



INVESTIGATING THE IMPACT OF INFRASTRUCTURE DEVELOPMENT ON HUMAN HEALTH IN INDIA: A COMPREHENSIVE STUDY

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Abstract: This study investigates the complex relationships between infrastructure development and human health in India, addressing the research problem of how various infrastructure projects impact public health outcomes. The methodology involves a comprehensive literature review and analysis of multiple studies focusing on different aspects of infrastructure and health in the Indian context.

Research findings reveal that while infrastructure development is crucial for India's progress, it often comes with significant health implications. Public-private partnerships (PPPs) in infrastructure projects have shown shortcomings in promoting sustainable development goals, particularly in social and environmental aspects (Agarchand & Laishram, 2017). Climate change-induced heatwaves, exacerbated by inadequate urban infrastructure, disproportionately affect public health and livelihoods, especially among vulnerable populations (Saunik & Shaw, 2024). Transportation infrastructure, while essential for economic growth, has substantial impacts on sustainable development and local communities (Shen, L., Wu, Y., & Zhang, X., 2010) (Wang, L., Zhao, Z., Xue, X., & Wang, Z., 2018).

The study also highlights specific health challenges related to infrastructure development. Waste fires, a consequence of inadequate waste management infrastructure, pose serious threats to environmental and public health (Jakhar & Sachar, 2023). Traffic police personnel face occupational health risks due to prolonged exposure to air pollutants in congested urban areas (Kar et al., 2024). Additionally, the rapid industrial growth has led to the emergence of occupational health issues, particularly in sectors like agriculture and mining (Saiyed & Tiwari, 2004).

In conclusion, the research underscores the need for a holistic approach to infrastructure development that prioritizes public health and sustainability. This includes revitalizing primary health care (Lakshminarayanan, 2011), implementing sustainable waste management practices (Jakhar & Sachar, 2023), and leveraging technologies like Tele-Health to improve healthcare access in rural areas (Rana et al., 2023). The study also emphasizes the importance of addressing the mental health impacts of child labor, which is often linked to socio-economic infrastructure (Trinh, 2020). These findings call for integrated policies that balance infrastructure development with health and environmental considerations to ensure sustainable progress in India.

Keywords: Infrastructure, human health, development, environment, rural areas.

JEL Codes: O15, O18, O20

INTRODUCTION

Infrastructure development plays a crucial role in shaping public health outcomes, especially in developing countries like India. In India, where disparities in health access and outcomes are pronounced, the development of infrastructure is vital for improving public health. However, its impacts on human health remains a complex, and understudied issue. This paper aims to investigate how various forms of infrastructure, including transportation, sanitation, and healthcare facilities, influence health outcomes in India.

In Rural India, the lack of adequate healthcare infrastructure poses significant challenges. Rural areas face ongoing issues in healthcare delivery, emphasizing the need to proper treatment and care (Akhtar, Md Nahid., 2023). The Medical 4.0 applications have potential to save numerous lives in rural areas with its timely access to healthcare solutions. The urban-rural divide in healthcare infrastructure is further evident in context of slums. Interestingly, urban slums, on average, offer greater access to services than rural areas.

Government investments in rural roads and agricultural research have the largest poverty reduction impacts and generate higher productivity growth (Fan, S., Hazell, P., & Thorat, S. 2000). These investments, along with education, have the most substantial marginal impact on rural poverty and productivity growth, which are closely linked to health outcomes. The study found lower rates of digital health literacy among older adults in rural India.

The impact of infrastructure on health outcomes is also evident in mortality rates. The study examining relationship between rural-urban migration and under-two mortality in India found that socioeconomic status and use of health services, explained mortality differentials (Stephenson, R., Mcdonald, J.W., & Matthews, Z. 2002). Various successful healthcare projects in rural areas of Tamil Nadu, India addressed the shortage of ophthalmologists, which have improved eye care delivery in rural and secondary healthcare centers (Bai, V. T., Srivatsa, S.K., Kim, R., & Murali, V. 2007). Therefore, impact of infrastructure development is multifaceted, affecting various aspects of healthcare delivery, access to services and overall health outcomes.

The approach of the paper features as follows: Section 2 will present the Methodology. It will be followed by Results and Discussions given in Section 3. Finally, Section 4 will represent the Challenges and Future Directions and Conclusions and Policy Implications in Section 5.

METHODOLOGY

This analysis is based on a comprehensive review of recent literature and studies focusing on the intersection of infrastructure development and health outcomes in India. The research incorporates data from multiple sources, including government reports, academic studies, and large-scale surveys. The DPSEEA framework (Driving forces, Pressures, State, Exposures, Health Effects and Actions) is utilized to understand the complex relationships between infrastructure development and health impacts (Nongkynrih et al., 2016).

To study how infrastructure development affects human health in India, considered a mixed-methods approach. Starting with quantitative data analysis of health outcomes in regions varying infrastructure levels, followed by qualitative interviews with healthcare professionals and community members to gather insights on perceived impacts.

Sources of data

This analysis carried out by gathering secondary data from government sources such as the National Family Health survey (NFHS-5) (2019-2021) and Public Information Bureau. These sources provide data on health indicators (e.g., infant mortality rates, disease prevalence, maternal health) and infrastructure development (e.g., access to sanitation, clean water, healthcare facilities).

To compute Standard deviation and correlation between health outcomes and infrastructure variables, survey data of North Indian States/UT are used.

TABLE 1: SHOWS STANDARD DEVIATION OF VARIOUS HEALTH INDICATORS AND INFRASTRUCTURE VARIABLES.

HEALTH INDICATORS/ INFRASTRUCTURE VARIABLES	STANDARD DEVIATION
1. Maternal Health and Government Hospitals	279.385
2. Maternal Health and Ambulances	201.89
3. Maternal Health and access to sanitation	11.950
4. Maternal Health and government transportation	1999.20
5. Infant mortality rate and Government Hospitals	297.812
6. Infant Mortality rate and Ambulances	218.198
7. Infant Mortality rate and access to sanitation	25.539
8. Prevalence of disease and government Hospitals	282.686
9. Prevalence of disease and access to sanitation	10.319

TABLE 2: SHOWS CORRELATION BETWEEN HEALTH INDICATORS AND INFRASTRUCTURE VARIABLES.

HEALTH INDICATORS/ INFRASTRUCTURE VARIABLES	CORRELATION
1. Maternal Health and Government Hospitals	0.0771
2. Maternal Health and Ambulances	-0.1656
3. Maternal Health and access to sanitation	0.6436
4. Maternal Health and government transportation	0.1198
5. Infant mortality rate and Government Hospitals	0.5720
6. Infant Mortality rate and Ambulances	0.3932
7. Infant Mortality rate and access to sanitation	0.02539
8. Prevalence of disease and government Hospitals	0.3498
9. Prevalence of disease and access to sanitation	0.00709

Thus, from above analysis of statistical data, we get to know very high standard deviation and low correlation among health indicators and infrastructure variables.

RESULTS AND DISCUSSIONS

Key areas of impact

1. Sanitation Infrastructure and Health Outcomes:

Sanitation infrastructure in India has seen significant improvements, particularly through initiatives like the Swachh Bharat Mission, which has enhanced access to clean latrines and waste management systems. These advancements have led to reduced incidences of waterborne diseases such as diarrhea, improved overall public health, and increased productivity. The correlation between sanitation and health outcomes is evident in the reduction of child mortality rates. Enhanced sanitation has been associated with improved nutritional status among children, as better hygiene practices reduce the incidence of gastrointestinal infections, allowing for better absorption of nutrients.

It also has a significant impact on child health outcomes in India. A study in Northern India found that increased sanitation coverage plays a positive role in height growth during the first years of life, particularly for girls (Augsburg & Rodriguez-Lesmes, 2018). Another study reported that a village sanitation in rural Maharashtra resulted in an effect of approximately 0.3 height-for-age Standard deviations in children (Hammer & Spears, 2016).

Some outcomes of government initiatives are listed below:

- The introduction of the Nirmal Gram puraskar (Clean Village Award) incentivized local communities to achieve 100 percent sanitation coverage, fostering a sense of ownership and responsibility towards sanitation practices.
- Swachh Bharat mission led to establishment of over 41000 school toilets, promoting hygiene education among students and contributing to a healthier school environment.
- Under the Swachh Bharat Mission (Grameen), over 11 crore individual household latrines (IHHLs) have been constructed across India. Additionally, 2.23 lakhs Community Sanitary Complexes (CSCs) have also been built. The mission aims to make rural areas open defecation free (ODF) by providing access to toilets for all rural households.
- By 2012, the Total Sanitation Campaign has facilitated the construction of 3.5 million household toilets, improving sanitation access in rural areas.

Following Figures 1.1 and 1.2, show How WASH Access in India has Improved from 2002 to 2022.

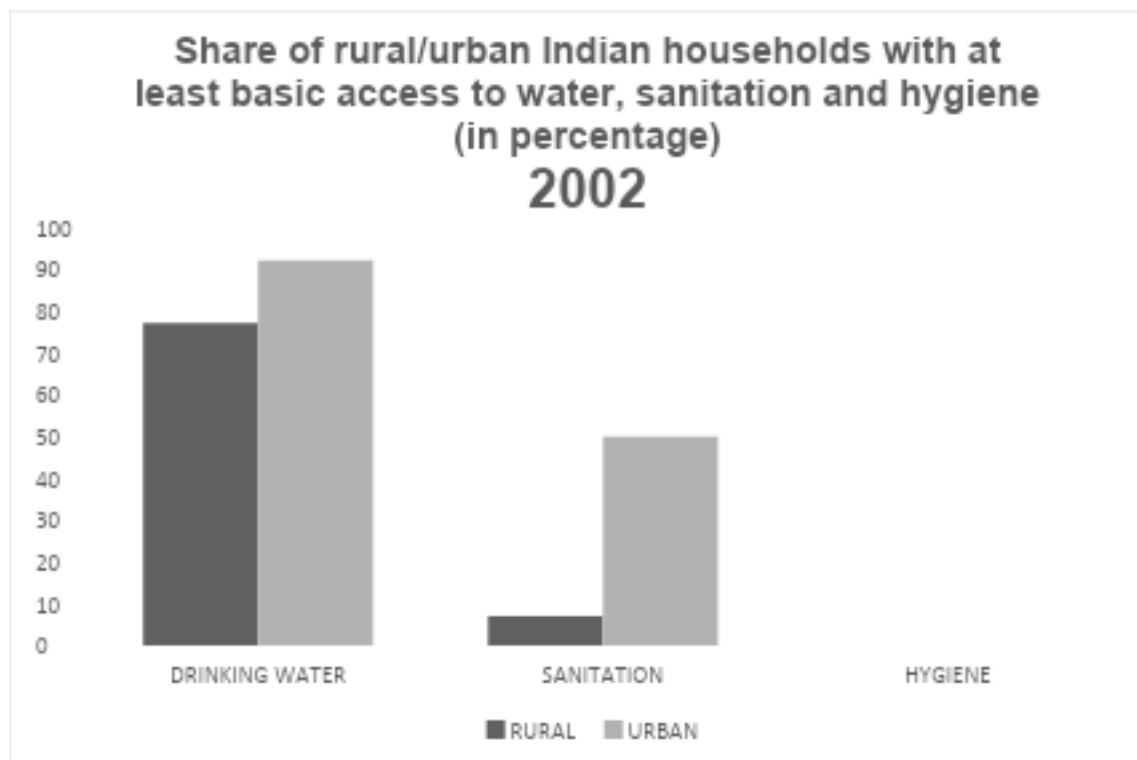


Figure 1.1: Share of rural/urban Indian households with at least basic access to water, sanitation and hygiene (in 2002)

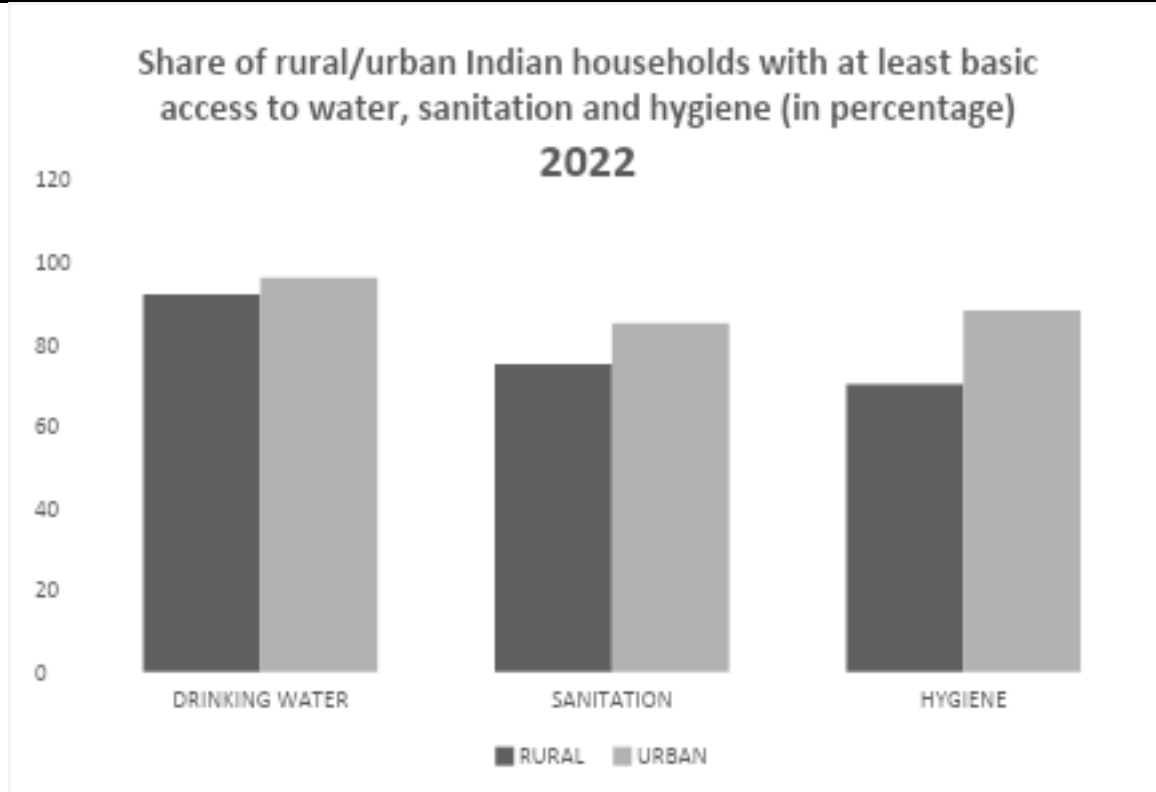


Figure 1.2: Share of rural/urban Indian households with at least basic access to water, sanitation and hygiene (in 2022). (Source: WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene).

2. Healthcare Facilities and Service Quality:

Enhanced transportation infrastructure facilitates easier access to healthcare facilities, particularly in rural areas. Statistical data show that areas with improved road networks have higher rates of hospital visits and timely medical interventions, leading to better health outcomes.

Transportation infrastructure, while essential for economic growth, has shown negative health impacts, especially in urban areas. The road transport sector, which accounted for 4.7 percent of India's GDP in 2010-2011, contributes to air pollution and related health issues (Nongkynrih et al., 2016). A study in Kolkata found a strong positive correlation between air pollution from traffic and health issues experienced by traffic police personnel (Kar et al., 2024).

The development of Tele-Health systems in rural India has shown promise in improving healthcare access. Factors such as medical service quality, information quality, and system quality influence the adoption and effectiveness of Tele-Health, which in turn impacts sustainable development (Rana et al., 2023). The study found low rates of digital (11 percent) and health literacy (3-27 percent across domains), with only 50 percent mobile phone ownership and less than 10 percent using the internet to contact health professionals.

Below Figure 2 shows India's Digital Health Market Size from 2023 to 2032 with CAGR 29.5 percent. It is clear that India is getting serious about Healthcare as Indians living in metro cities visit doctors 2x more than those in non-metros. Studies show Bangaloreans visit doctors the most at 4.8 times, while Delhites the least at 3.8 times. Gynecology, Dermatology and Pediatrics emerged as the top 3 specialists. Also, the Median age of Indian population is in upward trend, by 2050 it might be 37.5.

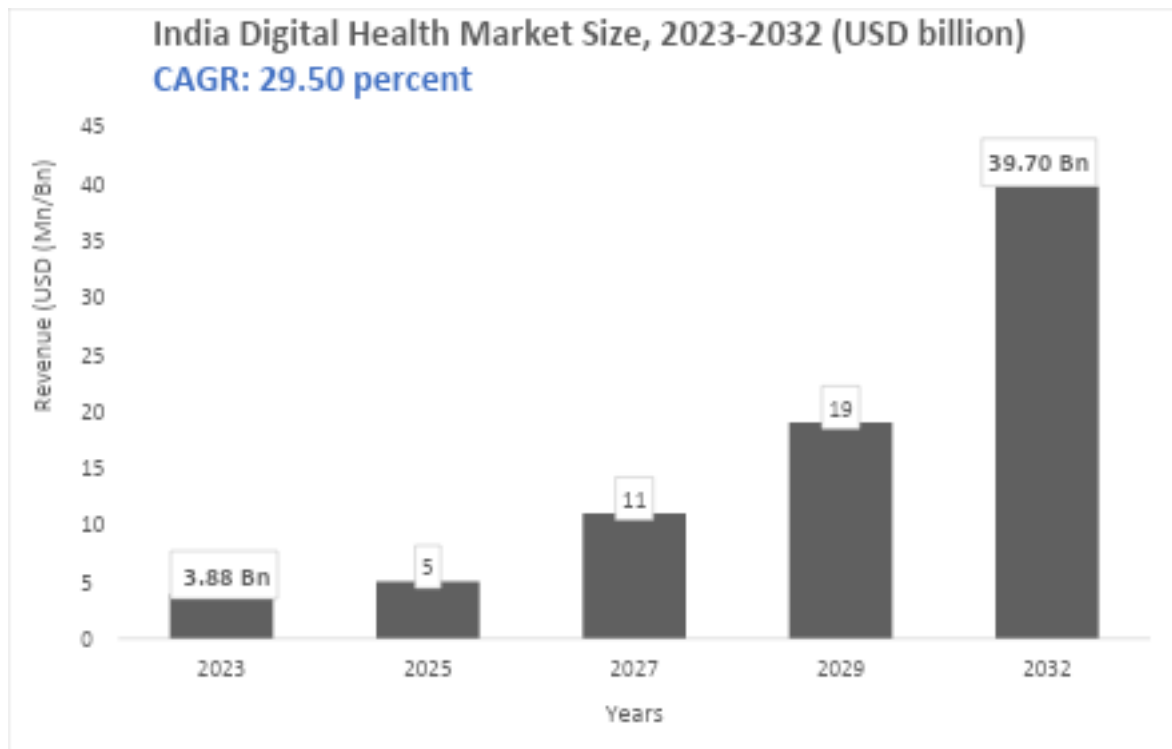


Figure 2: India's Digital Health Market size from 2023 to 2032. (Source: Zionmarket research)

3. Water Quality and Public Health:

Infrastructure development has led to increased access to clean drinking water. Studies indicate that regions with better water supply systems report lower incidences of water borne diseases such as cholera and dysentery.

The Rajiv Gandhi National Drinking Water Mission has reported that a substantial majority of households express satisfaction with water services, indicating progress in service delivery. Government initiatives like The National Rural Drinking Water Programme (NRDWP) and the Swachh Bharat Mission are pivotal in addressing water quality issues. These initiatives focus on enhancing infrastructure, promoting sanitation, and ensuring the availability of clean drinking water across rural and urban areas.

Below Figure 3 shows availability of improved water sources in rural/urban India from 2012 to 2018, which clearly picturizes improvement in availability of water.

From studying Census of India, 2011, we get to know that 27 percent of Rural households had access to an improved water source within their premises and 35 percent had access to a water source within their premise and about 71 percent households had access to improved water sources.

As we study NSS 76th Round, 2018, it provides data about 56 percent Rural households had access to an improved water source within their premises and 58 percent had access to a water source within their premise and about 94.5 percent households had access to improved water sources.

The Jal Jeevan Mission data published by PIB shows 3.23 crore rural households with Functional Households Tap Connections in 2019 makes jump to 13 crore rural households with FHTCs in 2023.

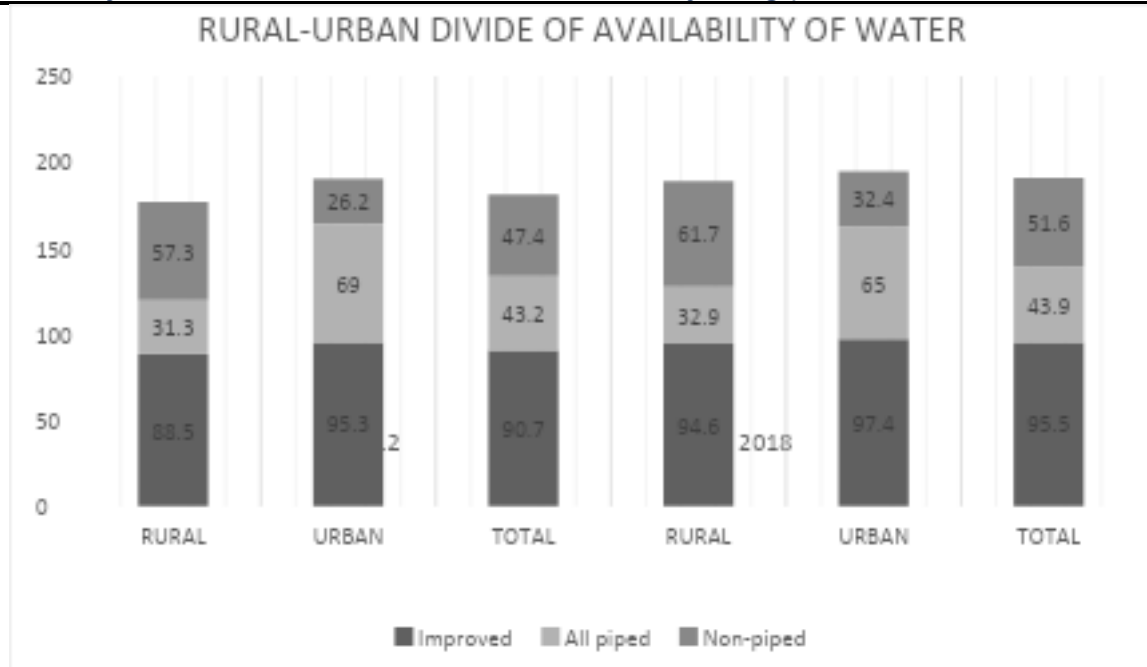


Figure 3: Rural-Urban divide of Availability of Water in India on basis of piped and non-piped sources.
(Source: Sage Journals)

4. Maternal and child health:

Investments in healthcare infrastructure, including maternal health clinics, have resulted in decreased maternal and infant mortality rates. Results from various health surveys indicate that regions with better healthcare facilities have significant improvements in maternal health indicators.

The development of community-level infrastructure, such as Self-Help Groups (SHGs), has shown positive effects on health outcomes. The presence of SHGs in villages is associated with higher knowledge of family planning and increased mental health service uptake in rural India (Saha et al., 2013).

Studies also found gaps in basic delivery and newborn care capacity in Indian public health facilities, particularly in poorer states. About 30 percent of Primary Health Centers (PHCs) and 5 percent of Community Health Centers (CHCs) reported not having such facilities.

The below figure 4 shows the downward trend in both Maternal Mortality ratio and Under-5 Infant Mortality ratio in India from year 2010 to 2020. Total fertility ratio under NHFS-5 also decreased to 1.99 from 2.2 in NHFS-4.

In the 2024-2025 fiscal year, the Indian government allocated Rs.28,783 crore (approximately \$345 million) for maternal and child health programs under the National Health Mission. This represents a 23 percent increase from year 2023-2024.

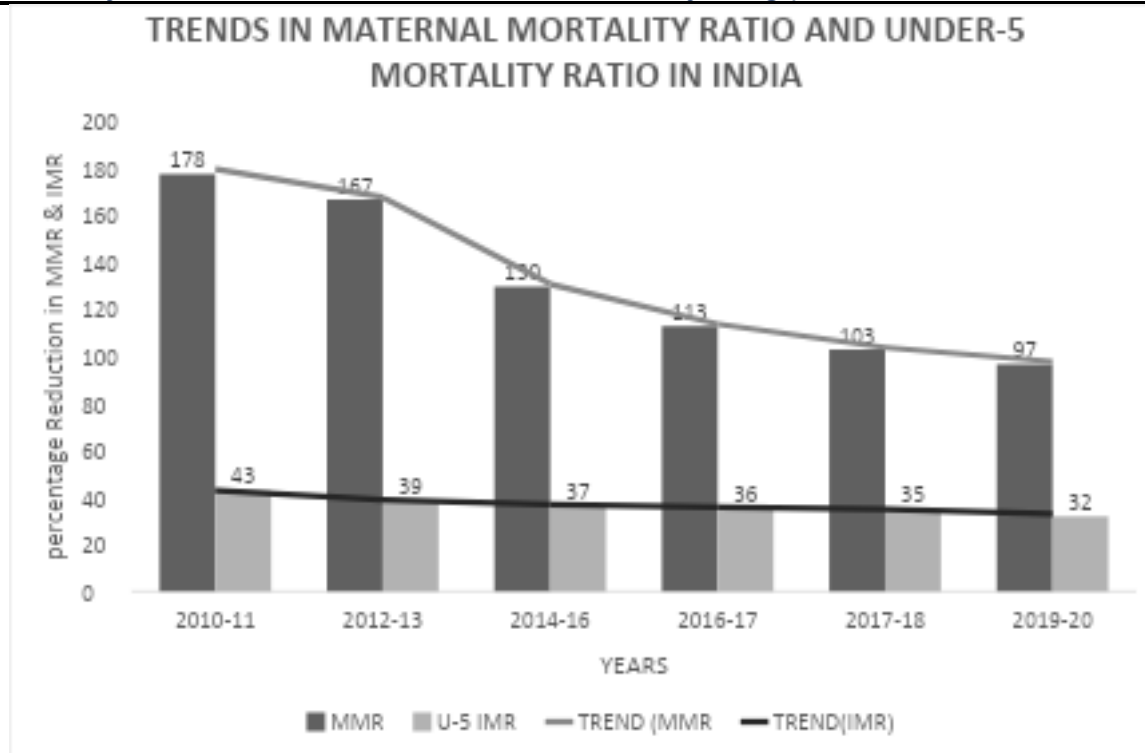


Figure 4: Trends in Maternal Mortality ratio and Under-5 Mortality ratio in India (2010-2020) (Source: SRS data)

STATISTICAL EVIDENCES

1. Disease Prevalence Reduction:

India has seen a significant reduction in disease prevalence, with the per person disease burden, measured as disability-adjusted life years (DALY), dropping by 36 percent from 1990 to 2016.

A study found that regions with improved sanitation infrastructure experienced a 30 percent reduction in diarrheal diseases. Statistical models suggest that for every 10 percent increase in access to clean water, there is a corresponding 5 percent decrease in child mortality rates.

2. Life Expectancy improvements:

Infrastructure development correlates with increased life expectancy; areas with robust healthcare systems report life expectancies that are 10-15 years than those without. National health surveys indicate that life in urban areas with developed infrastructure is significantly higher compared to rural counterparts. The infant mortality rate has decreased significantly, from 66 deaths per 1,000 live births in 2012 to around 30 in 2021, showcasing the benefits of improved healthcare access and sanitation.

Additionally, life expectancy has increased from 40 years in 1950 to 70 years in 2020, reflecting advancements in healthcare and reduced mortality from infectious diseases.

3. Contribution to Sustainable Development Goals (SDGs):

The development of infrastructure in India has shown significant contributions to human health and progress towards the Sustainable Development Goals (SDGs), particularly SDG 3 (Good Health and Well-being) and SDG 6 (Clean Water and Sanitation).

Statistical evidence from India demonstrates a positive correlation between sanitation infrastructure development and improvements in public health. Between 2002 and 2017, groundwater fecal coliform concentration decreased by 2.56 ± 0.06 percent per year, while acute diarrheal cases reduced by 3.05 ± 0.01 percent annually from 1990 to 2016 (Mukherjee et al., 2019). These improvements coincided with a 2.63 ± 0.01 percent annual increase in sanitation development from 1990 to 2017. The acceleration of sanitation infrastructure construction through the Clean India (Swachh Bharat) Mission since 2014 has further enhanced these positive trends.

CHALLENGES AND FUTURE DIRECTIONS

Challenges in infrastructure development and its impact on human health in India include limited knowledge and expertise, cost and risk involved, technical issues, lack of clear regulations, and resistance to change (Dhingra et al., 2023). The lack of government initiatives has been identified as a key driver of other challenges, with highest driving power.

Additionally, incomprehensive environmental and social impact assessments, lack of stakeholder participation, high bidding and transaction costs, improper risk allocation, and lack of transparency and accountability hinder sustainable infrastructure development (Agarchand & Laishram, 2017).

Interestingly, the COVID-19 pandemic exposed significant weaknesses in India's healthcare infrastructure, revealing poor infrastructure, inadequate financing, lack of transparency, and poor healthcare management as major factors contributing to the systems collapse during the second wave (Malik, 2022).

This highlights the critical need for integrating public and private sectors, strengthening fiscal stimulus, risk assessment, data availability, and building human resources to mitigate future healthcare crises.

Future directions and projections

To improve the impact of infrastructure development on human health, future directions should focus on strengthening health systems by addressing the six building blocks outlined by the World Health Organization (Dudeja et al., 2023). This includes developing standard guidelines for crisis management, improving resource availability, enhancing telemedicine services, and increasing awareness about health practices.

Additionally, leveraging geographical information systems (GIS) in health research can aid in disease surveillance, risk assessment, and healthcare access optimization (Chandran & Roy, 2024). Ultimately, a holistic approach that considers the intricate relationship between health and socio-economic development is crucial for building responsive and resilient health systems in India (Ramani & Mavalankar, 2006).

The Healthcare sector is projected to grow significantly, with investments in medical technology and infrastructure expected to reach Rs. 4,34,350 crore (US\$ 50 billion) by FY31. The telemedicine market is anticipated to reach US\$ 5.4 billion by FY25, driven by technological advancements and increased demand for remote healthcare facilities.

CONCLUSIONS

In Conclusion, infrastructure development is a vital determinant of human health in India. While improvements in sanitation, healthcare facilities, and community organizations have shown positive impacts on health outcomes, challenges remain in areas such as urban air pollution and equitable access to healthcare. To achieve universal health coverage and improve public health, India needs to focus on comprehensive infrastructure development that considers both economic growth and health impacts. This requires a multisectoral approach, involving various government departments and community organizations, to address the social determinants of health alongside physical infrastructure development (Lakshminarayanan, 2011).

The evidence presented in this paper underscores the need for ongoing investment in infrastructure to achieve better health outcomes, especially for marginalized populations. Future policies should prioritize sustainable and equitable infrastructure development to maximize health benefits. Future research should focus on fine-tuning models for infrastructure development that can be effectively implemented in diverse settings across India, particularly in remote and rural areas (Babu et al., 2023).

Policy implications

1. Investment Strategies
Recommendations for prioritizing infrastructure projects that directly impact health.
Importance of public-private partnerships in funding infrastructure development.
2. Equity in Infrastructure Development
Strategies to ensure equitable access to healthcare infrastructure across different regions.
Addressing the needs of marginalized communities in infrastructure planning.

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