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Exploring the impact of smart cities on improving the quality of life for people with disabilities in Saudi Arabia

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By using advanced technologies and data analytics, smart cities can establish conditions that are both inclusive and accessible, addressing the distinctive needs of disabled people. This research aims to examine the benefits of smart city technologies and develop strategies for developing environments that serve the requirements of individuals with disabilities in Saudi Arabia. Using a sequential mixed method, the study uses the social disability model. The initial phase involves gathering quantitative data from 427 individuals with disabilities in Saudi Arabia. Further, qualitative data was obtained through semi-structured interviews with a sample of four professionals employed in Saudi smart city initiatives. Quantitative data is analyzed using Partial Least Square-Structural Equation Modeling (PLS-SEM), while qualitative data is analyzed using thematic analysis. Quantitative findings revealed the robustness of the measurement model, confirming the significant effects of Smart City Initiatives on Accessibility Enhancement, Inclusive Information, and Health and Wellbeing Improvement. The respondents indicated that they are satisfied with the initiatives and their effectiveness, providing them with equal services and opportunities without discrimination. The qualitative analysis further revealed themes, i.e., Technology Integration for Accessibility, Inclusive Design, Inclusive Planning for Health, and others. Participants indicated special consideration for implementing the designs and approaches to ensure inclusivity and availability of services to disabled people. Besides, implementing infrastructure and policies to ensure the health and wellbeing of disabled people also remained prevalent. Hence, it is concluded that smart city initiatives break obstacles and improve the wellbeing of individuals with disabilities. Improved healthcare services and inclusive urban planning highlight the transformative effect of these initiatives on health and wellbeing, promoting an equitable and sustainable services environment. Finally, research implications and limitations are discussed.

KEYWORDS

smart city, urban planning, strategy, disabled people, Saudi Arabia, sustainability

1 Introduction

Smart cities can play an important role in improving the quality of life for people with disabilities in Saudi Arabia (BusinessWire, 2022; Nassuora, 2012). By leveraging advanced technologies and data analytics, smart cities can create an inclusive and accessible environment that caters to the needs of people with disabilities (Kolotouchkina et al., 2022a). One of the key areas where smart cities can make a difference is transportation (van der Meer et al., 2018). In Saudi Arabia, people with disabilities face significant challenges when it comes to transportation (Kwon, 2021). Many public transportation systems are not designed to accommodate people with disabilities, which makes it difficult for them to travel around the city independently (Neirotti et al., 2014). Smart cities can use GPS, real-time tracking, and automated vehicles to make transportation more accessible and convenient for people with disabilities. Smart cities can also use technology to improve access to public spaces and buildings (De Guimarães et al., 2020). For example, smart cities can use sensors and data analytics to monitor the accessibility of public spaces, such as parks and sidewalks, and make necessary modifications to ensure they are fully accessible to people with disabilities (Alzaed and Balabel, 2020).

Similarly, smart buildings can use voice-activated controls and automated doors to make it easier for people with disabilities to access buildings and use their facilities (Al-Sayed et al., 2022). In addition, smart cities can leverage technology to improve healthcare access and delivery for people with disabilities (Fegert et al., 2020; Khan et al., 2021). For example, telemedicine can provide remote medical consultations, which can be particularly beneficial for people with disabilities who may have difficulty traveling to medical facilities. Smart cities can also use data analytics to identify health disparities among people with disabilities and develop targeted interventions to address these disparities (Aina, 2017). Additionally, smart cities can use technology to create inclusive communities that promote social connectedness and participation for people with disabilities (Kolotouchkina et al., 2022a). For example, smart cities can use social media platforms and virtual reality technologies to create virtual communities that connect people with disabilities and the broader community (Almalki et al., 2022). Smart cities can also use data analytics to identify opportunities for community engagement and develop programs and events that are accessible to people with disabilities. So smart cities can play a critical role in improving the quality of life for people with disabilities in Saudi Arabia (De Guimarães et al., 2020; Alam et al., 2021; Al-Sayed et al., 2022). By leveraging technology and data analytics, smart cities can create an inclusive and accessible environment that caters to the needs of people with disabilities and promotes their full participation in society (Sobnath et al., 2020).

1.1 Research objectives and gaps

Therefore, the study aims to explore the role of smart cities in improving the quality of life for people with disabilities in Saudi Arabia. The study aims to identify the potential benefits of smart city technologies and strategies for creating inclusive and accessible environments for people with disabilities. The research gap in this area is that there is limited research on the specific needs and challenges faced by people with disabilities in Saudi Arabia and how smart city technologies are used to address these challenges. While there have been studies on smart cities and accessibility in other countries, there is a lack of research on the implementation of smart city technologies in Saudi Arabia and their impact on the quality of life for people with disabilities (Fallatah, 2016; Al-Sayed et al., 2022; Alam and Mohanty, 2022; Asiri et al., 2022). Therefore, this study aims to fill this research gap by examining the specific challenges faced by people with disabilities in Saudi Arabia and how smart city technologies create inclusive and accessible environments that cater to their needs. By identifying the potential benefits and challenges of smart city technologies in this context, this study can contribute to the development of effective strategies for creating smart cities that are inclusive and accessible for all.

2 Review of literature

2.1 Smart cities technology in Saudi Arabia-an overview

Saudi Arabia has taken several steps toward improving the quality of life for people with disabilities and promoting their inclusion and participation in society (Thompson, 2017). The Kingdom has developed a comprehensive strategy known as the "Saudi Vision 2030," which includes several initiatives to improve the lives of people with disabilities (Grand and Wolff, 2020). Under the Saudi Vision 2030, the government has set a goal of increasing the employment rate of people with disabilities to 5% by 2020 and 12% by 2030 (Amran et al., 2020). The government has also established the General Authority for the Care of Persons with Disabilities, which is responsible for promoting the rights and welfare of people with disabilities and providing them with the necessary services and support (Fallatah, 2016; Thompson, 2017). In addition, the Saudi government has launched several initiatives to improve the accessibility of public spaces and transportation for people with disabilities (Grand and Wolff, 2020). For example, the government has developed the "Accessible Public Transportation Program," which aims to make public transportation more accessible for people with disabilities by providing specialized buses and other facilities (Amran et al., 2020). The Saudi government has also taken steps to promote education and training opportunities for people with disabilities (De Guimarães et al., 2020; Alam et al., 2021; Khan et al., 2021; Kåresdotter et al., 2022). The government has established special education programs in schools and universities to cater to the needs of students with disabilities (Jonek-Kowalska, 2022).

Additionally, the government has launched several initiatives to provide vocational training and employment opportunities for people with disabilities (Kohli et al., 2022). Overall, the Saudi Vision 2030 demonstrates the government's commitment to improving the lives of people with disabilities and promoting their inclusion and participation in society (Alam et al., 2021). While there is still work to be done to achieve these goals fully, the initiatives taken by the government represent a significant step forward in improving the quality of life for people with disabilities in Saudi Arabia (Fallatah, 2016).

2.2 Social disability model

The Social Model of Disability provides a way to understand disability as an outcome of societal barriers rather than an intrinsic characteristic of an individual (Kohli et al., 2022). The relevant model supports the present research as it helps shift the focus from the individual's disabilities to the environmental and social aspects that form barriers. It acknowledges that inaccessible infrastructure, biased policies, and opposing attitudes contribute to the challenges faced by individuals with disabilities (Deitz and Lobben, 2021). In line with the social disability model, there are some more theoretical backgrounds consistent with the current conceptualization of smart cities and disabilities. For instance, Universal Design supports the creation of environments and products that are functional for all people, to the greatest extent possible, without the need for adaptation or specialized design (Pineda and Corburn, 2020). Universal Design principles inform the development of inclusive technologies and infrastructure that serve the needs of people with disabilities (Kapsalis et al., 2024). By incorporating features such as accessible public transportation systems, smart navigation tools, and inclusive digital interfaces, smart cities can improve the quality of life for people with disabilities while benefitting the entire population. Further, applying the capability approach, applied to the context of smart cities and disability inclusion, the relevant theory assumes the significance of providing people with disabilities the capabilities to fully participate in social, economic, and cultural life within urban environments. Smart city initiatives that improve accessibility, connectivity, and participation can develop the capabilities of people with disabilities, helping them to lead more fulfilling and autonomous lives. From the intersectional theory perspective, smart cities and disability inclusion need to consider the diverse experiences and needs of people with disabilities from different social, cultural, and economic backgrounds (Calvi, 2022; Macaya et al., 2022). Smart city initiatives must account for the intersecting identities and backgrounds of individuals to ensure that urban environments are truly inclusive and fair for all residents.

However, focusing on the social disability model, this study assumes that the Social Model of Disability is crucial for recognizing and understanding the precise obstacles that people with disabilities confront in Saudi Arabia. The evaluated smart city technologies can then be examined regarding how effectively they address or perpetuate these barriers (Naberushkina et al., 2022). By using this model, this study aims to acquire insights into the perceptions of individuals with disabilities and the stakeholders in smart city development. Notably, smart city technologies, with attributes like accessible transportation systems and inclusive information services, can break down obstacles highlighted by the Social Model (Panta et al., 2019). The model guides the study in assessing how these technologies improve social participation and quality of life for people with disabilities. It highlights the significance of designing smart cities with inclusivity in mind, encouraging the creation of environments that are accessible and adaptable for everyone. Besides, the Social Model is also assumed to report the study's recommendations for policy and practice (Rebernik et al., 2021). It is aimed to encourage a shift towards inclusive policies and practices that consider the diverse needs and abilities of individuals with disabilities in the development of smart cities. Thus, by applying the Social Model of Disability, this research contributes to social change, supporting inclusivity and improved quality of life for people with disabilities in the evolving landscape of smart city technologies in Saudi Arabia. Based on the Social Model of Disability, this research includes three aspects illustrated in Figure 1 of the study.

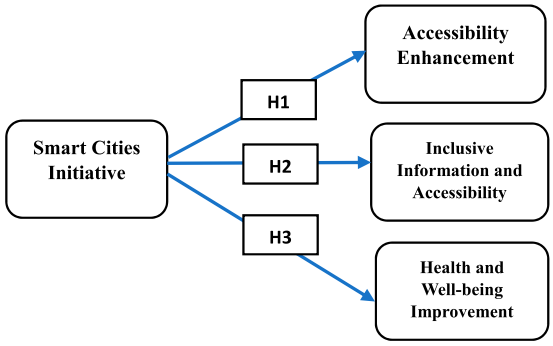

FIGURE 1
Explanatory framework of current study.

2.3 Accessibility enhancement

Accessibility enhancement is the improvement of access and usability for individuals with disabilities (Kolotouchkina et al., 2022a; 2022b). The concept is consistent with the Social Model of Disability, highlighting that disability is usually a result of environmental and societal impediments. Accessibility enhancement involves executing measures and using smart city technologies to eliminate or decrease these barriers, encouraging inclusivity and equal participation for people with disabilities (McMaughan et al., 2021). According to Salha et al. (2020), the key components of prospective smart cities include smart citizens, smart energy, smart mobility, smart buildings, smart technology, smart infrastructure, smart healthcare, smart education and governance, and smart security. Within the smart city framework, building accessible infrastructure is important for promoting inclusivity, especially for individuals with disabilities. This inclusive environment aims to enable their integration into the community, assuring they can exercise their civil, cultural, political, economic, and social rights. The preliminary goal of the study is to incorporate people with disabilities into society, encouraging active participation and leading to a more normal life. In their study, Apostolidou and Fokaides (2023) reviewed and highlighted applications designed to ensure accessibility for disabled people in Cyprus. According to the results, these apps are designed to assist individuals with chronic conditions and disabilities, serving different aspects of their lives. These apps include Access Now, Assistive Touch, Google Voice, Instacart, Roger Voice, Sleep Cycle, Sworkit, and others. These apps encompass a myriad range of functionalities (Kylili et al., 2020; Alimoradi and Gao, 2021), including task management, health and fitness tracking, accessibility information, medication

management communication, mindfulness, navigation, mental wellbeing, assistance with daily activities, and more. This research hypothesized that.

H1. Smart city initiatives have a significant effect on accessibility enhancement in Saudi Arabia.

2.4 Inclusive information

An inclusive city is a place where everyone has the ability and empowerment to fully engage in the social, cultural, economic, and political opportunities that cities offer without any discrimination (Pineda and Corburn, 2020). In such environments, diversity is considered, and barriers and exclusions are dismantled for the benefit of all (Norman et al., 2007; Sullivan, 2012; Wu and Cheng, 2018; Al-Sarayrah et al., 2021). Discrimination prevails for everyone with disabilities, especially regarding mobility and accessing different urban infrastructures and services, including transportation, housing, clean water, health services, education, employment, and information technology. This discrimination leads to exclusion and results in rarer prospects for employment, education, or political participation. Individuals expelled due to conflicts or disasters may face more challenges, i.e., legal status, loss of assistive devices, trauma, assets, and jobs (Disability Inclusive and Accessible Urban Development, 2021).

Consequently, inclusive Information is the measures and practices within smart urban governance that assure impartial access to information and digital resources for all, including people with disabilities. It makes information and digital content easily obtainable and usable by everyone, irrespective of their disabilities or abilities (Więckowski et al., 2014; Al-Sarayrah et al., 2021). One considerable matter in smart cities revolves around encouraging digital inclusion, which relies on providing affordable and strong broadband connections. These accessibility devices serve user needs, promoting digital literacy, offering quality technical support, and creating online content that promotes self-sufficiency and participation. Despite existing research identifying the empowering possibility of digital technologies for the quality of life and social engagement of Persons with Disabilities (PwD), the significance of digital inclusion and equity remains relatively understood in the realm of urban governance (Kolotouchkina et al., 2022b). Thus, it is proposed that.

H2. Smart city initiatives have a significant effect on inclusive information in Saudi Arabia.

2.5 Health and wellbeing improvement

Health and Wellbeing Improvement is defined as the efforts and initiatives strived at improving the physical and mental health and the quality of life for individuals within urban environments, especially focusing on those with disabilities (Al-Sarayrah et al., 2021; Aina, 2017). This advancement encompasses different aspects, including access to healthcare services, supportive environments, and improving mental and emotional wellbeing (Pineda and Corburn, 2020). The process of smart cities needs significant changes to the foundational aspects of urban systems. These modifications target the structural components, i.e., physical infrastructure, social and political arrangements, technology, and operational aspects. The efforts to improve urban sustainability are transformative in speed and scale. For example, initiatives focused on developing neighborhood walking and cycling programs to encourage health benefits through increased physical activity and supporting the environmental benefits of low-carbon transportation have largely been limited in size and have only produced modest effects. While local adjustments to existing systems may be relatively easy to execute and are more readily accepted by city planners, they must catch up to the extensive, system-wide changes required for effective climate action (Bricout et al., 2021). Here, Badr (2023) cited an example of providing and ensuring equal healthcare opportunities to all. As noted, smart cities focus on overarching efforts to acquire rudimentary goals related to quality of life, sustainability, and productivity. Some well-developed smart city initiatives inadvertently aggravate inequality when lacking transparency, excluding community involvement, or overlooking residents' myriad needs and preferences. The basic conceptualization of smart cities can address persistent health disparities among individuals with certain disabilities (Sobnath et al., 2020). Prioritizing patient-centered preventive healthcare that handles their physical and mental wellbeing is crucial. Shifting smart city initiatives from a technology-centric strategy to one that is citizen-centric is critical, with a focus on engagement and inclusion (Neto, 2019). Thus, relying on the cited literature, it is proposed that.

H3. Smart city initiatives significantly affect health and wellbeing in Saudi Arabia.

3 Methodology

3.1 Research design

The methodology for this study involves a mixed-methods approach/design that combines qualitative and quantitative data collection and analysis methods. Notably, the mixed-method design used in this research presented several benefits by combining quantitative surveys and qualitative interviews; the research captured the breadth and depth of the phenomenon under investigation. The quantitative surveys allowed for systematically compiling data on different aspects of Smart City initiatives. On the other hand, the qualitative interviews with government officials offered insights into the decision-making processes and contextual factors shaping Smart City development in Saudi Arabia, improving the richness and depth of the analysis. Besides, integrating mixed-method approaches enabled triangulation, allowing researchers to corroborate findings across different data sources and techniques (Creswell, 1999). This strengthens the validity and reliability of the research findings by decreasing the potential for bias and increasing the credibility of the results. Also, the mixed-method approach allows for a more subtle understanding of complex phenomena, i.e., the interaction between policy decisions, technological innovations, and the lived

TABLE 1 Items and sources of measurement items.

Variables	Items	Sources	# Of items
Smart City Initiatives	Smart city initiatives in our community effectively use technology to improve efficiency and connectivity The transparency and accessibility of information regarding smart city projects and their influence within our community are satisfactory Smart city programs actively evaluate the myriad needs and preferences of our community Smart city initiatives prioritize sustainability and environmental concerns effectively in planning and execution	(Rosa et al., 2018; Jin et al., 2020).	04
Accessibility Enhancement	The enactment of accessibility features in our city effectively serves the needs of individuals with myriad abilities Information about our city's public spaces, infrastructure, and services is available to individuals with disabilities Smart city initiatives vigorously address and eradicate physical, institutional, and attitudinal barriers faced by individuals with disabilities The smart city initiatives in place adequately evaluate the accessibility needs of all community members, promoting inclusivity	(Suhaida et al., 2014; Więckowski et al., 2014; Al-Sarayrah et al., 2021)	04
Inclusive Information and Accessibility	The information provided by smart city services is designed to be easily understandable and usable by individuals with diverse abilities Digital content in our city is inclusive and accessible to individuals with different disabilities Smart city initiatives promote communication and interaction for individuals with sensory impairments, assuring their engagement in the digital landscape The smart city's commitment to inclusivity is mirrored in its efforts to make public information, services, and digital resources available to all community members	(T. Alam et al., 2021; Alzaed and Balabel, 2020)	04
Health and Wellbeing Improvement	The healthcare services provided in our smart city improve the physical and mental wellbeing of all residents Inclusive urban planning and infrastructure positively affect the health outcomes of individuals, including those with disabilities The smart city initiatives prioritize equivalent access to healthcare services, striving to reduce health disparities among diverse population segments Our smart city's efforts to create a health-focused environment positively impact the social and economic outcomes for individuals, families, and the wider community	(Sobnath et al., 2020; McMaughan et al., 2021)	04

experiences of individuals with disabilities in Smart City environments (Creswell and Clark, 2017).

3.2 Participant selection criteria

For the quantitative data collection phase of this study, respondents were selected based on specific criteria to ensure comprehensive representation and reliability of the survey results. Respondents included individuals with disabilities, and their families and caregivers, living in Saudi Arabia. This criterion ensured that the survey captured the perspectives and experiences of individuals directly affected by disabilities, and those closely associated with caregiving and support roles. Efforts were made to select respondents representing diverse demographic characteristics, including age, gender, and geographic location. This criterion aimed to ensure that the survey results were reflective of the diverse population of individuals with disabilities and their caregivers across different regions of Saudi Arabia. All selected respondents were needed to voluntarily participate in the survey, with informed consent obtained before data collection. This criterion maintained ethical standards of research conduct, respecting the autonomy and rights of the individuals involved and ensuring their willingness to share their perspectives and experiences. For the qualitative data collection phase of this study, participants were selected based on specific criteria to ensure the relevance and richness of the insights collected. Participants were selected from government officials specializing in smart city development, disability studies, and urban planning. This selection criterion strived to ensure that participants had relevant knowledge and expertise to provide insightful perspectives on the role of smart cities in improving the quality of life for people with disabilities in Saudi Arabia. Preference was given to participants actively involved in the planning, enactment, or oversight of smart city projects within Saudi Arabia. This criterion ensured that participants had firsthand experience and insights into the development and implementation of smart city initiatives, thereby increasing the qualitative data with practical insights and contextual understanding. All chosen participants were required to express willingness and consent to participate in the qualitative interviews. This criterion ensured voluntary participation and sustained ethical standards of informed consent, respecting the independence and rights of the individuals involved.

3.2.1 Data collection tools

Data is collected through surveys and semi-structured interviews (Summers, 2018; Habes et al., 2021). First, surveys and further interviews are conducted, indicating a sequential mixed-method approach. The quantitative data-gathering tool is developed by adopting different measurement items from different studies

TABLE 2 Interview questionnaire.

S/R	Questions	Codes
1	Can you provide insights into how smart city endeavors have affected the accessibility attributes in our city, especially in addressing the needs of individuals with disabilities?	C1,C2, C3
2	How do you consider smart city initiatives contribute to the inclusivity and accessibility of information in Saudi Arabia, specifically for individuals with disabilities?	C1,C2, C3
3	How do you consider smart city initiatives to impact the health and wellbeing of disabled people, including factors related to healthcare services, urban planning, and community wellbeing?	C1,C2, C3

based on a five-point Likert scale (See Table 1). The surveys are distributed to people with disabilities, their families, and caregivers to understand their experiences and perceptions of living in smart cities. Interviews are conducted with experts in smart cities, disability studies, and urban planning to gain insights into the potential benefits and challenges of smart city technologies for people with disabilities in Saudi Arabia. The interviews are based on three major questions, which further helped generate different themes. The questionnaire for the qualitative data gathering is given below in Table 2.

3.3 Study populations and sampling

Stratified sampling was employed for the quantitative phase of this study to ensure the representativeness and accuracy of the survey findings. Stratified sampling remained comparatively more precise and efficient compared to this study due to the known differences within the population (Acharya et al., 2013a). The relevant sampling method allowed for a more precise estimation of population parameters and decreased the possibility for sampling bias (Haute, 2021). As the quantitative population of current research involves people with disabilities, their families, and caregivers to understand their experiences and perceptions of living in smart cities, a sample of 427 respondents is selected. First, the sample size is determined by estimating population proportions. According to Acharya et al. (2013b), the relevant formula is often used when the researcher aims to estimate the proportion of a population with a certain characteristic or attribute. Thus, 384 respondents had a Z score of 1.96% and 0.05% margin error. However, rounding up the nearest whole number to ensure an acceptable sample size, the researchers arrived at a sample size of approximately 385 respondents. 427 responses are gathered during the given timeframe, providing a sufficiently large sample to estimate population proportions with a 95% confidence level and a margin of error of 5%.

In this regard, purposive sampling was used for the qualitative participants' selection to choose individuals having specific knowledge, expertise, and experience relevant to the research topic. Notably, purposive sampling allowed for the targeted selection of government officials with expertise in smart city development, disability studies, and urban planning. This approach ensured that participants had the requisite knowledge and insights to provide informed perspectives on the topic under study as suggested by Gentles (2019). Furthermore, selecting a qualitative sample size of four participants is based on the American Anthropological Association guidelines. Rusu Mocanau (2020) emphasizes that qualitative research focuses on capturing diverse perspectives and experiences rather than acquiring statistical generalizability. Small sample sizes can be sufficient for in-depth qualitative interviews, especially when the research aims to explore complex phenomena. Another important consideration for selecting a sample of four participants is based on a wider disagreement on the qualitive sample size. For instance, Ali et al. (2024) consider the sample size of 12–50 participants as sufficient and also applied in their own study. While, Morse (1995) argue that the number of participants does not involve any specific size rather, the research should gather more details with a few number of participants. Morse (1995) and some more researchers (See Fusch and Ness, 2015; Saunders et al., 2018) also encourage the authors to take some additional aspects under consideration including the nature of study, to ensure the richness of study. Creswell and Clark (2017) suggest a sample size of 10–30 participants for a grounded theory study. While, rule of thumb is also considered another consideration for the qualitative sample size selection, indicating a sample of 5–10 individuals sufficient for a study (Sarfo et al., 2021). Thus, the sample size in the current research is based on scope and complexity of the topic, focusing on the stakeholder's response to the smart cities' objectives and their usefulness for the disabled people, the sample size of four individuals is considered sufficient to provide in-depth details to avoid repetitions in gathered data and a limited sample size may provide in-depth insights.

3.4 Data gathering

The data is gathered by using KANTAR research services. KANTAR is one of the most popular research and data gathering services providers in the Gulf and Saudi Arabia, with its headquarters in Jeddah and Riyadh (KANTAR, 2022). The data is gathered by using the KANTAR online survey pool. They utilized their existing panel of respondents, comprised of individuals who have opted to participate in research studies. KANTAR's panels cover diverse demographics and geographic regions across Saudi Arabia, ensuring a representative sample for the study. The research team worked closely with KANTAR to specify the target population based on criteria such as age, gender, disability status, and geographic location. KANTAR then distributed the survey links to the panel members who met the specified criteria. Respondents received invitations to participate in the survey via email or other communication channels managed by KANTAR. They were provided information about the study objectives, confidentiality measures, and their rights as participants who chose to

participate. They also provided informed consent before completing the survey (from October 2023 to December 2023).

Further, the interviews are conducted through personal visits to the four government officials working at different positions in the country's strategy design and implementation of Smart City projects. The qualitative data was gathered from 6 December 2023, to 24 December 2023. For the qualitative phase of the study, participants were recruited through purposive sampling to ensure diversity and richness of perspectives. First, potential participants were identified based on their relevance to the research topic, professionals, and policymakers. Recruitment efforts involved directly approaching individuals who met the criteria through personal contacts, professional networks, and referrals from key informants. Participants were provided with information about the study objectives, their involvement, and the voluntary nature of participation. Those who expressed interest were screened to ensure they met the eligibility criteria and were willing to participate in in-depth interviews. Interviews were scheduled at mutually convenient times and locations, with provisions made for accommodations as needed to ensure accessibility for all participants.

3.5 Data analysis approaches

The collected data is analyzed using both qualitative and quantitative analysis techniques. Qualitative data is analyzed using thematic analysis, which specifies and generates specific themes that emerge from the acquired responses. Thematic analysis is conducted based on the steps highlighted by Braun and Clarke (2006). At the same time, quantitative analysis involves Partial Least Squares- Structural Equation Modelling. According to Nunkoo and Ramkissoon (2012), Partial Least Squares-Structural Equation Modeling (PLS-SEM) is especially relevant for research where the relationships between variables are complex and multidimensional. PLS-SEM allows researchers to model latent constructs and their relationships, even with small sample sizes, making it ideal for mixed-methods research designs with quantitative and qualitative data. Considering current research, PLS-SEM offers several advantages, including analyzing complex relationships between variables, accommodating measurement error and non-normal data distributions, and providing insights into the underlying mechanisms driving outcomes such as health outcomes and social inclusion among individuals with disabilities.

Thus, first, the study respondents' demographics are calculated. Analyzing the survey participants, it was found that most respondents were males, while 64.9 (were females (35.1%). Concerning the age groups, 22.7% of respondents were 18 years old or below, 48.7% were 19–30, 15.2% were 31–40, and 13.3% were 41 years old or above. Descriptives of respondents' education revealed that 41.5% have a Master's degree, 35.1% have a Bachelor's or below, 18.8% said they have a Doctorate, while 3.7% marked "Other." Finally, 62.1% of respondents revealed that they have physical disabilities, 29.7% indicated that they have Sensory Impaired Disorders, 4.2% indicated behavioral or emotional disability, and 4.7% said that they have developmental disability.

Further, the personal profiles of the interviewees indicated that one interviewee is working as an urban Planner and One as an Infrastructure Specialist. Two interviewees are working as Policy Analysts. Regarding the work location, three participants indicated they reside in Riyadh, while one lives in Jeddah. Finally, the participants with experience as Urban Planners have work experience of more than 7 years; Infrastructure Specialist has work experience of fewer than 5 years; Policy Analysts indicated their work experience of 16 years, and the Policy Analyst has less than 5 years of work experience. Table 3 provides a summary of study participants.

3.6 Data normality

As this research involves quantitative design, testing the data normality is crucial to affirm the application of parametric tests (Mishra et al., 2019). Thus, data normality is assessed by using the Kolmogorov-Smirnov and Shapiro-Wilk tests of normality. Results indicated that the significance value related to each sub-construct exceeds the significance value p 0.000, indicating that the data is not normally distributed. Thus, applying the parametric test will be suitable.

4 Data analysis and results

The quantitative data analysis involves two steps, using the sequential mixed-method approach. First, the quantitative data is analyzed using Partial Least Square-Structural Equation Modelling. Later, qualitative analysis is conducted. The first part involved analyzing the inner model and outer model as follows.

4.1 Inner model assessment

The inner model assessment systematically involved testing the validating and reliability of the research tool, also known as the measurement model. First, Confirmatory Factor Analysis (CFA) uses convergent validity, including construct reliability, model fit, and discriminant validity. Table 4 represents the results of convergent validity and construct reliability. First, it was found that most of the factor loading related to each item was higher than the threshold of 0.5. Besides, the Average Variance Extracted (AVE) also exceeds the threshold of 0.5 (Mello and Collins, 2001) (Smart City Initiatives 0.536, Accessibility Enhancement 0.519, Inclusive Information 0.693, and Health and Wellbeing Improvement 0.670). Regarding the construct reliability, the Cronbach Alpha values exceed the threshold 0.7 (Smart City Initiatives 0.787, Accessibility Enhancement 0.721, Inclusive Information 0.714, and Health and Wellbeing Improvement). Also, the composite reliability values exceeded the threshold of 0.7 (Bonett and Wright, 2015) (Smart City Initiatives 0.795, Accessibility Enhancement 0.704, Inclusive Information 0.721, and Health and Wellbeing Improvement 0.798).

As some items have lower factor loads, model fit is checked to ensure suitability for the final structural model. Thus, the items with lower loading values were removed, and the model fit was tested. Figure 2 represents the results of the model fit. Notably, while testing the model fit, some items still having values less than 0.5. However, these items are retained following existing studies (See Almarzouqi

TABLE 3 Demographics of qualitative study participants.

Participant code	Designation	Location	Work experience
Participant 1	Urban Planner	Riyadh	More than 7 years
Participant 2	Infrastructure Specialist	Riyadh	Less than 5 years
Participant 3	Policy Analyst	Jeddah	Sixteen years
Participant 4	Policy Analyst	Riyadh	Less than 5 years

TABLE 4 Confirmatory factor analysis.

Variable	Items	Loadings	AVE	CA	CR
Smart City Initiatives	SCI1	0.661	0.536	0.787	0.795
	SCI2	0.587			
	SCI3	0.669			
	SCI4	0.779			
Accessibility Enhancement	ACE1	0.616	0.519	0.721	0.704
	ACE2	0.189			
	ACE3	0.921			
	ACE4	0.329			
Inclusive Information	INFO1	0.037	0.693	0.714	0.721
	INFO2	0.314			
	INFO3	0.824			
	INFO4	0.007			
Health and Wellbeing Improvement	HWI1	0.317	0.670	0.782	0.798
	HWI2	0.038			
	HWI3	0.972			
	HWI4	0.559			

et al., 2022; Elareshi et al., 2022; Farhi et al., 2023; Habes et al., 2024; Youssef et al., 2024), in which, items with lowers loadings are retained and did not affect the structural model in the latter stage. After conducting a model fit test, it is evident that the loading values for key variables such as SCI1, SCI3, SCI4, ACE3, INFO3, and HWI3 surpass the commonly accepted threshold of 0.5. These loading values show the strength of the relationship between the observed variables and the basic constructs within our statistical model. With SCI1 at 0.655, SCI3 at 0.667, SCI4 at 0.785, ACE3 at 0.923, INFO3 at 0.830, and HWI3 at 1.048, it is appropriate to assume that the model shows promising compliance with the data. These values suggest that the variables effectively apprehend the characteristics of the constructs, contributing to a better model fit.

Thus, the Standardized Root Mean Square Residual (SRMR) values for both models are relatively low, with the saturated model having a slightly lower value (Saturated model: 0.130, Estimated model: 0.136) (Al-Maatouk et al., 2020), suggesting a better fit. Besides, both the d_ULS and d_G values, which measure the difference between observed and expected covariance matrices, are slightly lower for the saturated model (Saturated model: d_ULS = 1.323, d_G = 120.472; Estimated model: d_ULS = 1.438, d_G = 120.558) (Barrett, 2007), suggesting better fit. Regarding the chi-square values, both models have infinite values. This is typical for saturated models as they perfectly replicate the observed data, resulting in no degrees of freedom for chi-square calculation (Davcik, 2014).

4.2 Normality testing

The results from both the Kolmogorov-Smirnov and Shapiro-Wilk tests indicate the level of significance for assessing the normality of each variable as Table 5. Across most variables, the *p*-values obtained from both tests consistently exceed the conventional significance level of 0.05, suggesting that these variables adhere to a non-normal distribution. Thus, these findings show the normal distribution of data in the current research. Table 6 provides an overview of the second stage of normality testing after removing the lower loadings values and items.

Further, the discriminant validity is assessed using a two-step criterion, including Fornell-Larcker and Heterotrait-Monotrait

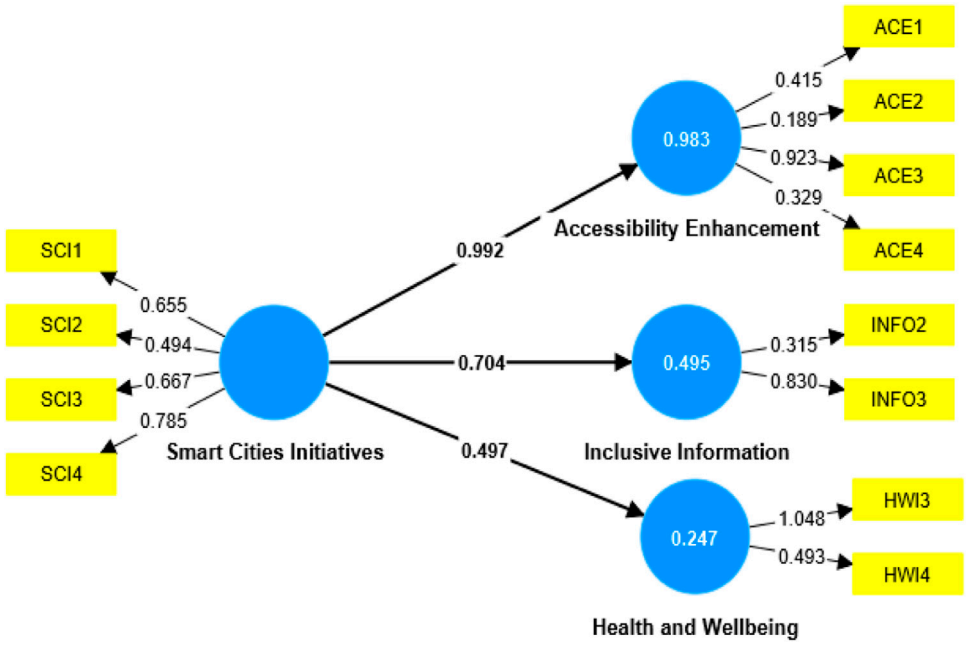

FIGURE 2
Final measurement model.

TABLE 5 Data normality testing.

	Kolmogorov-Smirnov[a]		Shapiro-Wilk	
	Statistics	Sign	Statistics	Sign
SCI1	0.223	0.540	0.862	0.327
SCI2	0.218	0.533	0.837	0.397
SCI3	0.296	0.519	0.772	0.426
SCI4	0.216	0.509	0.823	0.458
ACE1	0.192	0.460	0.869	0.297
ACE2	0.222	0.536	0.883	0.269
ACE3	0.216	.533	0.823	0.326
ACE4	0.276	0.530	0.839	0.213
INFO1	0.225	00.536	0.831	0.159
INFO2	0.212	0.536	0.858	0.263
INFO3	0.361	0.539	0.714	0.342
INFO4	0.191	0.526	0.866	0.454
HWI1	0.252	0.4097	0.837	0.412
HWI2	0.311	0.512	0.769	0.433
HWI3	0.261	0.464	0.813	0.216
HWI4	0.240	0.537	0.835	0.370

Scales, as suggested by Mello and Collins (2001). First, results using the Fornell-Larker criterion indicated no correlation between the study constructs. Besides, the HTMT values related to all study constructs also remained below the threshold value of 0.85 (Cheung and Wang, 2017). Thus, it is concluded that discriminant validity does exist in the current study. Table 7 and Table 8 represent the results of discriminant validity.

4.3 Outer model assessment

The inner model is further assessed to examine the potential of the independent construct and proposed effects of study variables. First, the predictive potential of the independent variable is tested to indicate its effectiveness. Later, the structural model is tested to assess the study hypotheses. First, assessing the predictive power of independent variables involves applying the coefficient of determination R^2 (Figueiredo Filho et al., 2011) and testing the effect size (f^2) (Samartha and Kodikal, 2018). Table 9 summarizes the results of both assessments. First, the R^2 value of Accessibility Enhancement is 0.983 (Adjusted R^2 0.983), the R^2 value of Inclusive Information is 0.247 (Adjusted R^2 0.246), and the R^2 value of Health and Wellbeing Improvement is 0.495 (Adjusted R^2 0.494). Concerning the effect size, the effect of Smart City Initiatives on Accessibility Enhancement is 58.313 (Large), the effect of Smart City Initiatives on Inclusive Information is 0.329 (Moderate), and the effect of Smart City Initiatives on Wellbeing Improvement is 0.981 (Large).

Concerning the study hypotheses, path analysis was used following an initial assessment of the predictive power and influence of the independent construct, which was in line with the methodology advocated by Streiner (2005). The examination mainly focused on the relationship between Smart City Initiatives and Accessibility Enhancement, as posited in the first hypothesis. The analysis results supported

TABLE 6 Results of Kolmogorov Smirnov and Shapiro-wilk tests.

	Kolmogorov-Smirnov[a]		Shapiro-Wilk	
	Statistic	Sig	Statistic	Sig
SCI1	0.223	0.647	0.862	0.256
SCI2	0.218	0.254	0.837	0.224
SCI3	0.296	0.963	0.772	0.224
SCI4	0.216	0.141	0.823	0.281
ACE1	0.192	0.634	0.869	0.219
ACE2	0.222	0.565	0.883	0.186
ACE3	0.216	0.733	0.562	0.229
ACE4	0.276	0.614	0.237	0.241
INFO2	0.212	0.736	0.261	0.276
INFO3	0.361	.296	0.558	0.478
HWI3	0.261	.216	0.714	0.327
HWI4	0.240	.192	0.413	0.573

this hypothesis robustly, with a considerable beta coefficient (β) value of 0.992, indicating a substantial positive effect of Smart City Initiatives on Accessibility Enhancement. Also, the significance value of 0.000 ($p < 0.000$) and a high t-value of 26.061 underscored this relationship's statistical significance and strength. These findings align closely with the study's objectives, suggesting that Smart City Initiatives indeed play a significant role in improving urban accessibility, a key focus of the research.

Further, the analysis expanded to examining the impact of Smart City Initiatives on other constructs outlined in the study, including those proposed in the second and third hypotheses as Figure 3 shweng Results of structural model analysis. The results indicated significant support for both hypotheses, highlighting the broader influence of Smart City Initiatives beyond mere accessibility enhancement. Especially the beta coefficient value (β) of 0.704 for the second hypothesis, coupled with a significance value of 0.000 ($p < 0.000$) and a substantial t-value of 14.972, highlighted the notable effect size of these initiatives on the related construct. The third hypothesis also acquired significant support, with a beta coefficient value (β) of 0.497, a significance value of 0.000 ($p < 0.000$), and a t-value of 20.730, indicating a significant positive impact of Smart City Initiatives on the outcome under consideration. These results affirm the initial hypotheses and provide practical empirical insights into the broad-ranging benefits of Smart City Initiatives in urban development and enhancement initiatives. Table 10 represents the results of hypothesis testing.

4.4 Qualitative data analysis

This section discussed the qualitative data gathered from government officials through their semi-structured interviews. As this research involves three primary questions, further themes are generated based on analyzing each answer. Table 11 provides the overview of themes and codes applied in the current research. It is notable that, The selection of interview participants was guided by the principle of purposive sampling, which involved selecting individuals with precise expertise and experience relevant to the research topic. Government officials specializing in smart city development, disability studies, and urban planning were identified as key informants due to their firsthand involvement in shaping policies and initiatives related to smart cities and disability inclusion in Saudi Arabia. The decision to include four participants in the qualitative interviews was informed by the concept of data saturation, as additional interviews cease to yield new information or insights relevant to the research objectives. Existing research supports the idea that data saturation can often be completed with a relatively small sample size in qualitative studies, especially when the aim is to capture diverse perspectives rather than achieve statistical generalizability. Studies by Guest et al. (2017) and Saunders et al. (2018) have shown that data saturation can generally be acquired within the range of three to six interviews, especially when participants possess specialized knowledge and experiences relevant to the research topic. Also, the qualitative aspect of the study allowed for in-depth exploration of participants' perspectives, thereby mitigating the need for a large sample size.

4.4.1 Insights regarding smart city endeavors have affected accessibility, especially in addressing the needs of individuals with disabilities

The first qualitative question was, "Can you provide insights into how smart city endeavors have affected the accessibility attributes in our city, especially in addressing the needs of individuals with disabilities?". According to Bricout et al. (2021), urban planning for accessibility holds critical importance in promoting an inclusive and unbiased environment for individuals with disabilities. This approach ensures that urban spaces are thoughtfully planned to cater to the diverse needs of the disabled population, encouraging autonomy, mobility, and a sense of belonging within the community. Thorough urban planning considers the enactment of accessible infrastructure to eliminate certain barriers. Thus, analyzing the obtained responses further led to the generalization of two primary themes indicating technology integration and inclusive design and community engagement as prevalent.

4.4.1.1 Theme 1- technology integration for accessibility

Regarding the first question, the participant, who is an urban planner with more than 7 years of experience, revealed that.

> "With my extensive experience as an Urban planner in the smart city initiatives in Saudi Arabia, I have witnessed accessibility for people with disabilities. As advanced technologies are used, we have incorporated features like smart traffic control, sensor-equipped pedestrian crossings, accessible public transportation, and many others. We have designed these to improve mobility and convenience for people with disabilities, confirming that they can steer the city more easily."

TABLE 7 Fornel-Larcker criterion.

	Accessibility enhancement	Health and Wellbeing	Inclusive information	Smart cities initiatives
Accessibility Enhancement	0.54			
Health and Wellbeing	0.413	0.819		
Inclusive Information	0.597	0.65	0.628	
Smart Cities Initiatives	0.992	0.497	0.704	0.658

TABLE 8 Hetreotrait-Monotrait Ratio.

Hetreotrait-monotrait ratio	HTMT
Health and Wellbeing <-> Accessibility Enhancement	0.524
Inclusive Information <-> Accessibility Enhancement	0.014
Inclusive Information <-> Health and Wellbeing	0.609
Smart City Initiatives <-> Accessibility Enhancement	0.209
Smart City Initiatives <-> Health and Wellbeing	0.546
Smart City Initiatives <-> Inclusive Information	0.302

According to participant 2 from Riyadh City.

> "As an Infrastructure Specialist, I have been executing cutting-edge technologies to enhance accessibility. Smart applications provide real-time information on accessible routes, parking spaces, and public facilities. We have designed these applications to be user-friendly for individuals with disabilities, including features like voice commands and intuitive interfaces. Also, smart sensors and IoT devices are placed to monitor and improve accessibility, ensuring a friendly experience for everyone."

4.4.1.2 Theme 2- inclusive design and community engagement

Concerning the second theme, "inclusive design and community engagement," participants 3 and 4 highlighted the importance of inclusive urban planning and design. For instance, Participant 3 argued that.

> "I have been functional in ensuring that our smart city schemes prioritize inclusivity through comprehensive community engagement. Regular meetings and workshops involving individuals with disabilities are conducted to understand their precise needs and challenges. This community input directs the enactment of inclusive design principles in public spaces, confirming that smart city developments are not only technologically developed but also socially inclusive."

While participant 4 said that.

> " As a Policy Analyst focusing on Riyadh, I am critical in establishing and implementing guidelines to ensure accessibility adherence in all smart city projects. This includes implementing universal design standards in new constructions and retrofitting existing infrastructure to fulfill accessibility criteria. By implanting accessibility prerequisites in our policies, we ensure that smart city developments meet the highest standards of inclusivity."

4.4.2 Smart city initiatives impact the health and wellbeing of disabled people, including factors related to healthcare services, urban planning, and community wellbeing

Disability Inclusive and Accessible Urban Development (2021) argued that integrating smart technologies within comprehensive urban planning is key to improving accessibility. Real-time information systems, smart traffic management, and others contribute to a seamless and efficient experience for people with disabilities. Accessible public transportation services, guided by intelligent solutions, further help disabled individuals to navigate with greater ease, decreasing dependency on traditional modes of transportation. Three themes are generated based on the relevant premises, including inclusive planning for health, technology in healthcare services, and policy framework for inclusivity and wellbeing.

4.4.2.1 Theme 1- inclusive planning for health

First, a theme that emerged from the impacts of smart city initiatives is the inclusive planning for healthcare services, including disabled people. Participants indicated equal facilities for all accompanied by modern technology. According to participant 1.

> "Smart city initiatives have a deep influence on the health and wellbeing of disabled people. Through strategic urban planning, we have designed accessible and inclusive public spaces that contribute to enhanced community wellbeing. Besides, smart technologies enable better healthcare services by allowing remote health monitoring and swift emergency response systems, providing a more holistic strategy for the health of disabled residents."

Participant 4 further added that.

> "I've seen the direct result of smart city initiatives on the health of disabled individuals. Our policies prioritize integrating technology in healthcare assistance, ensuring accessibility and efficiency. Our urban planning guidelines implement creating green spaces and recreational areas, contributing to the general wellbeing of disabled citizens by encouraging a healthier and more engaging community environment."

4.4.2.2 Theme 2- technology in healthcare services

The second sub-theme from the gathered data is integrating technology into current healthcare services. It was found that this implementation is aimed at improving overall healthcare services. For instance, participant 2 opined that.

> "I've seen the transformative impact of smart city initiatives on the health of disabled individuals. The enactment of smart infrastructure, such as sensor-equipped healthcare structures and real-time monitoring systems, improves access to healthcare services. Again, urban planning considers the precise needs of disabled individuals, encouraging a healthier and more supportive environment for all citizens".

4.4.2.3 Theme 3- policy framework for inclusivity and wellbeing

Furthermore, the third theme generated from the gathered responses is the focus on policy development and wellbeing as a priority of smart city initiatives. According to participant 3.

> "From a policy standpoint, smart city initiatives have positively affected the health and wellbeing of disabled people. Our focus on inclusive approaches has enhanced accessibility in healthcare services and public spaces. Further, community wellbeing is addressed through policies that encourage social inclusivity and support networks, confirming that disabled individuals have equivalent opportunities for a healthy and fulfilling life."

4.4.3 Can you provide insights into how smart city endeavors have affected the accessibility attributes in our city, especially in addressing the needs of individuals with disabilities?

Finally, the last question focused on examining the participants' insights regarding the potential effect of smart city initiatives to address the special needs of disabled people. The responses indicated that two primary themes emerged from them, including comprehensive urban planning for accessibility and a policy framework for inclusive development.

4.4.3.1 Theme 1- comprehensive urban planning for accessibility

The first theme from the last question highlighted the design and implementation of strategies focusing on comprehensive urban planning for accessibility. According to Apostolidou and Fokaides (2023), a robust policy framework for inclusive urban development is critical in supporting the rights and wellbeing of individuals with disabilities within a society. Such frameworks provide that accessibility is an aspiration and a legally required and actively implemented aspect of urban development. By integrating universal design principles, policies create an environment where disabled people can partake fully in civic life, contributing to a more fair and cohesive society. The participant indicated the incorporation of smart structures and accessibility landscapes as their priority. For example, participant 1 argued that.

> "Smart city endeavors have greatly changed the accessibility landscape of our city, particularly for individuals with disabilities. Through detailed urban planning, we have included accessible infrastructure such as ramped sidewalks, tactile paving, and inclusive public areas. Further, using smart technologies has enabled real-time information on accessible ways and improved public transportation services, guaranteeing that individuals with disabilities can wander the city with greater comfort and independence."

Participant 2 also argued that.

> "Working as an Infrastructure Specialist, I have seen the discernible effect of smart city initiatives on accessibility. The enactment of smart infrastructure, including sensor-equipped traffic lights and pedestrian crossings, has improved safety and amenities for individuals with disabilities. Furthermore, smart applications provide real-time information on accessible facilities, contributing to a better inclusive urban environment."

4.4.3.2 Theme 2- policy framework for inclusive development

The second theme from the data highlighted the policy framework for inclusive development, particularly for disabled people. According to participant 3.

> "From a policy stance, smart city initiatives have brought about extensive changes to address the needs of people with disabilities. Our policy framework now mandates universal design principles in all new developments and modifications of existing infrastructure. This commitment guarantees that accessibility is not an afterthought but an essential part of every smart city project, promoting a more inclusive and equitable city for everyone regardless of discrimination."

Participant 4 also argued that.

> "I have been actively concerned with shaping the regulatory framework to improve accessibility. Smart city initiatives have established guidelines prioritizing accessibility in public spaces, buildings, and transportation. By implanting these requirements in our policies, we focus on addressing the precise needs of individuals with disabilities in every aspect of urban development."

5 Discussion on results

Smart cities can significantly enhance social and economic results for individuals with diverse disabilities, their families, and their wider communities. The growing focus on building cities and societies that acknowledge human diversity, social inclusion, and equality is important for promoting a truly inclusive and sustainable future for all (Zubizarreta et al., 2016). Urbanization, in this context, presents prospects for social inclusion, impartial access to services and livelihoods, and the employment and mobilization of formerly marginalized populations (Rosa et al., 2018; Amran et al., 2020; De Guimarães et al., 2020; Jin et al., 2020; Al-Sarayrah et al., 2021). It is also possible to design a motivating environment that accurately mirrors how urban inhabitants access their communities and lead their lives (Alimoradi and Gao, 2021).

Thus, the research problem focused on assessing the effect of smart city initiatives on the accessibility, inclusivity, and

TABLE 9 Coefficient of Determination R^2 and Effect Size f^2 Measurements.

Independent variable	Dependent Variables	R-Square	R-Square adjusted	f^2	Effect size
Smart City Initiatives	Accessibility Enhancement	0.983	0.983	58.313	Large
Smart City Initiatives	Inclusive Information	0.247	0.246	0.329	Moderate
Smart City Initiatives	Health and Wellbeing Improvement	0.495	0.494	0.981	Large

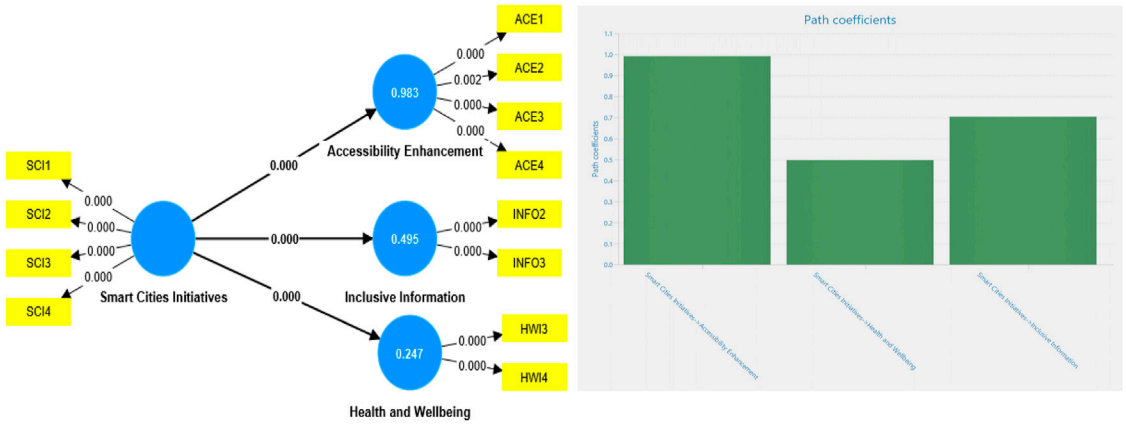

FIGURE 3
Results of structural model analysis.

wellbeing of individuals with disabilities in Saudi Arabia. The research objectives guiding this investigation were systematically addressed through a mixed-methods technique involving structured surveys, semi-structured interviews, and data analysis. Starting with the general perspectives, the study indicated that smart city initiatives significantly improve accessibility for individuals with disabilities. According to the survey respondents, smart city initiatives effectively use technology to provide the best services. They also considered transparency and accessibility of information concerning smart city projects to be satisfactory to them. Survey respondents also indicated that smart city programs actively evaluate their community's various needs and preferences. Besides, these initiatives prioritize sustainability and environmental concerns while executing the initiative. A similar stance is witnessed by using social disability model regarding smart cities. Retief and Letšosa (2018) note that smart city initiatives invest in accessible infrastructure and provide real-time information on accessible routes and transportation options through mobile apps. They also contain assistive technologies like audio signals for the visually impaired and prioritize their needs in emergency response systems. By gathering data on how people with disabilities use public services, smart cities can make informed decisions to assure equal access and create more inclusive communities where everyone can prosper. Talking about the study hypothesis, the first assumption is that "Smart city initiatives have a significant effect on accessibility enhancement in Saudi Arabia." The respondents revealed that integrating accessibility features effectively serves the needs of disabled people. These features ensure that information about our city's public spaces, infrastructure, and services is available to individuals with disabilities. Respondents also agreed that smart city initiatives vigorously address and eradicate physical, institutional, and attitudinal barriers faced by individuals with disabilities. Also, the smart city initiatives in place adequately evaluate the accessibility needs of all community members, promoting inclusivity. Notably, the social disability model emphasizes that disability is not solely a result of individual impairments but is also influenced by societal barriers; in this model, the focus shifts from improving the individual to addressing the social and environmental factors that hinder their full participation in society. Smart cities further use technology to improve urban living, including accessibility. By incorporating the principles of the social disability model into smart city initiatives, accessibility is significantly enhanced. Burholt et al. (2017) noted that smart cities can use data-driven approaches to identify areas for improvement in accessibility and prioritize resources accordingly. By collecting and analyzing data on the usage of public services by people with disabilities, policymakers can make informed decisions to enhance accessibility across various domains. Also, community engagement platforms facilitated by smart city initiatives can empower individuals with disabilities to voice their concerns and actively participate in decision-making processes related to urban planning and development. Through these efforts, smart cities can serve as models of inclusive and accessible environments

TABLE 10 Hypotheses testing (path analysis and regression weights).

Relationships	*M*	*SD*	*t*	*β*	*P*	95% confidence interval	
						2.5%	97.5%
Smart City Initiatives → Accessibility Enhancement	0.992	0.077	26.061	0.992	0.000	0.927	1.071
Smart City Initiatives → Inclusive Information	0.704	0.627	14.972	0.704	0.000	0.481	0.866
Smart City Initiatives → Health and Wellbeing Improvement	0.497	0.573	20.730	0.497	0.000	0.329	0.632

TABLE 11 Themes and codes in the qualitative data.

Questions	Themes	Codes
Can you provide insights into how smart city endeavors have affected the accessibility attributes in our city, especially in addressing the needs of individuals with disabilities?	Technology Integration for Accessibility	C1 C2
	Inclusive Design and Community Engagement	
How do you consider smart city initiatives to impact the health and wellbeing of disabled people, including factors related to healthcare services, urban planning, and community wellbeing?	Inclusive Planning for Health	C1,C2,C3
	Technology in Healthcare Services	
	Policy framework for Inclusivity and wellbeing	
Can you provide insights into how smart city endeavors have affected the accessibility attributes in our city, especially in addressing the needs of individuals with disabilities?	Comprehensive Urban Planning for Accessibility	C1, C2
	Policy Framework for Inclusive Development	

where everyone can fully participate in society and enjoy equal opportunities and services regardless of their abilities. Qualitative participants, on the other hand, argued that they ensure the effective implementation of smart city initiatives to ensure the equal distribution of facilities, including disabled people. They further cited an example of several features designed and implemented to ensure design principles. This community input directs the enactment of inclusive design principles in public spaces, confirming that smart city developments are not only technologically developed but also socially inclusive. The purpose of their implementation is based on mobility and ease for disabled people; they may further cater to their certain needs. These results are consistent with the existing literature on smart cities and urban planning and development in different countries, including Poland and Spain (Alpopi, 2016; Capra, 2016), particularly for disabled people. As noted by Kempin Reuter (2019), the concept that the city should be accessible to all residents, as articulated in the universal Declaration of Human Rights and the New Urban Agenda, is commonly known as the "right to the city" or "rights in the city." Focusing on the case of individuals with disabilities, aligning urban development and planning with established human rights standards is of greater significance. Notably, a truly inclusive urban environment, upholding the right to the city, can only be accomplished through a collaborative urban design process involving multiple stakeholders and careful consideration.

Similarly, the second study hypothesis is "Smart city initiatives have a significant effect on inclusive information in Saudi Arabia." Regarding the social disability model and inclusivity, it is crucial to consider that information should be presented in multiple formats to accommodate different needs. For instance, providing written information alongside audio descriptions or sign language interpretation can cater to individuals with visual or hearing impairments (Connors and Stalker, 2014). Also, ensuring that digital platforms and communication channels are designed with accessibility features, i.e., screen readers, resizable text, and keyboard navigation, can facilitate access for individuals with diverse abilities. Besides, inclusive information entails considering the diverse needs and preferences of disabled individuals. This includes providing information in multiple languages, considering cultural sensitivities, and offering personalized support where required (Levitt, 2017). Collaborating with disability advocacy groups and consulting directly with disabled individuals can also ensure that information is designed to their specific needs and preferences. However, it is notable that inclusive information goes beyond just accessibility and encompasses the content. Information should be relevant, accurate, and comprehensive to empower disabled individuals to make informed decisions and actively participate in society. This may involve providing resources on disability rights, accessible healthcare services, educational opportunities, employment support, and social inclusion initiatives (Smith and Bundon, 2018). The survey respondents also agreed that integrating accessibility features can serve the needs of disabled people. Also, information about public spaces, services, and

infrastructure is available for disabled people. According to the respondents, smart city initiatives vigorously address and eradicate physical, institutional, and attitudinal barriers faced by individuals with disabilities and evaluate the accessibility needs of all community members, promoting inclusivity. Consistent with the survey responses, the interview participants also highlighted the positive effect of smart city initiatives on the health and wellbeing of disabled individuals. Urban planning, driven by smart technology, creates available and inclusive public spaces, contributing to improved community wellbeing. According to the participant, integrating smart technologies improved healthcare services, including remote health monitoring and emergency response systems. Policies prioritize technology in healthcare assistance, assuring accessibility and efficiency. Participants also highlighted the transformative effect of smart infrastructure, i.e., sensor-equipped healthcare structures and real-time monitoring systems, on the health of disabled individuals. The general agreement is that smart city initiatives positively affect the health and wellbeing of disabled people through inclusive approaches, improved accessibility, and supportive policies. Existing literature on smart cities and urban development also indicates that technology corporations provide improved services, ensuring sustainable development for the people without any discrimination (Komninos et al., 2019; Oh, 2020). According to Mohanty and Choppali (2016), smart city initiatives highlight a citizen-centric approach to smart city initiatives, emphasizing the importance of citizens' equal involvement in enacting smart city projects, integrating planning, management, and stewardship. Also, the provision of sustainable smart city services to address citizens' needs and improve their overall quality of life. Today, there is an increased emphasis on integrating citizen and community inputs in the planning and designing of smart cities' physical environments, i.e., appointing community-level services.

Finally, the third hypothesis proposed that "Smart city initiatives have a significant effect on health and wellbeing improvement in Saudi Arabia." Regarding the social disability model, improving health and wellbeing for disabled individuals involves addressing systemic obstacles that hinder access to healthcare services, facilities, and resources. This includes guaranteeing that healthcare facilities are physically accessible, staff are trained to provide inclusive care, and medical equipment accommodates diverse needs. Also, healthcare policies and programs should be designed with input from disabled individuals to address their specific health concerns and promote preventive care and early intervention (Sobnath et al., 2020). According to Andrews (2017), promoting the social inclusion of disabled individuals is crucial for their overall health and wellbeing. This involves creating opportunities for participation in social, recreational, and community activities and ensuring access to education, employment, and housing. Social support networks play a critical role in promoting mental health and reducing feelings of isolation and loneliness among disabled individuals. Bailey et al. (2015) stated that empowering disabled individuals to advocate for their health and wellbeing is essential within the social disability model. This includes providing access to information and resources on disability rights, self-care, and community support services. Besides, promoting partnerships between disabled individuals, healthcare providers, policymakers, and community organizations can facilitate collaboration in addressing health disparities and promoting inclusive practices. The study respondents agreed that the healthcare services provided in our smart city contribute to improving all residents' physical and mental wellbeing.

According to them, inclusive urban planning and infrastructure positively affect the health outcomes of individuals, including those with disabilities. Besides, the smart city initiatives prioritize equivalent access to healthcare services, striving to reduce health disparities among diverse population segments. Finally, respondents indicated that our smart city's efforts to create a health-focused environment positively impact the social and economic outcomes for individuals, families, and the wider community. In this regard, participants emphasized the transformative effect of smart city initiatives on urban accessibility, particularly for people with disabilities. Precise urban planning, incorporating accessible infrastructure, has significantly improved the city's accessibility landscape. Integrating smart technologies provides real-time information on accessible facilities and enhances public transportation services. These measures ensure that individuals with disabilities can comfortably steer the city.

Further, participants highlighted the substantial changes brought about by smart city initiatives in addressing the needs of people with disabilities through a policy framework for inclusive development. The policy requires incorporating universal design principles in all new developments and transformations of existing infrastructure, making accessibility a critical aspect of every smart city project. According to Sánchez-Corcuera (2019), such commitments seek to foster a more inclusive and equitable city, confirming that accessibility is a fundamental consideration in public spaces, buildings, and transport. Establishing guidelines and provisions within these policies echoes a sustained focus on addressing the specific needs of individuals with disabilities across different aspects of urban development.

5.1 Study implications

Integrating the Social Disability Model within this study has significant implications for readers, policymakers, and urban planners. The results highlight the transformative possibility of extensive urban planning and policy frameworks in promoting inclusivity and enhancing the lives of people with disabilities. First, the focus on Technology Integration for Accessibility mirrors a paradigm transformation in urban planning, where smart technologies play a key role in building a more accessible environment. This not only improves the physical accessibility of urban spaces for individuals with disabilities but also represents a wider societal commitment to leveraging technology for the usefulness of all citizens. The adoption of smart traffic control, sensor-equipped pedestrian crossings, and accessible public transportation echoes a commitment to independence and mobility, aligning with the principles of the Social Disability Model. Also, the theme "Inclusive Design and Community Engagement" indicates a move towards a more participatory and empathetic strategy

for urban planning. The engagement of individuals with disabilities in periodic meetings and workshops shows a commitment to comprehending their unique needs and challenges. By incorporating community input into the planning process, smart city developments are technologically progressive and socially inclusive, supporting the significance of community engagement in achieving true inclusivity. The effect on the health and wellbeing of disabled individuals, as emphasized through Inclusive Planning for Health and Technology in Healthcare Services, provides a holistic approach to smart city initiatives. Technology integration in healthcare services, including remote health monitoring and smart infrastructure, glances at a commitment to enhancing overall wellbeing. Besides, the emphasis on policy frameworks for inclusivity and wellbeing reinforces the idea that accessibility and health are both technological considerations and critical components of a complete policy approach. This approach aligns with the Social Disability Model, which highlights societal and structural factors affecting the experiences of individuals with disabilities.

5.2 Policy implications

The results of this study hold some policy implications for the development and enactment of Smart City projects in Saudi Arabia. First, the study emphasizes the significance of assuring Smart City initiatives prioritize accessibility and inclusivity for people with disabilities. Policymakers should consider incorporating universal design principles into urban planning and infrastructure development to guarantee that Smart Cities are accessible to all individuals, regardless of their physical or cognitive abilities.

Further, the study highlights the need for government agencies involved in Smart City projects to team closely with relevant stakeholders, including disability advocacy groups and organizations. By engaging with individuals with disabilities and integrating their perspectives and feedback into the planning and implementation process, policymakers can better address this population's precise needs and requirements. Besides, this study suggests the significance of establishing clear guidelines and regulations regarding accessibility standards in Smart City development. Policymakers should consider implementing solid regulatory frameworks that mandate the inclusion of accessibility features in all Smart City infrastructure projects. This could include prerequisites for accessible transportation systems, public buildings, digital technologies, and communication platforms. Finally, this research emphasizes the significance of ongoing monitoring and evaluation mechanisms to assess the effectiveness and impact of Smart City initiatives on the quality of life for people with disabilities. Policymakers should prioritize gathering data on accessibility metrics and indicators to track progress over time and identify areas for improvement. By regularly monitoring the implementation of accessibility measures and addressing any shortcomings, policymakers can ensure that Smart Cities truly enhance the quality of life for all residents, including those with disabilities.

6 Conclusion

Smart city initiatives play a key role in modern urban development, presenting various advantages beyond technological innovation. Particularly in the Saudi Arabian context, these initiatives hold precise significance as the country continues to experience rapid urbanization and adopts digital transformation. The importance of smart city initiatives in Saudi Arabia lies in their prospect to improve efficiency, sustainability, and the overall quality of life for all citizens. For people with disabilities, the effect of smart city initiatives is mainly profound. These initiatives contribute to creating inclusive urban spaces, assuring that the needs of disabled individuals are prioritized in the design and implementation of various projects. As societal norms and urban infrastructure are growing rapidly in Saudi Arabia, the significance of smart city initiatives for disabled individuals cannot be denied. By comprising inclusive design principles and leveraging technology, these initiatives can break down deterrents, promote autonomy, and promote a sense of belonging within the disabled community. The transformative effect on health and wellbeing, as evidenced by improved healthcare services and inclusive urban planning, highlights the role of smart city initiatives in developing a more unbiased and supportive environment.

6.1 Study limitations and recommendations

Although this research is based on extensive data gathering and conceptualizations, it has some primary limitations. First, the generalizability and scope of this research are focused on Saudi Arabia. Future researchers can overcome this limitation by replicating and conducting this research in other regions. The second limitation involves involving individuals with diverse disabilities. At the same time, it is assumed that focusing on any particular disability can provide further insights. To counteract this limitation, researchers can specify the types of disabilities and further analyze the smart city initiatives and their effectiveness. The third limitation involves analyzing the effect of smart city initiatives on only three factors while existing literature witnessed other factors that were also affected by these endeavors. Scrutinizing the relevant effect of the other different factors can provide an in-depth insight into broader policy implications and action plans. The fourth limitation involves the potential for sample bias in the quantitative surveys. Since the surveys are conducted using a five-point Likert scale, the responses may be affected by individual perceptions and biases.

Participants may interpret the survey questions differently, leading to variations in responses that may not accurately mirror the broader population of people with disabilities in Saudi Arabia. Another limitation relates to the qualitative interviews with government officials. While interviewing government officials provides practical insights into the strategy design and enactment of Smart City projects in Saudi Arabia, there is a risk of bias in the collected data. Government officials may have vested interests or constraints influencing their interview perspectives and responses. Finally, the use of Partial Least Squares Structural Equation Modeling (PLS-SEM) for analyzing the quantitative data may have limitations. While PLS-SEM is suitable for exploring complex relationships between variables in small sample sizes, it

may not provide as robust results as other statistical methods, i.e., covariance-based SEM, especially with larger datasets. The interpretation of the structural model and the validity of the results depends heavily on the quality and reliability of the data input, including the measurement model and the relationships specified in the model.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Author contributions

RA: Writing–original draft. MH: Data curation, Writing–original draft. AhA: Project administration, Writing–original draft, Writing–review and editing. AmA: Conceptualization, Supervision, Writing–original draft. RA: Conceptualization, Project administration, Supervision, Writing–original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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