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Modelling the determinants for sustainable smart city through interpretive structure modelling and analytic hierarchy process

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Abstract

Rapid increasing urbanization and resource scarcity are global phenomena nowadays, leading to the urban transformation of cities into smart cities. This article explores sustainability by using the lens of the spirit of place (SOP) for smart city development by proposing a model for the transformation of the cities into smart cities and attainment of the sustainable development simultaneously based on Interpretive Structure Modelling (ISM) and Analytic Hierarchy Process (AHP). This study followed a systematic approach by utilizing an analytical framework that included an extensive literature review and urban experts' opinions for the identification of a pool of indicators and its evaluation for validity, pilot testing, and administration of a questionnaire to a population sample. The study utilizes a sample of 142 participants who have witnessed the transformation of their city over the years. The research showed that every place has its own identity known to be the 'spirit of place' that helps in assessing the sustainable characteristics and utilizing that in the path of planning and development for the attainment of sustainable development. It also showed that urban developers should consider local populations' views and important aspects in designing and planning development projects to achieve sustainable development with resilient infrastructure. This study will help facilitate sustainability at a local level for urban developers, planners, and decision-makers while crafting strategic plans.

Keywords Smart city, Sustainable development, Urban development, Interpretive structure modelling (ISM), Analytic hierarchy process (AHP), Scale development

1 Introduction

Smart cities are found to be fuel for the economic development of any country (Jain et al., 2017) and have been an important topic of discussion for solving today's challenging urban problems. Various smart city indicators (economic, social, environmental, etc.) found to be useful in measuring sustainability aspects (Brown et al., 2016) require the involvement of citizens in urban development (Dassen et al., 2012). Various researchers have attempted to define a smart city over the last two decades (Khan et al., 2020). The cities can be more liveable as well as wealthier when they can consume fewer resources and minimize the impact on environment (Bibri & Krogstie, 2017). Cities should minimize ecological impact and help in maximizing social sustainability by supporting quality of life (De Jong et al., 2015). Every city comprises social, economic, and ecological aspects which vary from place to place due to the geography and history attached to the place. These aspects are known as the spirit of place (SOP) and are responsible for differentiators of location, atmosphere, and awakening strong disposition as well as a feeling of coherence in people visiting them

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(Zimmermann, 2019). 'Spirit of place' gives importance to a specific place, town, and city with attached history. Every place has its character, traditions, and conventions. Each place has its credible soul because of which every resident is fascinated by the specific area, normally referred to as home place. SOP also refers to the activities and practices followed via generations and are unique to the place instead of individual. The identity of a place, called its soul, can be seen through what that place is known for i.e., its historical value and importance attached to it which is normally defined by the tag attached to that place like the learning hub, visiting the site, pilgrim place, and much more. The identity of any place is also responsible for the place's economy and directly and indirectly enhances the economic standard of its citizens. The primary focus of smart city development should be on safeguarding and advancing cultural assets, including historical landmarks, traditional customs, and indigenous knowledge systems. This not only cultivates a feeling of connection to a certain location among residents but also enhances social unity and inclusiveness. SOP offers a structure for comprehending the natural surroundings of a location and incorporating nature-oriented solutions into urban design. Cities can increase their ability to withstand the impacts of climate change and reduce their negative impact on the environment by utilizing local ecosystems and natural resources. Community participation is a fundamental principle of the SOP, highlighting the need to engage local stakeholders in decision-making processes. To implement a participatory approach in the creation of smart cities, inhabitants must be allowed to actively contribute to the formulation of urban policies, plans, and projects (Geng et al., 2023). Implementing interventions from the bottom up not only improves their legitimacy and effectiveness but also cultivates a feeling of ownership and responsibility among citizens. SOP promotes the adoption of place-based innovation in cities, which involves developing solutions that are customized to address the unique demands and problems of each specific location (Odendaal, 2020). Cities may enhance the development of sustainable and resilient technologies and practices by utilizing local resources, expertise, and cultural assets that are deeply connected to the essence of the area. The local governance structure or local leaders or administrators share equal responsibility with residents to maintain the identity of that place which adds to the cultural richness of the place (Consiglio, 2013).

Cities being complex ecosystems encompass creativity and innovation to ensure a sustainable environment and quality of life (Florida, 2003). Smart cities are built through the combination of endowments and activities of citizens (Giffinger et al., 2010) which improves the human capital side by Information and Communications Technology (ICT) and transforming cities (Hollands, 2008). Boyd Cohen has proposed an indicator framework for smart cities for deep assessment of key indicators which included smart government, smart economy, smart environment, smart mobility, smart people, and smart living. A "*Smart City proposes a holistic vision of future communities where new intelligent technological tools, services, and applications are integrated into a unique platform, providing interoperability and coordination between these several sectors".* The definition of a smart city is one where citizens enjoy many facilities and opportunities whereas little power affects smart city formation or governance. The betterment in life quality is important for smart cities and sustainability is a main goal for smartness (Mohseni, 2020). The strategic vision of a smart city is important for driving local policies for implementing smart initiatives pursuing shared goals. The benefits of a smart city are often declared but not measured whereas smart city performance is important for realizing outcomes for citizens and various stakeholders (Book, Dameri, 2016).

The identification of underlying and often forgotten values which means to be smart in urban context yielding conclusions on strategic planning for the development of smart cities today (Angelidou, 2015). The valuation of smart city performance should not only use indicators measuring the efficiency of deployment of smart solutions but also impact indicators measuring contribution towards ultimate goals such as environmental, economic, and social sustainability (Ahvenniemi et al., 2017). A smart city facilitates interoperability between various sub-systems for betterment in the quality of life of the citizens. Smart city depends on advanced data processing, and platform that depends on interoperability among devices (Silva et al., 2018).

United Nations (2012) established sustainable development goals to guide development programs through 2030 which aims to make cities and human settlements safe, liveable, inclusive, resilient, and sustainable. Livelihood and ecological sustainability are the two important phases of liveability. Where livelihood means being able to have a healthful living and to be liveable, any city should provide livelihood, quality of life, and a livable environment. The liveability of the environment includes ecology, society, economy, and culture parameters. Smart cities provide urban settlements to capitalize on technology so that it can improve liveability, workability, and sustainability (Alizadeh, 2017). Citizen involvement via the adoption of online, open-source platforms in urban planning enhances quality and management to cope with social problems. This realizes sustainability, equitable, and livable cities. Further, the collaboration of government, industry, and academic agencies plays an important role in developing and delivering urban liveability.

The term 'livability' is underpinned by a common set of guiding principles: accessibility, equity, safety, comfort, available services, walkability, transit, and participation (Book, Kar et al., 2017). Resilient cities absorb, adapt, and transform external pressures and ensure urban safety in the unexpected event of any crisis, hazard, or disaster (Rus et al., 2018). The inclusivity in the city aims to "create a safe, livable environment with affordable and equitable access to urban services, social services, and livelihood opportunities for all the city residents". To facilitate inclusivity in smart cities, it needs to create a safer and livable environment that provides affordability and equitable access to urban services to residents. Inclusive smart cities support all citizens to have access to urban technologies including disabled or senior citizens. Governments, policymakers, and city planners should consider vulnerability and social inclusion. While considering approaches for building smarter and inclusive cities it should look for awareness and identify an action for strategies showing commitment towards inclusive practices (Neirotti et al., 2014).

Whereas, resilience plays an important role in establishing the role of a smart city in sustainable urban development. Urban planning of cities can become resilient through land use management and by shaping the built environment (Jabareen, 2013). While considering other aspects of the smart city, it is equally important for a smart city to be safe at the same time (Desouza & Flanery, 2013). Therefore, resilience becomes important in smart city planning. The city should be capable of recovering from natural calamities, economic breakdown, and many more (Coaffee, 2013). A risky society can bring the ability of a city to absorb, adapt, and respond to changes in the urban system. Through this, a city can be developed that can resist shocks, hazards, and pressure of calamities which ensures the sustainability of a city.

At present, the transition of cities into smart cities in developing countries is at an early stage. The relationship between urban design and the sustainability of projects is not clearly defined in the literature (Yildiz et al., 2019). This necessitates improving ingrained habits related to urban planning or citizen behavior to enable shifting toward the smart city. Through smart cities, city planners and managers can increase efficiency in many sectors, including energy, water, transportation, telecommunication, and many more by taking a holistic approach (AL-Dabbagh, 2022). Indian government launched the smart cities mission in 2015 to promote cities that provide "core infrastructure, clean and sustainable environment, drive economic growth and decent quality of life to their citizens through the application of smart solutions". A total of 100 cities have been selected for development as Smart Cities. The government of India (GoI) defined the smart city as "*it is a city, which is liveable, sustainable and has a thriving economy offering multiple opportunities to its people to pursue their diverse interests*". According to the literature most of the research is being carried out in the context of developed countries. However, there is a deficiency of empirical research aimed at developing countries that are in the process of becoming smart. With that in mind, the theoretical contribution of the present study aimed toward developing a methodological approach for analysing urban transformation based on citizen perspective in the context of developing countries.

This study explores sustainability by using the lens of the spirit of place (SOP) for smart city development and proposes a model for the transformation of the cities into smart cities and attainment of the sustainable development simultaneously from the perspective of local inhabitants. This study contributes insight into urban transformation, hence broadening the existing knowledge. The focus of this study is on sustainable development for developing countries. It offers useful insights into interdisciplinary fields of study, including human development, sociology, urban development, humanities, city management, urban planning, and environmental science. It expands the limits of human understanding and enables further exploration and study in multiple fields.

In this research paper we address the following two research questions: What are the indicators and their classifications for a sustainable smart city? And how decision-makers and urban planners can prioritize and recognize the most critical indicators in smart city development for implementing sustainability?

The present study is structured as follows: We begin with a review of existing literature in "Literature review" followed by a description of methodology used in "Proposed Methodology". "Results" presents the results, and a discussion of the results is presented in "Discussion". Conclusions are drawn and directions for future research are discussed in "Conclusions and Future Scope".

2 Literature review

Rapid urbanization and population growth affect sustainability. The emerging issues gave rise to the smart city concept thereby encompassing ICT and promoting quality of life, safety, and security. Effective and efficient consistency of smart city components plays an important role in the smart city to run effectively (Haque et al., 2021). The creative urban form of smart cities has become a strategic choice for global urban development in many parts of the world. Therefore, promoting the construction and development of smart cities, sharing successful experiences, summarizing current problems, and assessing the sustainability of smart city development has become necessary. Quality of life is an important indicator and most beneficial to citizens concerning the sustainable development of smart cities (Shao, et al., 2023). The historical and cultural backgrounds can be explored by understanding local citizens' needs and lifestyles. Smart cities and their developments can have different ambitions and planning depending on varied levels and the dimensions needed for livability and quality of life across areas and countries (Chen, 2023). Nowadays, with cities becoming digitally transformed and facing massive economic, social, governance, and environmental complications (Kumar et al., 2023b, 2023c), modern technologies such as automated systems, BIM, and artificial intelligence can support urban planning practices (Kumar et al., 2023b, 2023c). The impact of artificial intelligence in construction is still not fully explored, however, AI is being perceived as helpful in planning and design (Kumar et al., 2022). The variety of emerging technologies can be utilized in meeting challenges and supporting sustainable development. This requires collaboration and interaction among researchers, planners, organizations, and communities, who are the key decision stakeholders for the wider and complete adoption of these emerging technologies in smart cities (Son et al., 2023). The research involving citizen participation helps empower communities, stakeholders, and marginalized groups by giving them a voice, agency, and platform to participate in decision-making processes, advocate for their interests, and shape their futures. It promotes participatory approaches that prioritize inclusivity and equity. The smart city development helps in governance to become more efficient due to citizen participation (Bhattacharya et al., 2018). The urban development focus mainly on providing quality life to citizens. So citizen's participation plays very crucial role in planning stage itself. And citizens can accept and use ICT based services if they are safely designed and secure their privacy by providing quality services (Yeh, 2017).

The statesmen, business leadership, and community play important roles in the governance and planning of smart cities (Edge et al., 2020). Various studies have explored the effectiveness of smart city governance towards urban openness, infrastructure, sustainability (Ruhlandt et al., 2020), energy efficiency (Yu & Zhang, 2019), health (Wray et al., 2018), work and traffic (Hopkins & McKay, 2019), and quality of life (De Guimaraes et al., 2020). Smart cities, in many parts of the world, played an important role in the effective response to the crisis during the Covid-19 pandemic through track-and-trace using smart technologies (Shorfuzzaman et al., 2021). Investigation of smart cities' contribution to crises and pandemics has been proven to be an important part of the smart city strategy. The effective involvement of government structures and the absence of urbanization pressure can offer a discrete advantage toward engagement and innovative capacities for assessing cities. Smart cities, being a global phenomenon, led to innovative activities that remain context-dependent resulting in variations and uneven development across cities within a given authority (Duygan et al., 2022).

Smart city literature has been a disparate and interdisciplinary research body having polarised discourses that view the smart city as the remedy for all problems in urban development to other different critiques from different perspectives (Zhao et al., 2021).

2.1 Interpretive Structure Modelling (ISM)

Interpretive structural modelling (ISM) widely used for hierarchical structure modelling, is found to be useful in exploring the relationships between the factors (Subramanian et al., 2021). ISM was introduced by Warfield in 1973, which aimed to arrange elements associated with hierarchical relations and analyse complex social and economic systems. The ISM methodology helps in providing a hierarchy of the indicators (Sharma & Bhat, 2014) and is useful for identifying relationships among various factors defining any problem or situation (Jharkharia & Shankar, 2004). ISM is used in issues or situations that are complex and subjective and uses expert knowledge and practical experience to solve complex systems. ISM is based on the judgment of experts and shows an inter-relationship among indicators (Babu et al., 2020). ISM enables researchers to understand complex relationships among different variables found to be involved in complicated situations. A system having subsystem elements helps in constructing the multilevel structural model. ISM method involves the final criteria with their comparison in defining binary relations and constructing a reachability matrix. The ISM-MICMAC approach is more efficient in comparison to other MCDM approaches in developing any hierarchal structure for the factors in a system (Bux et al., 2020). The ISM-MICMAC helps in identifying the complex relationship of different elements (Iqbal et al., 2022).The analysis was performed as per the methodology proposed by (Ahmad & Qahmash, 2021) named as SmartISM, implement ISM technique and MICMAC (Matrice d'Impacts Croisés Multiplication Appliquée á un Classement (cross-impact matrix multiplication applied to classification)) to classify variables.

2.2 Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) developed by Thomas L. Saaty in the 1980s, is found to be the most useful and commonly used among other multi-criteria decision methods (MCDM). It helps address complex decision problems and is found to be a useful tool for urban and environmental strategies in assessing their planning and development stage. The AHP can be used for analysing qualitative as well as quantitative decision problems consisting of indicators with flexibility regarding the setting of objectives. AHP is widely used in a variety of research areas including operations management, healthcare, project risk assessment, etc. The basic principle of AHP includes decomposition, comparative judgments, and synthesis of priorities (Saaty, 2008). It breaks down a complex problem into many clusters of different hierarchies including, criteria, sub-criteria, and sub-sub-criteria. However, ISM or AHP alone is insufficient in explaining the deciphering interactions among indicators. Consequently, to fulfil the need for hierarchical structure with quantification between indicators and validation of the model, researchers have developed many ISM-based mixed methods with two widely used mixed methods being Interpretive structural modelling-analytic hierarchy process (ISM-AHP) and Interpretive structural modelling-analytic Network Process (ISM-ANP) (Yadav & Samuel, 2021).

3 Proposed methodology

The theoretical domain defined for the present study was 'smart city', 'sustainability indicators', 'sustainable development', and 'urban development'. It was used for developing a literature review using available databases and reviewing related theories and existing measures for identifying and developing a conceptual framework of main constructs and generation of item pool. After the identification of a representative pool of indicators, semi-structured interviews were performed with three experts to establish the structure between representative indicators by employing the ISM method as per recommendations of (Shen et al., 2016), (Ravi & Shankar, 2005) and (Kusrini et al., 2019).

The framework of the study (Fig. 1) includes various stages. Starting with the selection of indicators from the literature review and thematic coding followed by ISM, which results in a three-level model of decision hierarchy, and lastly application of AHP. So, the combined indicators for the present study were generated from interview data (Fig. 2) and others from the literature review (Table 1). These indicators may vary partially with the geographical area due to variable characteristics of each city which change according to the cities' locations and their characteristics. Therefore, the indicators and their relationship will also vary. Interviews, as a qualitative approach instrument, are used for capturing individual understandings of meanings and processes (Book, Given, 2008). The indicators apart from the literature review were generated by using thematic coding (Fig. 2). The interviews were manually transcribed, and data were coded and analysed manually to highlight the trends and differences in the respective interviewee's responses. Similar codes were collated and analysed, then themes were developed (Gioia et al., 2012). For ISM methodology, the data was collected from urban experts having expertise in development project execution in India. The citizen cum experts who witnessed the urban transformation over the years were interviewees for thematic coding (indicator generation) as well as the respondents for the AHP questionnaire (Table 2). Hence, the present study consists of both bottom-up (urban experts) as well as top-down approaches (end-users). A purposeful sampling approach was used to yield appropriate and useful information (Book, Bourgeault et al., 2010). The present study uses an extensive primary survey method to collect data from three different cities (Berardi, 2015). The present study includes three different Indian Smart Cities to provide opportunities for different smart city planners and policymakers to pay attention to smart city planning (Bhattacharya et al., 2018).

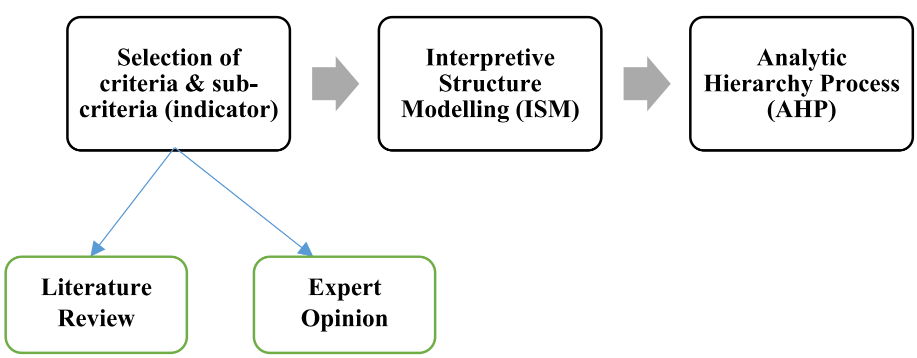

Fig. 1 The framework of the study

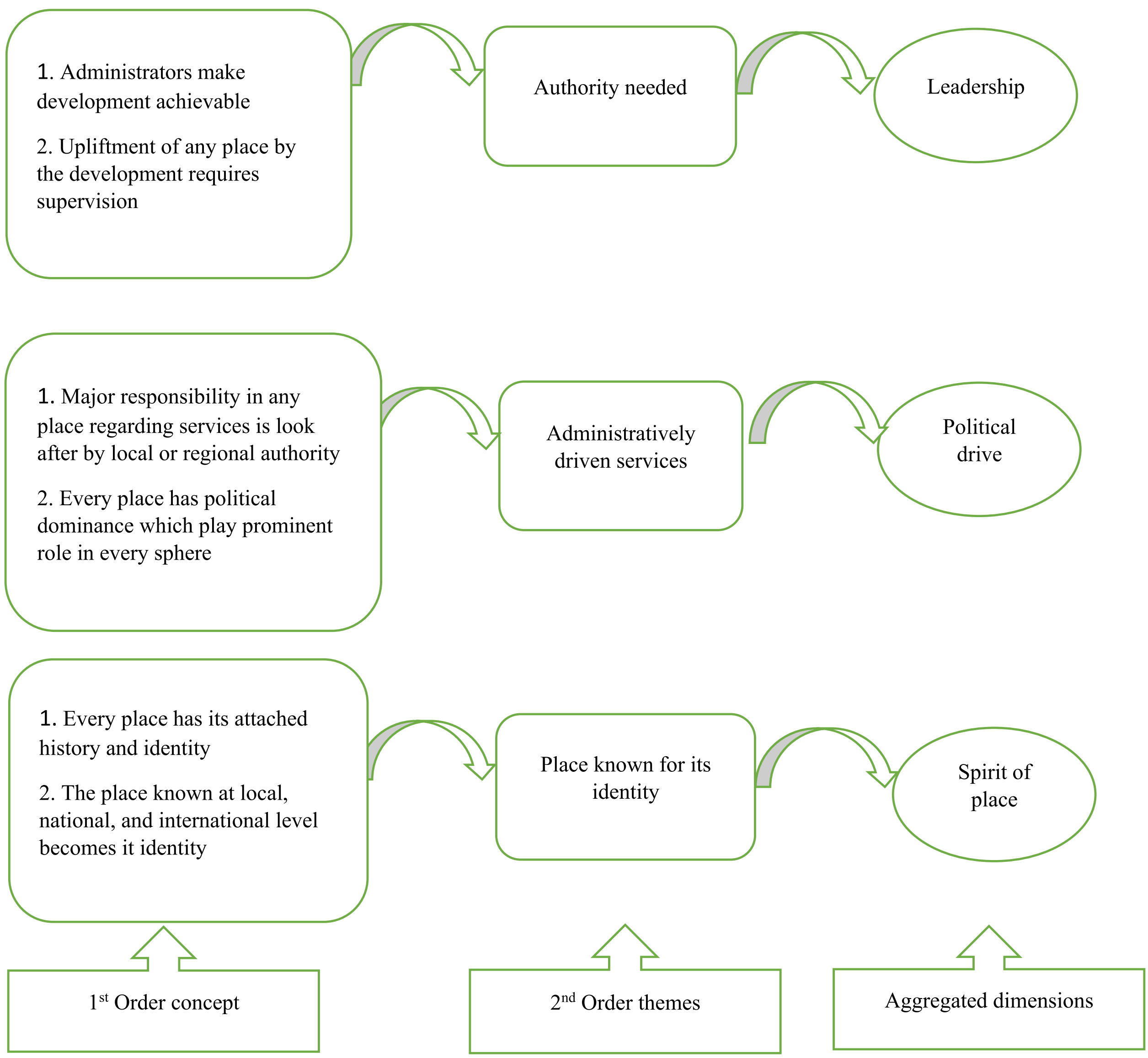

Fig. 2 Data structure used for the study

3.1 ISM-AHP approach

The present study used the interpretive structural modelling-analytic hierarchy process (ISM-AHP) mixed method. ISM imitates human thought processes whereas AHP minimizes discrepancies in the decision-making process (Kumar et al., 2019, 2023a). ISM describes relationships between various indicators and AHP uses assigned weights as well as evaluates each determinant's relative importance (Parthiban et. al., 2012). ISM methodology helps in the direct and indirect relationships between variables by incorporating judgemental inputs from experts in the particular field of study. The ISM enhances the usage of the interrelationship between performance factors as they are found only to be important in the interaction between criteria. The mixed method helps in analysing information with the help of ISM and ranking with verification by using AHP (Goel et al., 2022). AHP also includes non-quantifiable or qualitative factors significantly (Ravikumar et al., 2015). The non-quantifiable indicators generated from the interviews included leadership (L), political drive (PD), and spirit of place (SOP).

The AHP helps in ranking or prioritizing the indicators. Furthermore, a case-based study of three different upcoming smart cities {Varanasi city, Panipat city (subdivision under Karnal division), and Jaipur city} in India

Table 1 Smart city criteria & sub-criteria

Criteria/ Sub-criteria	Supporting literature
• Local government (LG) • Information Communication Technology (ICT)	Lee (2012), Neirotti, et al. (2014), Sotarauta and Beer (2016)
Citizen Involvement (CI) • Public hearings (PH) • Communication channels for city building (CC)	Margerum (2002), Kim (2017), Yongki, Kang (2008), Book, Deakin, (2013), Xu. H et. al. (2020)
Infrastructure (I) • Technology infrastructure (TI) • Human infrastructure (HI)	Taylor Buck & While (2016), Marzouk et al. (2020)
• Reorganization of Law and Policies; (RLP) • Local government cooperation (LGC)	Nesti, (2018), Molin Valdes (2012)
Stakeholders (S) • Direct stakeholders (DS) • Indirect stakeholders (IS)	Fernandez-Anez, (2016), Trunfio and Campana (2019), Koens et al. (2021), Trunfio and Della Lucia (2018), Pasquinelli and Trunfio (2020)
• Learning hub (LH) • Cultural hub (CH)	Book, Day (2002), Book, Garnham (1985), Silva (2015), Anthopoulos (2015), Book, Ferreira (2018)
Quality of Life (QOL) • Environmental well-being; (EWB) • Employment; (E) • Recreation amenities; (RA) • Health facilities (HF)	Thite (2011), De Guimarães et al. (2020), Easterlin and Angelescu (2007), Ebrahimzadeh et al. (2016)

Table 2 Sample size with methods used in the study

Methods used in the present study	Sample size
Thematic codes	16
Interpretive structure modelling	03
Analytic hierarchy process	123
Total	142

is provided to validate the proposed framework. The three-level decision hierarchy model generated was further verified by respondents or experts. The first level represents the goal with second-level criteria and third-level sub-criteria (Fig. 3). The participating experts were asked to identify relationships among sub-criteria and criteria. This inter-relationship is used to formulate a digraph for each determinant representing the interrelationship among sub-criteria.

After the ISM resulting model, a multi-criteria decision-making framework is proposed for sustainable smart city development. The sustainability in smart city development process involves multiple criteria such as leadership, infrastructure, and stakeholders, among others. Resulting, in the multicriteria decision-making (MCDM) problem with many of the criteria being qualitative. To attain sustainable development, the involvement of individual participation (citizens or experts) in the decision-making process helps in the effective implementation of the outcome in the future. Thus, aligning individual participation in smart city development becomes an important factor for the success of the entire development process. So, incorporating the above aspects related decision-making framework is further presented. The present study's population consisted of individual citizens and experts in and around the randomly selected three sampling units 'smart cities'. These cities have distinctive identities {Varanasi city, Panipat city (sub-division under Karnal division (Divisional commissioner Karnal, 2024)), and Jaipur city} among upcoming 100 smart cities under GoI smart city mission {Varanasi city, Panipat city (sub-division under Karnal division), and Jaipur city} and have witnessed the transformation of their home city over the years. All three cities have a rich heritage, unique culture, and distinct identity. Varanasi has a unique distinction of being the pivot where religion, art, culture, education, and handicrafts have flourished for over centuries. Jaipur is famous for its rich cultural, dance, music, and handicrafts traditions over the centuries. Panipat is well known for its historic legends, epic spirituality, and weaving traditions over the centuries. Likewise, every city is different from another in some way shape, or form which contributes to its identity.

A sample size of 100–200 is generally considered sufficient for scale construction studies (Cheng et al., 2021). A purposive sample of citizens residing in selected smart cities was selected through the authors' professional networks. Potential respondents were contacted over the phone and in person, and duly briefed about the background and purpose of this study before sharing the survey questionnaire. Participation in this survey was voluntary without the use of any form of incentive. The questionnaire was shared with the participants through

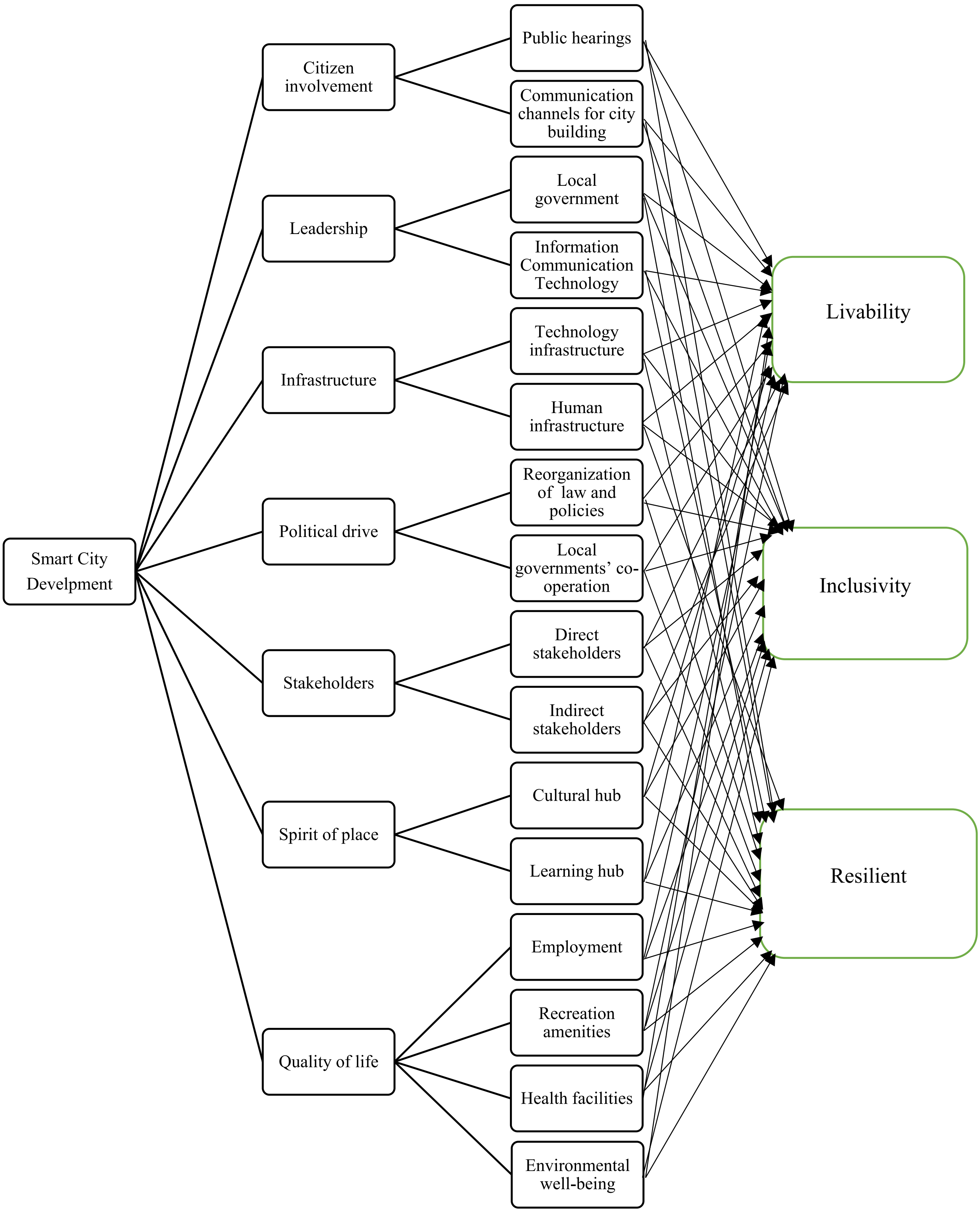

Fig. 3 Hierarchical tree

email. Annexure I contains the questionnaire shared with the respondents. In the survey questionnaire, the respondents were required to do a pairwise comparison (Saaty, 2008). The preference is expressed by a ratio scale ranging from 1–9, where level 1 shows an equal attribute while level 9 indicates the strongest preference attribute over another (Leskinen, 2000). The responses were checked for missing values and straight lines. For incomplete responses, follow-up was done requesting the concerned respondents to complete the missing details. The survey lasted three months and we distributed the sample questionnaire to a total of 200 respondents. We received a total of 142 responses out of which 123 responses were found valid for AHP (Table 2) giving 61.50% response rate. This study's sample size and response rate is comparable with previous research in this area. The count received from Varanasi 55, Jaipur 35 and Panipat 33 (subdivision under Karnal division).

3.2 Sensitivity analysis

The consideration of results provided by MCDM techniques needs more preciseness. So, it necessitates performing sensitivity analysis. The objectivity involved in sensitivity analysis is to evaluate the influencing degree of the variable on model output by controlling variables. The sensitivity analysis helps in determining the robustness of the assessment which is by examining the extent of results affected by changes in methods or models etc. It helps in the evaluation of minimum changes in the weights of criteria which can alter the positions of alternatives. The sensitivity analysis computation is performed by changing a single variable at one time and can be extendable to multiple variables. For this study, sensitivity analysis has been performed on AHP results for validation. The study used local government to be the most significant sub-criteria with the highest weight comparatively, those were set to be independent variables separately for obtaining a sensitivity graph (Fig. 4). Application of sensitivity analysis reveals that AHP results are robust, significant, and reliable. The graph shows the highest peak in line with AHP results.

4 Results

This study explores sustainability by using the lens of the spirit of place (SOP) for smart city development and proposes a model for the transformation of the cities into smart cities and attainment of the sustainable development simultaneously from the perspective of local inhabitants. The current study offers empirical facts and data-driven insights that can guide the creation of policies, decision-making, and strategic planning at the local level, with potential implications at the national and global levels. This tool can assist policymakers, practitioners, and stakeholders in making well-informed decisions and implementing efficient strategies to address intricate issues like urban development. Incorporating the SOP into urban planning processes allows cities to develop more contextually relevant and sustainable solutions that resonate with local residents. This involves understanding the unique characteristics and history of a place, which is crucial for designing smart city interventions. The SOP is intricately connected to the conservation of cultural heritage and the maintenance of identity.

4.1 ISM tables

ISM is interpretive, based on mutual relationships which portray all relationships among variables and is useful in knowing about the contextual relationship among indicators. A pairwise comparison was carried out to obtain a structural self-interaction matrix (SSIM) useful for checking transitivity. The reachability matrix (RM) divided into different levels is established by the structural self-interaction matrix (SSIM). The conical matrix developed by the reachability matrix makes the rearrangement of variables from different levels. A directed graph (also known as a digraph) is generated and its transitivity associations are removed. The directed graph is converted into a model generated by ISM, possible by substituting nodes of elements into statements. Generated model by using ISM which is then tested for conceptual consistency with the incorporation of necessary changes.

4.2 MICMAC

All the elements suitable for developing a sustainability culture across smart city development were grouped into different categories. This study identifies indicators of leadership, infrastructure, political drive, stakeholder, quality of life, the spirit of place, citizen involvement, local government, information communication technology, public hearings, communication channels for city building, technology infrastructure, human infrastructure, reorganization of law and policies, local government co-operation, direct stakeholders, indirect stakeholders, the learning hub, cultural hub, environmental wellbeing, employment, recreation amenities, health facilities as having strong driving power but low dependence. Whereas indicators of livability, resilience, and inclusivity have low driving power and low dependence, and they possess few links with other indicators. This study finds most of the variables being autonomous in nature and unrelated, and thus do not show any association with other variables. Hence, these need to be taken care of separately.

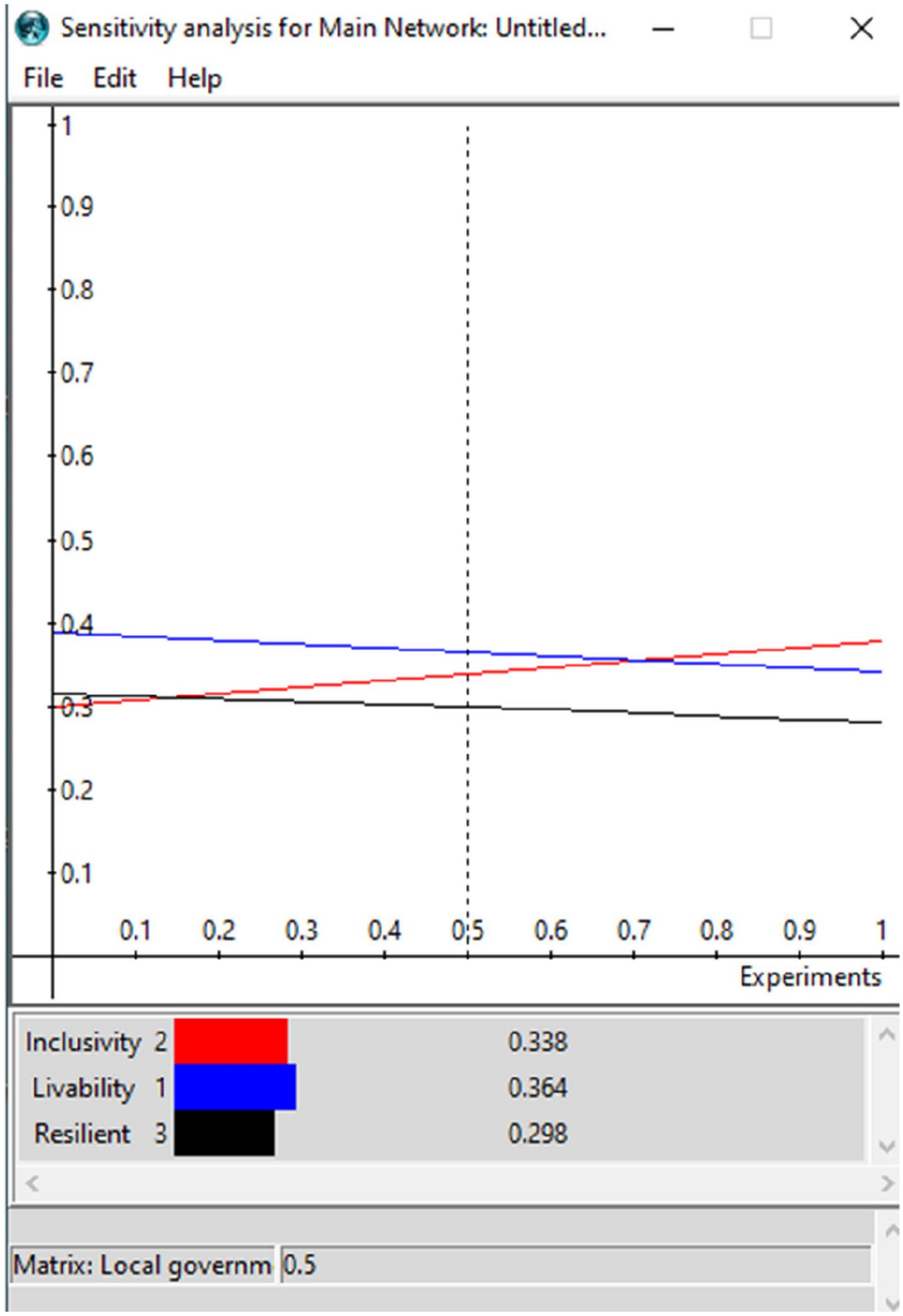

Fig. 4 Sensitivity analysis

4.3 AHP metrics

The data collected to perform the AHP methodology involved a total of 123 respondents who were citizens based in three smart cities {Varanasi city, Panipat city (sub-division under Karnal division), and Jaipur city} in India and have witnessed the transformation of the city over a decade. The priorities obtained at each level of decision hierarchy in AHP give weights to criteria that are based on the pair-wise comparison. The decision hierarchy included seven criteria and sixteen sub-criteria. The comparison then resulted in a summary score of the indicators (Tables 3, 4, 5). The obtained score was then multiplied and provided ranked scores (Myeong & Lee, 2018). The consistency index (CI) and consistency ratio (CR) values were less than 0.10 and λmax presents

Table 3 Weights of Indicators

Criteria	Criteria weights	Sub-criteria	Sub-criteria weight	Alternative			Alternative		
				A1	A2	A3	A1	A2	A3
Leadership	0.17152	Local government	0.51116	0.58119	0.23448	0.18431	0.05095	0.02055	0.01616
		Information communication technology	0.35128	0.41867	0.31662	0.26469	0.02522	0.01907	0.01594
Citizen Involvement	0.26037	Public hearing	0.39326	0.52022	0.31202	0.16774	0.05326	0.03194	0.01717
		Communication channels for city building	0.26083	0.42748	0.30309	0.26942	0.02903	0.02058	0.01829
Infrastructure	0.17894	Technology infrastructure	0.25919	0.37025	0.33615	0.29359	0.01717	0.01599	0.01361
		Human infrastructure	0.31909	0.33959	0.36031	0.30009	0.01939	0.02057	0.01713
Political drive	0.10521	Reorganization of Law and Policies	0.38873	0.35589	0.30437	0.33973	0.01455	0.01244	0.01389
		Local government co-operation	0.28966	0.42043	0.23571	0.34385	0.01281	0.00718	0.01047
Stakeholders	0.10282	Direct stakeholders	0.44563	0.33463	0.36681	0.29854	0.01533	0.01680	0.01368
		Indirect stakeholders	0.33182	0.42248	0.32919	0.24832	0.01441	0.01123	0.00847
Spirit of place	0.10864	Learning hub	0.24363	0.35053	0.32928	0.32017	0.00927	0.00871	0.00847
		Cultural hub	0.37064	0.40593	0.32463	0.26942	0.01634	0.01307	0.01085
Quality of life	0.07247	Environmental well-being	0.34533	0.42932	0.30739	0.26327	0.01074	0.00769	0.00658
		Employment	0.30881	0.31039	0.34565	0.34395	0.00694	0.00773	0.00769
		Recreation amenities	0.14857	0.39004	0.40658	0.20337	0.00419	0.00437	0.00218
		Health facilities	0.19727	0.54988	0.24946	0.20065	0.00786	0.00356	0.00286

Table 4 Weights and ranks of criteria

Criteria	Final priority weights	Rank
Citizen Involvement (CI)	0.260370924	1st
Infrastructure (I)	0.178940533	2nd
Leadership (L)	0.171524194	3rd

Table 5 Weights and ranks of Sub-criteria and Alternatives

Weights and ranks of Sub-criteria		
Sub-Criteria	**Final priority weights**	**Rank**
Local government (LG)	0.511169997	1st
Direct stakeholders (DS)	0.445633848	2nd
Public hearing (PH)	0.393263871	3rd
Weights and ranks of Alternatives		
Alternative	**Final priority weights**	**Rank**
Livability (Liv)	0.307546831	1st
Inclusivity (Inc)	0.221173496	2nd
Resilient (Resi)	0.183533792	3rd

the largest or principal eigen value of the matrix (Saaty, 1990).

Citizen involvement, infrastructure, and leadership were on the priority list (Table 4). This study's results indicate that citizens evaluate the success of smart cities and urban development based on the indicators of citizen involvement, infrastructure, leadership, local government, stakeholders, and public hearings. Smart city leadership can affect its political level, political risk, and corruption level. There is a growing literature on place-based leadership or local government within urban and regional studies (Sotarauta et al., 2017). Citizen involvement engages citizens in decision-making activities of the urban management process (Wilson et al., 2017). The development of a smart city requires continuous planning of the utility infrastructure and relevant requirements and changes for the development scheme of the city (Marzouk et al., 2020). The approach to city governance and its success depends on the goals of political and social representatives, citizens, and party action (Nesti, 2018). The interconnection of tourism stakeholders through ICT platforms, and smart destinations generates many chances to collaborate and innovate leadership and human capital (Trunfio & Campana, 2019). Stakeholders' involvement in urban planning makes it accountable and involved in sustainable development and smart hospitality (Koens et al., 2018). The urban strategies implementation and participation involve diverse stakeholders via hands-on decision-making (Trunfio & Della Lucia, 2018). The stakeholders have core human-technology interactions which are found to influence tourism stakeholders (Pasquinelli & Trunfio, 2020). This indicates a potential requirement to shift development policies into a smart perspective, i.e., multidimensional strategic transformation to achieve success on smart city projects. The results suggest for inclusion of sustainable development with the integration of environmental, economic, and social parameters in the local government's policy agenda. The stakeholder's involvement is previously identified as one of the critical success factors for success on large construction projects (Kumar et al., 2023c).

Respondents gave priority to livability and inclusivity (Table 5). This study has found livability as an important dimension for urban development cities focus more on providing a healthy environment for the population. Livability also supports shaping the social, economic, physical, and biological urban environment. Livability is a multi-dimensional concept associated with dimensions such as climate, infrastructure, safety, business environment and many more. Livability can help any city to maintain and improve to attract investments and remain alive. Whereas inclusivity for a sustainable urban environment depends upon creating a safer space, accessible and comfortable for citizens as it arranges smart technology for environmental safety. The adopted technology promotes sustainability aligned with the needs and experiences of citizens.

5 Discussion

This study explores sustainability by using the lens of the spirit of place (SOP) for smart city development and propose a model for the transformation of the cities into smart cities and attainment of the sustainable development simultaneously from the perspective of local inhabitants. For transforming a city into a smart city, infrastructure is considered to be the key driver of the smart city. From the creativity point of view, people, learning and knowledge, education and all-around development are the mains for the smart city. The city's growth requires jobs, labor, health amenities, knowledge networks, economy, and entertainment. It also focuses on education, art, culture, commerce and a mix of ethnic and social companies. It leads the city to be smart in managing resources such as; city administration, education, healthcare, transportation etc. by interconnecting, intelligently and efficiently. And this will create opportunities for new business and research hubs by companies, and research institutes and contribute to the development of entrepreneurial character. Citizen participation and engagement in smart cities vary depending upon the development it involves. It may also involve ICT-based solutions. The medium of interaction could be via media, social media, civic engagement, and many more.

An economic construct can be defined as the regional administration policies that play an important role by conveying narratives and connecting smart city initiatives in regional contexts for socioeconomic needs. Stakeholders should be included in every stage of smart city development, including planning and implementation, to ensure that projects are in line with the needs and values of local citizens. SOP promotes the active involvement of the community in decision-making processes and urban planners can optimize resource use by designing infrastructure and services that take into account the distinctive features of a place (Al Ani, 2023). This includes energy-efficient buildings, water conservation measures, and sustainable transportation systems that are customized to meet the individual demands of the community. SOP can help in achieving resilience through the recognition of both the vulnerabilities and strengths inherent in a certain location. Smart cities can utilize this knowledge to formulate adaptation measures that effectively reduce the consequences of climate change, such as constructing flood-resistant infrastructure or implementing urban green spaces that aid in mitigating heat island effects. SOP acknowledges the economic importance of local companies and industries (Han & Hawken, 2018). The creation of smart cities can bolster small-scale firms, facilitate local procurement of goods and services, and generate prospects for sustainable tourism, thus enhancing the economic life of the community (Richter et al., 2015). SOP promotes a comprehensive and sustainable approach to development. Smart city projects should give priority to sustainable practices that guarantee the welfare of both present and future generations, taking into account the interdependencies among environmental, social, and economic variables. The main components of city resilience encompass social, economic, infrastructure, built environment, and institutional resilience. On the other hand, urban livability is characterized by features such as accessibility, community well-being, and economic vibrancy (Kutty et al., 2022).Future cities must integrate the triple aims of sustainability, resilience, and livability with smartness in order to be effective and self-sustaining (Kutty et al., 2023).

Environmental construction can be defined as a smart city mission that transforms a city into a technically advanced city by overcoming several challenges such as poverty rate, traffic abnormalities, environmental pollution, city infrastructure, unhealthy living standards, etc. (Yigitcanlar et al., 2018). Smart cities have become a topic of discussion among academics, policymakers, and businesses when stimulating the enhanced productivity of cities (Borsekova & Nijkamp, 2018). The smart city helps in facilitating innovative technical solutions in the fields of environment, mobility and accessibility, health and education, public services, governance, and quality of life (Simonofski et al., 2021). The smart city agenda can be represented through the three 'S' of urban development – smart technology, society, and sustainability (Praharaj & Han, 2018). The present study suggests that the creation of economic values and social impact can spur economic growth, generate employment, and foster innovation through the promotion of entrepreneurship, technology transfer, and industry alliances. By enhancing the place's identity, it is feasible to achieve sustainable development. Every place has its character, traditions, and conventions and when we consider the identity of any place, it becomes more than a piece of land and there exists a 'spirit or soul' that varies from place to place. Therefore, each individual is spellbound in a specific area, maybe because of many opportunities offered by that place, which is home, the country. Different places on earth have fundamental indicators, distinctive vibrations, and diverse traditions, these many things offer plenty of chances to learn and enhance life by utilizing opportunities. The interaction between a place and its inhabitants plays extreme importance by shaping culture and art with literature. The local communities can develop organizational capacity to motivate and sensitize residents to adopt smart & environmentally sustainable energy utilization practices. The participation and engagement of citizens may vary depending upon the development it involves. Cities should adopt initiatives as per to the things which can truly make it smart so that can be assessed according to their liveability value. Sustainability has been divided into economic, social and environmental indicators (Elkington, 1994). These three dimensions; social, economic, and environmental have been widely accepted for sustainability and implementation (Goyal et al., 2013). Sustainability indicators developed by companies are used to check performance based on three sustainability indicators (Azapagic & Perdan, 2000). In the present study economic indicator, stakeholders, infrastructure, and spirit of place support the city to perform economically. The social indicator, stakeholder, leadership, and political drive, help the city in social upliftment directly or indirectly and environmental indicator; quality of life, offers the enhancement of living standards (Fig. 5).

6 Conclusion & future directions

Despite much research, smart city development in the urban transformation based on citizen perspective found rarely focused on a developing country. So, this study aims to propose a model for cities being transformed

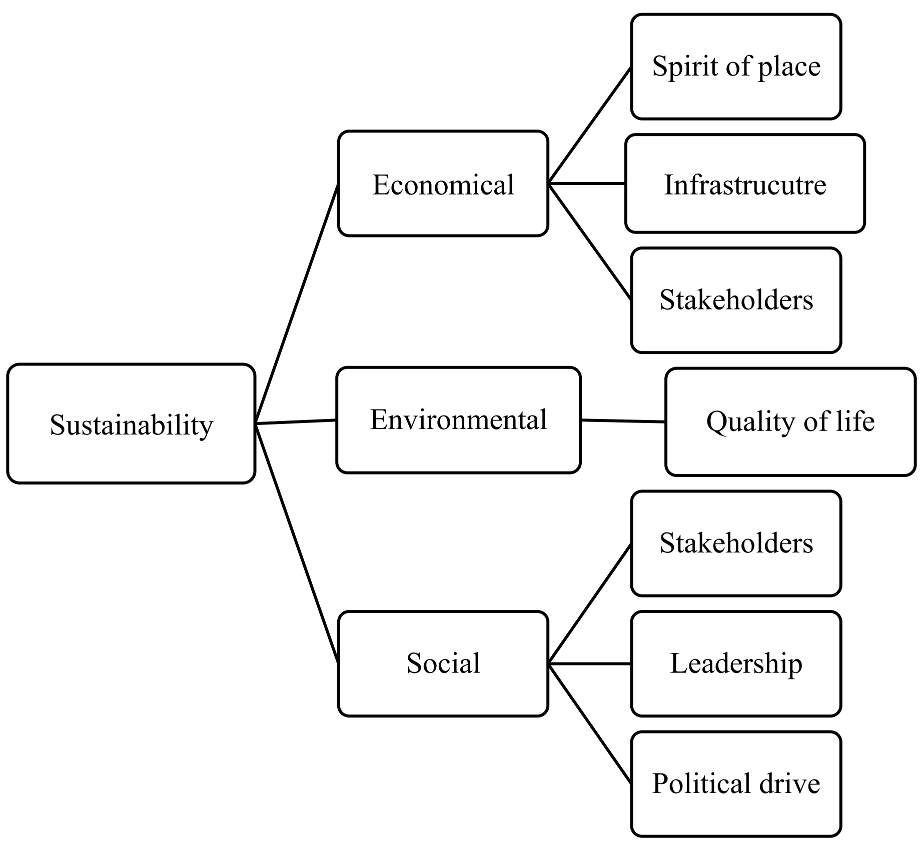

Fig. 5 Division of indicators based on sustainable indicators

into smart cities and at the same time attaining sustainable development. In India, regional planning has not been found on a sustainable path. This is without much thought on integrated transformation and consideration for cultural/religious legacy, social fabric, traditional economy, or ecological balance creating a soulless city. Cities are basic units of economic growth for any country. Hence, consideration of sustainability for urban growth and development becomes important for the government and citizens. Sustainability is a long journey for which the government can work by focusing on factors supportive of sustainability in the initial phases of development.

SOP highlights the significance of tackling socioeconomic disparities and guaranteeing that progress is advantageous for all sectors of society, especially those who are marginalized. By giving priority to social justice and inclusivity, cities may establish more equal and habitable environments that accurately represent the varied needs and ambitions of their inhabitants. By integrating the essence of a specific location into the development of smart cities, sustainability, resilience, and community well-being can be promoted. This can be achieved by embracing the local context, cultural heritage, and community participation. By doing so, cities can attain more comprehensive and significant results in their pursuit of urban sustainability. Sustainability initiatives in the creation of smart cities typically prioritize environmental preservation and resource allocation, while also extending their scope to cover social fairness and inclusivity. SOP focuses on comprehending and safeguarding the inherent characteristics and ecological integrity of a specific location. Smart city efforts can give priority to the preservation of green spaces, the conservation of biodiversity, and the sustainable management of resources, thus guaranteeing that development has minimal negative impact on local ecosystems. SOP acknowledges the significance of cultural history in influencing the character and essence of a location. Smart city initiatives have the potential to integrate local culture, architecture, and traditions into their designs, promoting a sense of community among people and safeguarding cultural variety. Design and mitigation incorporated to minimize developing urban climate can improve comfort, health, and outdoor space. This leads to enhancing sustainable urban livability.

Livability can benefit residents by serving better living conditions to end users and urban planners in designing livable cities and constructing stakeholder support by developing more livable properties. The livability concept can be supported by facilitating safety, built environments, public facilities, transport, walkability, and natural environment. The smart city having ICT-based solutions can enhance all subsectors by implementing technology for convenience to people. For example, e-government facilities are omnipresent public services that can improve livability for residents. Any inclusive city should have a safer and livable environment for its citizens, also it should provide affordable and equitable access to essential and other urban services with plenty of livelihood opportunities. Inclusive smart cities promote access to urban technologies to citizens including disabled, senior, and older persons. Urban planners and city planners can further extend the vision of inclusiveness by considering ways to engage all ignored segments of the population. This will help in building more smarter and inclusive cities.

The present study provides a model based on citizen perception, useful to local government (leaders or administrators). Many previous studies used a mathematical approach for ranking or comparing cities, but the gap remains in considering the sustainability of smart cities in developing countries. The present study proposes a novel approach with a contribution to the literature by identifying and ranking indicators for sustainable smart city development based on sustainability at the local level. The study suggests citizen perception is directly influenced by livability, inclusivity, citizen involvement, infrastructure, and leadership. The present study used data from a self-reported questionnaire and subjective evaluations by respondents cum experts from cities in India hence, expanding this study in other settings could prove beneficial. The further breakdown of main categories into further sub-criteria and, implementation of other different methods are to be considered. The research can be extendable to various other areas of a smart city viz health, public transport, ICT, etc. The position of indicators helps in identifying priorities with development strategies. The study contributes to understanding urban areas by providing implications to urban governance for policies and programs. The findings could be informative servings to policymakers in identifying potential scope which can be developed or transformed into policies, helpful to citizens' aspirations. The quality of life of citizens concerning urban development supports contributing to the economic growth of the city.

The study presents many opportunities that could be explored in future studies. The model outlined represents the final interaction among indicators associated with sustainability. Much of the analysis and discussion is centered on the interactions among sustainability indicators. Sharing resources and information that will allow partners to change their perception of sustainability needs further investigation. In most of the models, the investigation of the interactions among variables reached a successful conclusion. The models, however, did not take into account efforts that were introduced and failed. Further models can investigate these using real-life situations and confirm them with a longitudinal study. The data used to develop the ISM model and MICMAC graph was taken from three experts from the Indian Development Authority. A suitable model with a bigger sample can be carried out. By further incorporating various recommendations, a rigorous model could be made to determine the relationships among the indicators with their weights. It would be useful to compare AHP and fuzzy AHP with other existing statistical approaches. This would give a more accurate picture of the optimization of the factors. New methods can be included to get a clearer picture. The interrelationship issues among the dimensions need to be addressed in future studies. Literature reviews as well as classification schemes like bibliometric analysis, and meta-analysis can be applicable to get an in-depth understanding. Studies further developed can specifically check improvement in sustainability by using the findings of the present study.

Supplementary Information

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Supplementary Material 1.

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Declarations

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