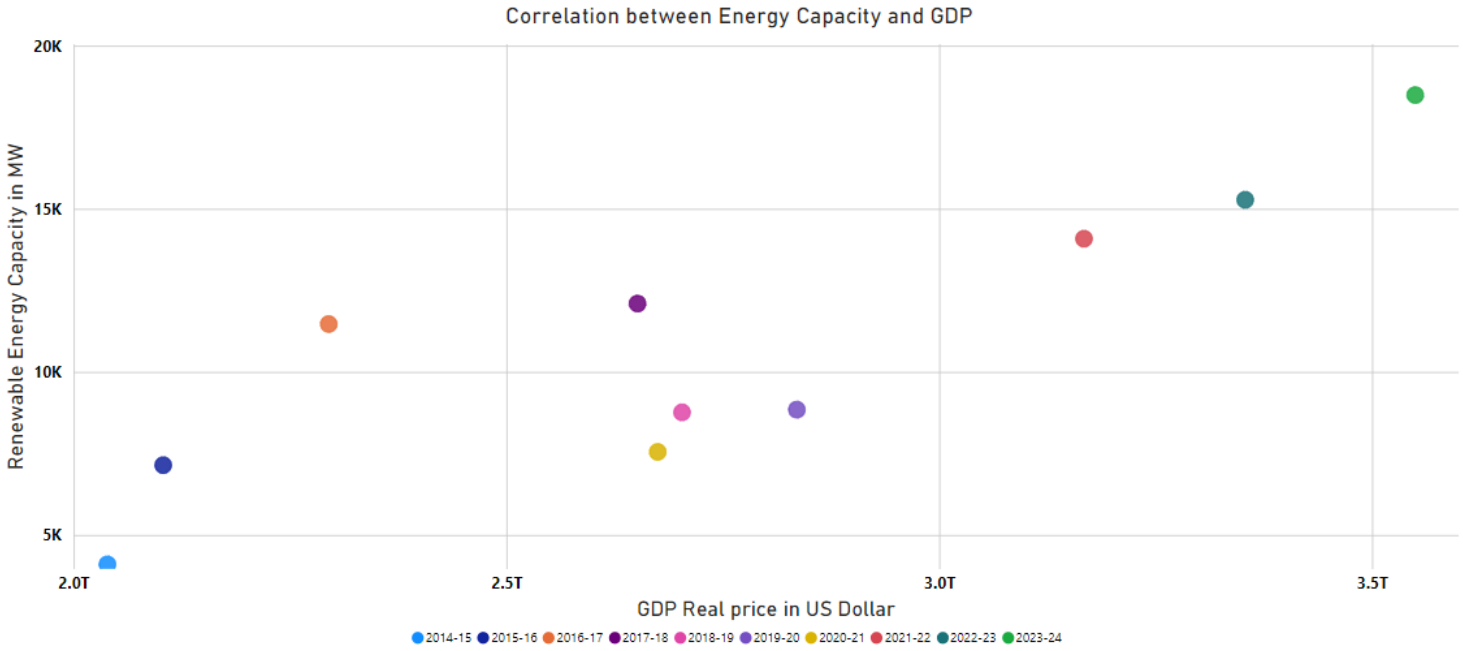


Table:

- The table lists different types of renewable energy capacities (like wind power, solar power, etc.) from the years 2014-2024, along with the total energy capacity in MW and GDP in US dollars for each year.
- Renewable energy capacity has increased significantly, especially in wind and solar power.
- GDP has also grown over time, rising from around $2.09 trillion in 2014-15 to approximately $3.55 trillion in 2023-24.

Scatter Plot:

- The scatter plot depicts the correlation between renewable energy capacity (MW) and GDP (in US dollars).
- Each dot represents a particular year between 2014-2024, with increasing energy capacity corresponding to rising GDP values.
- The correlation coefficient provided is **0.8611**, indicating a strong positive correlation between the growth in renewable energy capacity and the increase in GDP.

Analysis:

- **Strong Positive Correlation**: The correlation value of 0.8611 suggests that as renewable energy capacity increases, GDP also rises. This indicates that renewable energy expansion could be contributing positively to economic growth.
- **Trends**: Solar power and wind power seem to be the major contributors to the increase in renewable energy capacity over the years.
- **Sustainability**: The table reflects a steady commitment to renewable energy sources, which is not only good for sustainable development but also seems to align with economic growth, as shown by the correlation.

In conclusion, the data demonstrates that increasing renewable energy capacity is associated with a significant positive impact on GDP, reinforcing the economic benefits of investing in renewable energy sources.

A Case Study of Solar Energy Adoption in the Sundarbans

The Sundarbans, a vast mangrove forest delta shared by India and Bangladesh, is a unique ecosystem facing numerous challenges, including poverty, isolation, and natural disasters. Traditional energy sources have been inadequate in meeting the needs of this region. In recent years, solar energy has emerged as a promising solution, offering a sustainable and decentralised approach to power generation.

The Sundarbans' remote location and vulnerability to cyclones and flooding pose significant hurdles for grid-connected electricity. Solar energy, with its ability to generate power at the local level, offers a viable alternative. Solar home systems (SHSs) have been distributed to thousands of households, providing lighting, powering small appliances, and improving living standards. Additionally, solar

microgrids have been established in several villages, powering community facilities such as schools, health centres, and community centres.

The adoption of solar energy in the Sundarbans has faced challenges, including the high initial cost of solar systems, limited access to finance, and the need for proper maintenance. To address these issues, government subsidies, financing schemes, and capacity-building programs have been implemented. Moreover, research and development efforts are focused on developing more efficient and resilient solar technologies suitable for the region's specific conditions.

The success of solar energy in the Sundarbans can be attributed to several factors. First, the region's abundant sunlight makes it an ideal location for solar power generation. Second, the local communities have shown strong interest in adopting solar technologies, recognizing their benefits in terms of improved energy access and reduced dependence on fossil fuels. Third, the support of government agencies and NGOs has been crucial in promoting solar energy adoption and addressing the associated challenges.

Despite the progress made, the Sundarbans still faces significant energy challenges. Expanding solar energy adoption to reach a larger portion of the population remains a priority. Integrating solar energy with other renewable sources, such as wind and biomass, can enhance energy security and reduce reliance on fossil fuels. Furthermore, addressing the long-term sustainability of solar projects, including proper maintenance and disposal of solar panels, is essential for ensuring their long-term success.

ECONOMIC IMPACT OF THIS PROJECT

Thousands of Households Benefited: Solar home systems (SHSs) have been distributed to thousands of households in the Sundarbans, providing them with access to electricity.

Significant Reduction in Energy Costs: Households using SHSs have reduced their electricity bills by up to 50% or more.

Job Creation: Solar energy projects in the Sundarbans have created jobs in various sectors, including installation, maintenance, and manufacturing.

Increased Agricultural Productivity: Solar-powered pumps can help farmers improve agricultural productivity by providing reliable irrigation.

In conclusion, the case of solar energy adoption in the Sundarbans demonstrates the potential of this technology to transform the lives of people in remote and vulnerable regions. By overcoming challenges and leveraging the available opportunities, the Sundarbans can pave the way for a more sustainable and resilient future powered by clean energy.

A Case Study: The Rongtong Hydel Project

The Rongtong Hydel Project, located in the remote Lahaul-Spiti district of Himachal Pradesh, India, is a pioneering example of hydropower generation in a high-altitude environment. Situated at an elevation of 3,600 metres, the project harnesses snowmelt from the Rongtong Nullaha, a tributary of the Spiti river. Despite the challenging terrain and extreme weather conditions, the

project was successfully executed, demonstrating the potential of hydropower in even the most inhospitable regions.

The Rongtong Hydel Project was the first hydroelectric project in the Lahaul-Spiti region, aiming to uplift the lives of the local tribal communities. By providing electricity to the area, the project has enabled economic development, improved access to healthcare and education, and enhanced the overall quality of life for the residents.

However, the construction and operation of the project presented significant technical challenges. The high altitude, extreme temperatures, and remote location made it difficult to transport materials, mobilise equipment, and ensure the safety of workers. Despite these hurdles, the project was successfully completed, showcasing the ingenuity and resilience of the engineering teams involved.

In recent years, the Rongtong Hydel Project underwent a renovation by APE Power Pvt. Ltd. This renovation aimed to modernise the project's infrastructure, improve its efficiency, and ensure its continued operation for years to come. The successful completion of the renovation has solidified the project's position as a vital source of energy for the Lahaul-Spiti region.

ECONOMIC IMPACT OF THIS PROJECT

Increased Agricultural Production: The project has led to a significant increase in agricultural production, with farmers reporting higher yields and incomes.

Job Creation: The project has created direct and indirect jobs in the construction, operation, and maintenance of the project, as well as in related industries.

Improved Access to Services: The project has enabled the establishment of schools, healthcare centres, and communication facilities, improving access to essential services for the local population.

Tourism Growth: The project has contributed to a significant increase in tourism to the Lahaul-Spiti region, attracting visitors from both India and abroad.

The Rongtong Hydel Project serves as a valuable case study for other high-altitude hydropower projects. It demonstrates the potential of this renewable energy source to provide electricity to remote and underserved areas, even in the face of significant technical challenges. The project's success underscores the importance of careful planning, innovative engineering, and a commitment to sustainable development in harnessing the power of nature.

Challenges in India's Renewable Energy Sector

India, despite its ambitious renewable energy targets, faces several challenges in its transition to a cleaner energy future. Here are some of the key obstacles:

1. High Upfront Costs:

- **Initial Investment:** The initial capital expenditure for renewable energy projects, especially solar and wind power, can be substantial. This can deter potential investors and limit the pace of adoption.
- **Lack of Financial Support:** While the government has introduced various incentives, more financial support is needed to make renewable energy projects economically viable for both large-scale and small-scale players.

2. Intermittency and Grid Integration:

- **Fluctuating Output:** Solar and wind power are intermittent sources, meaning their generation varies depending on weather conditions. This can pose challenges for grid stability.
- **Storage Solutions:** The lack of efficient and affordable energy storage solutions makes it difficult to balance supply and demand during periods of low renewable energy generation.

3. Land Acquisition and Environmental Concerns:

- **Land Availability:** Large-scale renewable energy projects require significant land areas, which can conflict with other land uses such as agriculture and conservation.
- **Environmental Impact:** Concerns about the environmental impact of renewable energy projects, such as habitat destruction and visual pollution, can hinder their development.

4. Policy and Regulatory Hurdles:

- **Complex Regulations:** The regulatory landscape for renewable energy in India can be complex, with varying policies at different levels of government. This can create uncertainties and delays in project implementation.
- **Grid Connectivity:** Ensuring timely grid connectivity for renewable energy projects is another challenge, as it involves coordination between various stakeholders.

5. Technology Dependence:

- **Foreign Technology:** India is heavily reliant on foreign technology for manufacturing components and equipment for renewable energy systems. This can lead to supply chain disruptions and increased costs.
- **Domestic R&D:** Promoting domestic research and development in renewable energy technologies is crucial to reduce dependence on foreign sources.

6. Infrastructure Development:

- **Transmission and Distribution:** Upgrading the existing transmission and distribution infrastructure is essential to accommodate the increasing share of renewable energy in the grid.
- **Smart Grids:** Investing in smart grid technologies can help manage the integration of renewable energy sources and improve grid efficiency.

Addressing these challenges requires a concerted effort from the government, industry, and research institutions. By implementing effective policies, investing in research and development, and fostering a supportive ecosystem, India can overcome these obstacles and achieve its renewable energy goals.

CONCLUSION

The energy sector plays a crucial role in India's economic development, with both direct and indirect contributions to GDP growth over the past decade. This research demonstrates that investments in energy infrastructure, particularly in renewable energy, significantly impact GDP, job creation, and industrial productivity. By fostering energy access, stimulating technological innovation, and supporting rural electrification, energy infrastructure acts as a catalyst for broader economic growth.

The study highlights that public and private investments in energy, especially in renewables, have not only promoted energy security but also generated employment and driven regional development. Key projects like the Jawaharlal Nehru National Solar Mission have demonstrated the transformative power of renewable energy in shaping India's economic future.

By analysing historical trends and the synergies between the energy sector and other sectors, this research underscores the importance of continued investment in energy infrastructure to ensure long-term sustainable growth. Policymakers and investors are encouraged to prioritise strategic energy investments, particularly in renewables, to maximise economic returns while addressing pressing environmental and energy security challenges.

In conclusion, the energy sector remains integral to India's economic growth, and its role will continue to expand as the country advances toward a more sustainable and resilient economic future. The insights generated from this research provide valuable guidance for policymakers and stakeholders aiming to foster economic growth through targeted energy investments.

BIBLIOGRAPHY

Energy Sector Statistics- https://www.mospi.gov.in/sites/default/files/publication_reports/EnergyStatistics_India_publication_2024N.pdf

Ministry of new and renewable energy- https://www.mospi.gov.in/sites/default/files/publication_reports/EnergyStatistics_India_publication_2024N.pdf

Ministry of power- https://powermin.gov.in/

World Bank- www.worldbank.org

NDAP (Niti Aayog)- https://ndap.niti.gov.in/

MOSPI- https://www.mospi.gov.in/

Case Studies- https://feniceenergy.com/renewable-energy-in-remote-communities-case-study/

Government Data- https://www.data.gov.in/