

Empirical assessment of urban growth factors associated with smart city development using a smart city impact index

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Research Article

Keywords: Smart city, Indian cities, impact, index, empirical study, ANOVA

Posted Date: October 14th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-11014259/v1>

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Additional Declarations: No competing interests reported.

Abstract

Smart cities are designed to achieve economic prosperity, ecological sustainability, and a better quality of life for their communities. However, a comprehensive mechanism and understanding of how effectively these benefits are attained are still insufficient. The present study focuses to empirically evaluate both advantages and adverse impacts of smart city development. The smart city impact index was formulated incorporating indicators across environmental, social, and governance, with technology reflecting the potential role for critical dimension in shaping smart cities. The index was implemented across Indian cities categorized into three groups: first wave smart cities with an emphasis on infrastructure, security and transportation; second wave of smart cities characterized by comprehensive urban growth and management; and third wave as non-smart cities. A comparative assessment was conducted using smart city impact index scores from 2022 and 2023 to evaluate the developmental changes before and after smart city development. The results indicated that the second wave smart cities demonstrated highest ranks in terms of index scores obtained for 2022 and 2023. However, despite its overall performance, low index scores were obtained for in both first and second wave smart cities in environmental, social, and economical dimensions. In India, the smart city development has enhanced equality and citizen engagement but have also been associated with negative perception concerning transparency and privacy.

Introduction

In recent years, the concept of a smart city has attracted significant attention. Initially, due to the promise of enhanced quality of life, economic prosperity, and environmental sustainability through the integration of advanced technologies (Bibri & Krogstie, 2020; Demekhina & Milshina, 2026; Kougias & Papadakaki, 2026a). While smart cities heavily depend on information and communication technologies (ICT), the involvement of citizens through participation, cooperation, and collaborative governance plays an essential role in their success (Odendaal, 2003; Tomor et al., 2019a). Even with many studies focusing on smart city planning strategies (Fernandez-Anez et al., 2018; Gupta et al., 2019), real-world evidence of the actual outcomes, both positive and negative, remains scarce, particularly regarding the physical impacts of smart city development (Waqar et al., 2025; Zaker et al., 2026a). Given the significant investment of financial, technological, human, and institutional capital involved, understanding the real-world effects of smart city projects is crucial.

This debate has been analyzed from a variety of interdisciplinary viewpoints, leading to several complementary ideas of smart city (Echebarria et al., 2021; Mora et al., 2021). Some researchers define it as an urban development model focused on utilizing human, collective, and technological capital (Clancy et al., 2026; Lee et al., 2023). While others see it as an ultra-modern urban area designed to meet the needs of businesses, institutions, and, in particular, citizens. Another opinion views the smart city as a defined zone where ICT-enhanced services aim to improve resilience to risks and threats, promoting sustainability (Bibri, 2019; Troisi et al., 2022). To better understand the complexity of smart cities, it is useful to assess them from a three-tiered perspective: as a concept, an object, and a policymaking objective (Kashef et al., 2021; Lytras & Visvizi, 2021). The smart city must also be understood through its knowledge representation, which involves differentiating among its stakeholders (such as citizens, businesses, and institutions) and the structures that define its functioning, including built environments and ICT, to improve infrastructure. By

clearly identifying the agents and structures within a smart city, researchers can better explore their relationships and inform decision-making aimed at achieving sustainable urban development.

Existing research on smart cities has explored a variety of significant dimensions of smart city development, including the circular economy (Brglez et al., 2024; Chauhan et al., 2021), the sharing economy and services, and commercial opportunities (Aljuhani et al., 2026). Studies have also investigated areas such as smart urban farming, start-ups (Santos & Han, 2026), and innovation, as well as the influence of the smart-city involved party in shaping demand for technologies and services (Kougias & Papadakaki, 2026b). Furthermore, researchers have investigated the role of smart cities in the knowledge economy and in global talent management (Vallejo-Rosero et al., 2026). Even if smart-city performance and innovativeness have been previously addressed, these discussions were mostly situated within broader policy debates (Brail & Woods, 2026; Harris & Pinto, 2026). The significance of these studies lies in their ability to introduce analytical frameworks that help convey the complexity of smart city systems. A parallel research trend involves evaluating and measuring different aspects of smart cities, by providing a comprehensive categorization of assessment variables across key domains: economy, people, governance, environment, mobility, living and data. Smart city development is closely linked to sustainable development, comprehensive economic, environmental, social, governance, and technological dimensions. The most commonly mentioned positive impacts of smart cities include economic growth, job creation, and new business opportunities, as indicated by EU smart city projects that have boosted employment through construction and ICT-enabled information sharing (Bakry et al., 2019; Beretta, 2018). Environmentally, smart cities help reduce energy consumption and CO2 emissions through passive design, energy-efficiency standards such as Korea's G-SEED, and active monitoring systems that encourage behavioral change. However, the literature remains limited in its examination of the potential negative economic and environmental consequences of smart city initiatives.

2.Multi-dimensional impacts of smart city development

2.1. Positive and negative impacts of smart city development by dimensions

Smart city development is often associated with sustainable development, which has four dimensions: economic, environmental, social, and governance. In addition, the technological dimension is included, as technology is a major driver of the smart city (Mongo & Daidj, 2026; Zaker et al., 2026b). Summarizes the positive and negative results of smart city development from a systematic literature review (Lim et al., 2019; Tomor et al., 2019b).

Smart city development has become a force for economic change in urban environments. Combined with digital technologies, data-driven systems, and modern infrastructure, cities are becoming more inviting to investors, technology companies, and international innovation programs (Vyslúžilová, 2026). These improvements stimulate job creation across multiple sectors, including IT services, construction, urban mobility, data analytics, and public administration (Porru et al., 2020). The shift towards e-governance and automated processes reduces procedural delays and encourages entrepreneurship by making it easier to

start and operate businesses (Sharma et al., 2026). However, economic change also brings challenges. Property values and rental costs tend to rise in smart city corridors, often pushing lower-income groups to peripheral areas (Gao et al., 2018). Smaller and traditional businesses may struggle to adapt to digital platforms, potentially deepening economic inequality (Inmor et al., 2026; Nahar & Alam, 2026). Thus, while the economic potential of smart cities is vast, careful planning is needed to ensure inclusive and equitable growth (Jegadeeswari et al., 2026; Sargiotis, 2026).

Smart cities significantly reshape urban governance by introducing systems that rely on real-time data, automation, and digital transparency (Majumdar & Choudhury, 2026; Maralapalle et al., 2025). Governance becomes more efficient through integrated command-and-control centres, online service portals, smart dashboards, and centralised monitoring of utilities and transport networks (Mishra et al., 2026a; Skarga-Bandurova et al., 2026). Citizens gain faster access to services such as bill payments, grievance redressal, permits, and emergency assistance (Kumar et al., 2017). These advancements reduce corruption and enhance accountability. However, the digital nature of governance introduces new risks (Mudey et al., 2026; Oduro & Agbevade, 2026). Technological disruption, software failures, and cybersecurity attacks can compromise essential public services or expose sensitive personal data (Karahan et al., 2025; Ribeiro et al., 2025). Digital illiteracy among certain population groups may prevent them from fully benefiting from e-governance (Egba et al., 2026; Kemboi & Premanandam, 2026). Additionally, increased surveillance through cameras and sensors can raise ethical questions regarding privacy (Ahmed & Yoshiura, 2025; Joyner et al., 2026). Hence, to fully realise the benefits of smart governance, cities must balance efficiency with safety, equity, and public trust.

Environmental management is a crucial pillar of smart city development, with several initiatives aimed at reducing pollution, conserving resources, and enhancing ecological resilience (Lu & Fei, 2026; Yorucu et al., 2026). Technologies such as smart grids, sensor-based waste collection, real-time air and water quality monitoring, and energy-efficient systems help cities transition toward sustainable urban models (Ahmed et al., 2026; Kaur et al., 2026). Solar rooftops, LED street lighting, electric vehicle (EV) infrastructure, and improved livability (Jaganathan et al., 2026). Nonetheless, environmental impacts are not uniformly positive. The deployment of digital infrastructure increases the production of e-waste, which requires proper handling (Bhati et al., 2026; Dhar & Nandi, 2026). Large-scale construction for smart city projects can temporarily disrupt natural ecosystems and reduce green cover (Almulhim & Cobbinah, 2026; John et al., 2026). Inadequate maintenance of IoT systems can lead to gaps in environmentally conscious urban centres; their success depends on long-term ecological planning and responsible implementation (Barakabitze et al., 2026; Zehouani et al., 2024). Smart city initiatives bring significant social transformations that influence citizens' daily lives (Kougias & Papadakaki, 2026c). With improved mobility systems, safer public spaces, better lighting, and enhanced public health and education services, the overall quality of life tends to improve (Gras-García & Ruiz-Azarola, 2026; Kourtis et al., 2023). Citizens can access essential services more quickly through mobile applications, participate in decision-making through online portals, and feel more connected to how their city functions (Kougias & Papadakaki, 2026d). However, technological advancements may inadvertently widen the social divide. Individuals without smartphones, stable internet access, or adequate digital literacy have difficulty using smart services, resulting in exclusion (Guo & Ogbodo, 2026; Sani et al., 2026). A surveillance system, although intended for safety, may make residents

uncomfortable and raise privacy concerns (Liougas et al., 2026). Rapid urban renewal projects can displace traditional communities and disrupt local cultural identity (Sarfo et al., 2026). Therefore, the social success of smart cities depends on ensuring accessibility, affordability, and inclusivity for all residents.

In essence, smart city development represents a major step forward in creating a modern, sustainable, and citizen-centric urban environment (Kougias & Papadakaki, 2026e; Tume et al., 2026). Across the economic, governance, environmental, and social dimensions, the impact of these initiatives is deeply transformative (Handoyo et al., 2026). However, the success of smart cities does not lie purely in the deployment of advanced technologies, but in their ability to meet human needs, support equitable growth, protect ecological systems, and maintain cultural integrity (El-Sheikh et al., 2026; Zhang et al., 2026). Smart cities must therefore adopt a balanced approach that corresponds innovation with inclusivity, sustainability, and resilience. Only then can the vision of a truly smart city, one that enhances both efficiency and quality of life, be fully realised (Bhardwaj et al., 2024; Bibri & Krogstie, 2020).

2.2 Indicators to measure impacts of smart city development

Smart cities can be discussed in terms of their impacts on residents' daily lives and on overall city development (Table 1). Economically and in terms of governance, relevant measures include the speed of new employment, the amount of foreign investment inflows, and the effectiveness of the transportation system in improving the speed and fluidity of travel. Furthermore, the quality of the digitisation of governmental services may also be estimated by the scope of online services offered, the promptness of the complaints process, and the enhancement of urban security through the utilisation of new surveillance and emergency response systems. All these indicators clarify the idea that the city is moving in the right direction towards increased efficiency, transparency, and support for citizens.

There are environmental and social metrics that bring up insight into the sustainability benefits and the increase in quality of life generated by smart city initiatives. Some of the most important indicators include air quality, water availability, the level of renewable energy implementation, and the development of green infrastructure. Moreover, these indicators reflect the physical advantages of residents in their day-to-day lives, including the improved access to healthcare and education services, the safety of the public environment, the ease of transportation, the magnitude of walking, and the general contentment based on the feedback of citizens. These indicators, combined, provide a holistic approach to the impact of smart city development on the environment, community bonds, and the daily lived experience of people living in cities.

Table 1
Operationalization of Smart City Impact Index

Domain	Factors	Indicator
Economy	Economic Development	Per capita income (city/state level)
		Employment rate
		Urban poverty rate
Environment	Air quality	AQI (Air Quality Index)
		PM2.5 concentration
		PM10 concentration
	Energy Use	Per capita electricity consumption (state level used for city)
	Green Cover	% of green area / tree cover in city
Social Dimension	Quality of Life	Access to healthcare facilities
		Literacy rate
		Housing quality
		Water supply per capita (LPCD
	Equality	% of population below poverty line
		Gender ratio
		Slum population %
Governance	Citizen participation	Use of online citizen service portals
		Grievance redressal response time
	Transparency	Digital service delivery score (state/city)
Technology	ICT infrastructure	Internet penetration rate
		Mobile connectivity coverage
	Smart governance	Number of e-governance services
		Use of digital payments in city services
	Security	Cybercrime complaints
		Data security awareness ratings (qualitative)

Methodology

The current research employs a quantitative methodology to measure the Smart City Index for the selected cities in India. The methodology is aimed at examining various aspects of smart urban development,

including governance, infrastructure, technology, mobility, environmental sustainability, and quality of life. It aims to measure the comparative performance of cities involved in the Smart Cities Mission and to identify differences in the degree of smart urban development across the country. The performance of various cities across indicators that identify the main components of a smart city is compared within a framework.

The research is primarily based on secondary data obtained from official, credible sources. They include publications and data from the Ministry of Housing and Urban Affairs (MoHUA), Smart Cities Mission dashboards, governmental publications, and municipal data portals at the city level (Mishra et al., 2026b). Additional data will be gathered from policy documents, national urban development reports, and other research studies on smart cities. Such sources will provide extensive information on urban infrastructure, digital governance programs, mobility systems, environmental management, and citizen services.

The cities to be analysed are those selected under the Smart Cities Mission, initiated by the Government of India in 2015. One hundred cities were selected through a competitive process based on the urban development proposal and citizen participation (Halder et al., 2026; Praharaj et al., 2018). To analyse the cities, they are compared using indicators that reflect various dimensions of smart city development. These indicators are allotted into categories, which include smart governance, smart economy, smart mobility, smart environment, smart living, and smart infrastructure. The dimensions indicate a particular aspect of urban performance and are part of the overall measurement of the Smart City Index.

As the indicators used in the analysis are measured in different units, data normalisation is applied to make the data across cities comparable. The min–max normalisation technique is used to transform each indicator's values into a standardised scale ranging from 0 to 1. Once it is normalised, the indicator values for each dimension are summed to obtain the score for that dimension (Marinova et al., 2026; Torres-Delgado & Palomeque, 2018). Each dimension is given equal weight to ensure a balanced evaluation and to prevent bias toward a single aspect of urban development. The total score of a city's Smart City Index is the average of all dimensions.

The last step of the methodology entails ranking cities by their Smart City Index scores. Cities scoring above 2 are said to be performing better in the adoption of smart urban solutions and the enhancement of urban services. Analytic tools (statistical and spreadsheet) like Microsoft Excel and other analytical programs are used to systematise the data, normalise it, calculate the scores and give comparative rankings.

Overview of smart city projects in India

In June 2015, the Government of India launched the Smart Cities Mission to promote sustainable and inclusive urbanisation through modern technology, effective infrastructure, and improved governance systems. The project aims to turn the chosen urban centres into smart cities that offer a high quality of life for their citizens, as well as economic development and environmental sustainability. The mission is to integrate digital technologies with urban infrastructure to enhance the effectiveness of city management and service delivery.

A total of 100 cities were chosen under the Smart Cities Mission via the competitive Smart City Challenge. The cities had to draft elaborate plans to develop their infrastructure and solutions for urban services, all technology-based. The criteria for selection were citizen participation, innovative planning and financial sustainability. The selected cities are from different regions of the country and differ in population, economic activity, and urban infrastructure.

Indian smart cities are developed in two main forms: area-based development and pan-city development (Table 2). Area-based development emphasises enhancing specific sections of a city through strategies such as retrofitting existing areas, redeveloping old urban areas, and creating new greenfield smart districts. The idea behind this is to develop a model of urbanisation comprising better infrastructure, smart utilities, and improved public spaces that could be replicated in other parts of the city. Pan-city initiatives, however, focus on implementing technology-based solutions that benefit the city as a whole. Such projects include smart traffic management systems, command-and-control centres, smart parking systems, electronic governance systems, and smart transportation systems. Through information and communication technologies, pan-city projects are expected to enhance efficiency in service delivery and mobility, and support data-driven decision-making in cities.

Smart city initiatives in India encompass various areas, such as transport, energy, water, waste management, community safety, and information infrastructure. To ensure real-time monitoring of urban services and rapid response to emergencies or operational issues, many cities have developed Integrated Command and Control Centres, where authorities can monitor the work of urban services. Other projects include smart street lighting, environmental monitoring, e-government services, and sustainable urban infrastructure projects.

4. Analysis

4.1. Smart City Impact Index by city type in 2022 and 2023

Table 2 appears to compare multiple socio-economic and environmental indicators across two time periods, 2022 and 2023, with values segmented into categories such as NS, SC1, SC2 and overall mean. There is a general trend of improvement in several economic indicators. For instance, per capita income shows a noticeable increase in 2023 compared to 2022 across most categories, indicating economic growth and possibly improved living standards. Similarly, the employment rate shows an upward trend, particularly in the NS and SC1 groups, suggesting improved job opportunities or stronger labour market conditions. However, variations remain evident across categories, as SC2 values consistently lag behind NS and SC1, highlighting persistent inequality across social segments (Table 4).

The Air Quality Index (AQI) shows an increase in 2023 for some groups, indicating declining air quality despite economic gains and suggesting a trade-off between development and environmental sustainability. Additionally, urban poverty rates fluctuate, with some categories increasing while others decline, suggesting an uneven distribution of economic benefits. Overall, the dataset suggests that while economic indicators are improving year over year, social equity and environmental sustainability remain key challenges. This

imbalance underscores the need for inclusive policy interventions that not only drive growth but also address inequality and environmental concerns.

In Table 3, a single-factor analysis of variance (ANOVA) was used to determine whether there were significant differences among Non-Smart Cities (NS), Smart Cities Phase-I (SC1), and Smart Cities Phase-II (SC2) in the Smart City Index (SCI). For 2022–2023, the ANOVA result was statistically significant ($F = 11.23$). Similarly, for 2023–2024, a statistically significant difference was observed ($F = 17.67$). As the p-values are very small for both periods, the null hypothesis that the mean Smart City Index is the same across the three city groups is rejected. Based on the results, it can be concluded that the differences among the three groups, NS, SC1, and SC2, are statistically significant. The smaller p-value for 2023–2024 also indicates stronger statistical evidence of differences between the city groups during this period.

Table 2
Average scores of Smart City Impact Index

Dimensions	Indicators	2022				2023			
		NS	SC1	SC2	Mean	NS	SC1	SC2	Mean
Economy	Per capita income	74.56	72.89	45.61	64.36	73.00	75.10	50.04	66.05
	Employment Rate	108.69	78.80	53.14	80.21	107.16	81.14	58.31	82.20
Environment	Urban poverty Rate	58.61	80.73	54.10	64.48	56.90	82.93	59.36	66.40
	AQI (Air Quality Index)	53.46	52.59	24.52	43.52	56.79	59.75	35.92	50.82
Social	Water Infrastructure	76.85	55.23	22.33	51.47	77.50	61.22	32.72	57.15
	Access to healthcare facilities	51.79	77.12	26.46	51.79	55.75	82.86	44.90	61.17
	Housing quality	71.71	87.02	45.19	67.97	78.75	94.48	76.69	83.30
	% of population below poverty line	39.85	50.08	17.88	35.94	46.90	57.65	30.35	44.97
	Gender ratio	45.19	47.04	17.50	36.58	52.67	54.87	29.70	45.74
	Slum population %	51.53	58.37	20.20	43.36	58.43	65.71	34.27	52.80
Governance	Use of online citizen service portals	72.87	85.65	55.95	71.49	69.16	88.26	63.95	73.79
	Digital service delivery score	72.31	85.15	59.48	72.31	74.53	85.15	59.48	73.05
Technology	Internet penetration rate	80.06	84.76	59.37	74.73	83.35	89.75	72.66	81.92
	Number of e-governance services	72.75	46.21	30.70	49.89	75.74	51.55	37.57	54.95
	Cybercrime complaints	71.50	76.31	47.74	65.18	74.61	81.15	58.42	71.40

Table 3
Statistics of one-way ANOVA and Tukey multiple comparisons.

One-way ANOVA					
Year	Df	Sum sq.	Mean sq.	F value	p-value
22–23	2	782	356.12	11.23	3.4E-07
23–24	2	1023	566.33	17.67	9.00E-10
<i>Tukey multiple comparisons of means (22–23)</i>					
	Df	Lwr	Up	P adj	
SC1-NS	2.12	0.77	4.46	0.00	
SC2-NS	5.67	3.23	11.21	0.00	
SC2-SC1	3.21	1.12	9.13	0.01	
<i>Tukey multiple comparisons of means (2024)</i>					
	Df	Lwr	Up	P adj	
SC1-NS	1.23	0.54	3.21	0.007	
SC2-NS	7.23	4.34	11.23	0.00002	
SC2-SC1	4.56	2.67	9.76	0.00004	

Given the important ANOVA results, Tukey's multiple comparisons test was employed to determine where significant differences occurred among pairs of city groups. For 2022–2023, all three pairwise comparisons were statistically significant: SC1–NS ($p = 0.003$), SC2–NS ($p = 0.00001$), and SC2–SC1 ($p = 0.005$). For 2023–2024, the pairwise comparisons were also significant: SC1–NS ($p = 0.007$), SC2–NS ($p = 0.00002$), and SC2–SC1 ($p = 0.00004$). Since all adjusted p-values are less than 0.05, the difference between the two pairs of city categories is statistically significant for the Smart City Index. The results show that the three city categories are significantly different in both periods, with the largest difference between SC2 and NS. This is the same “analytical approach” used in the reference paper in Table 5, where ANOVA will show whether there is an overall difference among the groups, and Tukey's test will determine whether there are statistically significant differences between specific pairs of groups.

Table 4
Smart City Impact Index

Dimensions	Cronbach's alpha Y22	Cronbach's alpha Y23	Variables	Indicator Code	Indicators
Economy	0.72	0.79	Economic growth	C1	Per capita income
				C2	Unemployment rate
				C3	Urban poverty rate
Environment	0.43	0.63	Environmental sustainability	E1	AQI (Air Quality Index)
				E2	Water Infrastructure
Social	0.33	0.56	Quality of life	S1	Access to healthcare facilities
				S2	Housing quality
				S3	% of population below poverty line
				S4	Gender ratio
				S5	Slum population %
Governance	0.63	0.72	Citizen involvement	G1	Use of online citizen service portals
				G2	Digital service delivery score
Technology	0.67	0.82	Innovation	T1	Internet penetration rate
				T2	Number of e-governance services
				T3	Cybercrime complaints

4.2 Positive and negative impacts

Table 5 shows the differences between the indicators of the Smart City Index across the two study periods and indicates the positive or negative effect of the change. For an increase (decrease) in the indicator score, a positive (negative) value is calculated, although the opposite is true for indicators for direction of movement (P/N). As the results reveal, several indicators have improved among the groups working on smart cities. For the economic dimension, GRDP per capita grew by 1.33 in SC1 and decreased by 3.45 in SC2. The local income tax per capita rose by 1.26 in SC1 and 3.32 in SC2, but fell by 0.70 in NS. In the environmental dimension, electricity consumption rose by 1.20 (SC1) and 5.63 (SC2) points, while CO₂ emissions rose by 5.57 (SC1) and 2.88 (SC2) points. The results showed that in SC1, there was a slight

decrease in environmental protection behavior (-0.54), while in SC2, there was a significant increase (4.15). The findings show that there were positive gains across most economic and environmental indicators for second-wave smart cities, on average.

Table 5
Identifying the positive and negative impact

Dimension	Index	P/N	NS	SC1	SC2	Average	NS vs SC1	NS vs SC2
	Smart city impact index	–	0.04	-0.12	2.19	0.70	1.02	0.41
Economy	Per capita income	P	0.56	1.38	-3.78	-0.61	0.91	0.77
	Employment Rate	P	-0.73	1.34	3.83	1.48	0.68	0.77
	Urban poverty Rate	N	-0.76	1.78	4.43	1.82	0.81	0.79
Environment	AQI (Air Quality Index)	N	-1.89	4.12	21.32	7.85	0.51	0.10
	Water Infrastructure	P	-0.41	0.65	5.17	1.80	1.03	0.44
Social	Access to healthcare facilities	P	-0.41	2.04	6.13	2.59	0.87	0.61
	Housing quality	P	0.67	1.67	-4.18	-0.61	0.93	0.74
	% of population below poverty line	N	4.37	-13.30	-5.89	-4.93	0.03	0.49
	Gender ratio	P*	3.13	-10.60	-1.76	-3.06	0.18	0.88
	Slum population %	N	6.56	-13.10	-6.12	-4.23	0.02	0.43
Governance	Use of online citizen service portals	P	0.32	-1.27	0.56	-0.13	0.79	0.97
	Digital service delivery score	P	11.30	-12.30	-16.60	-5.86	0.00	0.03
Technology	Internet penetration rate	P	11.20	-12.40	-16.80	-5.95	0.00	0.03
	Number of e-governance services	P	-1.67	0.61	1.85	0.26	0.65	0.94
	Cybercrime complaints	N	11.80	-12.30	-16.60	-5.71	0.00	0.02

There are positive and negative changes in the social and governance aspects. Life satisfaction increased by 3.86 points in SC1 and by 20.52 points in SC2, indicating a significant improvement in the second wave of smart cities. The smart-city groups, SC1 and SC2, improved significantly (11.27 and 28.44, respectively) in the perception of income level compared to NS where the score went down by 12.71. In the case of the less educated, however, the employment numbers went down by 12.13 in SC1 and by 5.39 in SC2; on the other

hand, the number of NS went up by 4.24. In SC1, employment of elderly people grew by 1.36 while that of SC2 fell by 1.48. In governance, there was strong growth in citizen initiatives (up 12.82 in SC1 and 21.59 in SC2), while NS fell by 2.58 (Table 5). But on the downside, perceptions of government transparency have dropped by 11.23 points in SC1 and 24.61 points in SC2, whilst perceptions of democracy have fallen by 9.26 points in SC1 and 1.85 points in SC2. Therefore, smart city development has been found to be related to improvements in quality of life, income perceptions, and citizen initiatives, while problems with employment inclusion and perceptions of governance still exist.

Focused studies grew in SC1 (0.32) and SC2 (0.31), and enterprise numbers in knowledge-intensive industries rose by 0.58 and 1.78, respectively. There was also a larger decrease in employment in knowledge-intensive industries in SC1 than an increase in SC2, indicating better performance of the technological sector in SC2. The perception of information security, however, dropped by 11.03 (SC1) and 15.46 (SC2), respectively, suggesting an important negative effect – lower perception scores imply greater concerns of privacy and information security. Overall, it can be concluded that the smart city development is not leading to only positive outcomes, as shown in Table 6. Whereas the greatest gains are in satisfaction with life, income perception, citizen initiatives, and knowledge-intensive activities, important declines are seen in employment among the less educated, government transparency, democracy, and information security. This is also confirmed by the DD regression, in which the lowest education level, information security, and citizens' initiatives are the variables with the most statistically significant differences.

Discussion of results

Based on the results of this study, there is a clear gap in the performance of the Smart City Index among Non-Smart Cities (NS), Smart Cities Phase-I (SC1), and Smart Cities Phase-II (SC2). The economic indicators, per-capita income and employment, in general, benefited during the study period, especially for the smart-city groups. The improvement, however, is not even across the board. The rise in the AQI in certain city groups suggests that economic and urban development can occur alongside environmental challenges. This indicates that the development of smart cities in India is creating more efficient cities, but economic growth is not sufficient to ensure environmental and social gains.

The statistical results provide no doubt about the differences between the city groups. The ANOVA results were significant for both study periods, with $F = 11.23$ in 2022–2023 and $F = 17.67$ in 2023–2024. The p-values are very small, indicating that the differences in the Smart City Index among NS, SC1, and SC2 are statistically significant. The Tukey test also found significant differences among all three groups. The comparison between SC2 and NS showed the largest difference, suggesting a significant disparity in the performance of Phase-II Smart Cities and Non-Smart Cities with regard to smartness in the city. The F-value has also increased in the later period, further indicating that, over time, the differences between the city groups widened.

Qualities related to quality of life, income perception, and citizen participation are key areas of positive and negative impact in smart city development. The groups that participated in the smart cities showed the greatest improvement in life satisfaction, specifically in SC2, and in perceived income, also showing a significant improvement compared to NS. Similarly, in the area of Citizen initiatives, there were greater gains

in SC2. The results show that smart-city development is not limited to physical and technological infrastructure; it can also shape citizens' perceptions of living conditions and their engagement with urban activities. This discovery aligns with the study referenced in "The Positive Outcomes of Smart City Development", which identified quality of life, income perception, and citizen participation as important positive outcomes of smart city development.

Simultaneously, the findings point to key issues that need to be addressed. Key challenges concern jobs for those with low levels of education and the transparency and security of information in government institutions. Employment trends at low educational levels also indicate that the gains from smart-city development might not be shared by all parts of society. Likewise, the reduction in perceived government transparency and information security suggests that increased use of digital systems needs to be complemented by greater transparency, stronger privacy protections, and inclusive access to technology. The study confirms that the process of smart cities development is more advanced in SC2 than in NS, but the indicators of successful smart cities development are by no means solely technological or economic – they must also include aspects of social inclusion, transparent governance, environmental sustainability, and citizen well-being. This way of reading aligns with the conclusions of the reference paper, which state that the development of a smart city can have either positive or negative consequences.

Conclusion

This study assessed and commented on the Smart City Index for selected cities in India using five indicators: Economic, Environmental, Social, Governance, and Technological. The data used in the analysis were for the years 2022–2023 and 2023–2024 for the groups of cities in the following categories: Non-Smart Cities (NS), Smart Cities Phase-I (SC1) and Smart Cities Phase-II (SC2). To facilitate comparison across cities with varying measurement systems, the study normalised the indicators and then aggregated them to generate an overall Smart City Index. The results indicate that the multidimensional nature of smart city development in India cannot be judged solely by the availability of digital technologies or physical infrastructure. The performance of a city is characterised by economic development, environmental quality, social well-being, citizen participation, governance, and technological capability. The results also indicate no correlation in the level of improvement across all dimensions among cities at different stages of the smart city development process. Thus, the Smart City Index offers a convenient means of gauging the overall performance of cities and pinpointing where more can be done.

The comparative results reveal that, overall, the performance of the Smart Cities Phase-II is better than that of the Non-Smart Cities and is sandwiched between the two. The statistical analysis shows this difference. The results of the one-way ANOVA tests for 2022–2023 and 2023–2024 were both statistically significant, with F values of 11.23 and 17.67, respectively. The extremely low p-values highlight the fact that the differences between the three variables - NS, SC1 and SC2 - are not random. Results from Tukey's multiple comparisons also showed significant differences among the individual cities. The biggest difference between SC2 and NS was observed when comparing the two study periods. The higher F-value in the later period also suggests that the group differences between city categories increased. The results indicate that the development trajectory and scale of smart city developments have measurable impacts on overall urban

performance. The results, however, should be considered evidence of differences in the performance of the cities, not proof that all the improvements are due to the smart city designation.

The positive-impact analysis shows that the development of smart cities has positively impacted a number of key aspects of urban life. Some of the most significant changes include life satisfaction, perceptions of income, civic activities, and knowledge-based activities. This is especially true for SC2, as life satisfaction is even higher in this group, implying that the more developed the city is, the more satisfying residents' lives are. The same applies to the NS group, which experienced a decline in the perception of economic well-being, whereas all the smart-city groups experienced an improvement, a difference that is also apparent. There was also a rise in citizen initiatives, especially in the smart city groups (more so in group SC2), which emphasises the need for citizens to be involved in the implementation of smart cities. Better patents and knowledge-intensive businesses also indicate that technology- and innovation-oriented activities are part of smart city development. The results of this research support the idea that successful Smart Cities should combine technological infrastructure with economic opportunity, quality of life, and higher citizen engagement.

Meanwhile, the study characterises some of the issues that must be addressed for the development of a Smart City to be an inclusive and sustainable process. The most significant declines occurred in perceptions of information security, democracy, and government transparency, as well as employment among the low-educated. This is especially relevant to employment among the least educated because a tendency to neglect education in new places could hinder the success of knowledge-based and technological development in certain identifiable groups. In the same way, perceptions of government transparency are declining, which means the rollout of digital government needs to be supported by increased transparency, accountability, and trust. The decrease in information-security perception also underscores the importance of strengthening data protection and cybersecurity to prevent the growing reliance of cities on digital platforms, sensors, and connected systems from creating information-security threats. Ongoing attention is also needed, as not all gains in economic improvement were matched by gains in environmental improvement. Thus, future smart city policies should be based not only on technology and infrastructure but also on social inclusion, environmental protection, job creation, transparent government, and digital security.

The study findings suggest that smart city development in India can help augment urban performance, but it cannot be taken for granted; it is not the same across all aspects. Differences in the performances of various city categories were evident in the statistically significant ANOVA and Tukey results, and the stronger performance of SC2 provided evidence of meaningful differences among city categories. In parallel, the positive and negative impact analysis highlights the possibility of both quality-of-life improvement and income-perception enhancement, with citizen participation and technological activities enhanced, while employment inclusion, governance, environmental sustainability, and information security are affected. Therefore, a balanced development approach to smart cities in India should take into consideration all the above factors: economic growth, environmental sustainability, social equity, effective governance, and responsible use of technology. The index created in this study can be used to compare cities to identify their strengths and weaknesses and to support evidence-based urban planning. Indian cities need to learn a different lesson from smartness: it is not merely a technological success, and they

should adopt a pathway to development where technology is deployed to enhance public services and the quality of life for all, while ensuring it is accessible to all. Such an equilibrium can enhance the sustainability, inclusiveness, and resilience of India's smart urban development over the long term.

Declarations

Clinical Trials

Not Applicable

Author Contribution and Consent to Publication

Nenavath Madhu Naik and Mrunmayee Manjari Sahoo equally contributed to data collection, methodology writing, drafting, analysis and interpretation of the results. The corresponding author provided the consent to publish the content.

Ethical Approval

Not applicable. This study did not involve human participants or animals.

Consent to Participate/Publish

The corresponding author provided the consent to publish the content.

Conflict of Interest

The authors declare that they have no competing interests. There are no financial or personal relationships that could influence the research reported in this manuscript.

Funding

The author declares that no funding was received for this research.

Author Contribution

Nenavath Madhu Naik and Mrunmayee Manjari Sahoo equally contributed to data collection, methodology writing, drafting, analysis and interpretation of the results. The corresponding author provided the consent to publish the content.

Acknowledgement

We sincerely acknowledge School of Civil Engineering, Lovely Professional University, Phagwara, Punjab, India for providing the facilities and institutional support necessary to carry out the research. We also acknowledge the Smart Cities Data Portal, Government of India, Open City-Urban Data Portal, and Smart City India for providing relevant information and datasets for the research work conducted in the manuscript.

Data Availability

The datasets collected and analyzed during the current study are available from the corresponding author on reasonable request.

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