

Artificial Intelligence Role in Promoting Saudi Arabia's Smart Cities: Addressing SDGs for Socio-Cultural Challenges

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The study explores the use of artificial intelligence (AI) to address socio-cultural challenges in Saudi Arabia while promoting Sustainable Development Goals (SDGs). Using a structured narrative review method with a critical approach, the study highlights AI's versatility in analyzing complex social phenomena, understanding human behavior, and optimizing urban infrastructure. With its unique socio-cultural challenges, Saudi Arabia aims for sustainable development through Saudi Vision 2030 and various smart city projects, emphasizing the importance of addressing challenges like gender equality, cultural preservation, an increasing youth population, rapid urbanization, and climate change.

The study identifies ten AI applications and models to address these challenges and promote relevant SDGs across six areas: Predictive Analytics and Forecasting, Optimization and Decision Support, Natural Language Processing, Computer Vision, Generative AI, and Geospatial AI. These AI models can help address issues like gender equality, youth education, and employment, as well as optimize water management, energy use, and urban planning to address rapid urbanization and climate change challenges.

By aligning AI development with the goals outlined in the SDGs, Saudi Arabia can unlock the potential of AI to create sustainable, resilient, and inclusive smart cities that effectively address

socio-cultural challenges. However, the study emphasizes the necessity of customizing AI applications in smart cities based on Saudi Arabia's religious and cultural values to ensure ethical and culturally sensitive implementations. The findings of this study hold relevance not only for Saudi Arabia but also for other countries facing similar challenges. The study provides practical recommendations for policymakers, urban planners, and technology experts to leverage AI effectively for sustainable development. It also outlines future research directions to address the limitations identified, such as exploring implementation challenges and ethical considerations.

Keywords: AI; SDGs; Socio-cultural challenges; Smart Cities; Saudi Arabia; Saudi Vision 2030; NEOM

Introduction

Artificial Intelligence (AI) has significantly impacted social and urban sciences, analyzing social phenomena and optimizing urban infrastructure (Karimi et al., 2024). It is also instrumental in urban planning, resource allocation, and urban infrastructure optimization (Adibhesami et al., 2024). AI is widely acknowledged as a valuable tool for effectively implementing and enhancing sustainable development goals (SDGs) (Mashhood et al., 2023). Implementing SDGs can create jobs, increase income levels, provide innovative solutions, improve infrastructure productivity, provide quality services like education and healthcare, promote economic growth, generate knowledge centers, strengthen social and cultural vibration, and improve living standards (Dhanraj et al., 2023; Gómez-Villarino, Briz, 2022). AI has the potential to enhance sustainability in communities and cities while maximizing positive impact (Mashhood et al., 2023). Research indicates that AI can expedite progress toward the United Nations' SDGs, promoting sectors such as environmental monitoring, energy efficiency, climate change mitigation, and healthcare (M. Yadav, Singh, 2023). However, a careful, ethical, and systematic approach to AI technology development and integration is required to harness this potential (Chen et al., 2023).

"Smart cities" refer to urban areas that leverage digital technologies and data analytics to enhance the quality of life for residents, optimize resource management, and ensure sustainable development (Kondepudi, Kondepudi, 2018). AI encompasses a range of technologies that enable machines to perform tasks that typically require human intelligence, such as learning, reasoning, problem-solving, and decision-making. In this study, AI is presented as a tool that supports the achievement of SDGs by providing innovative solutions to socio-cultural challenges (Ziesche et al., 2023).

Therefore, AI can be introduced as a suitable tool to strengthen the SDGs in a particular society, which will lead to solving the socio-cultural problems of that society. Saudi Arabia is one of the countries that is rapidly modernizing and struggling with various socio-cultural challenges. By implementing the Saudi Arabia 2030 vision for sustainable development, Saudi Arabia has taken essential steps to create a sustainable society (Al-nasser, Musallat, 2022; Balabel, Alwetaishi, 2021). In addition, various smart city projects such as NEOM and Visionary Downtown Riyadh increase the intelligence and sustainability of Saudi communities. NEOM is a groundbreaking urban development project in Saudi Arabia, aimed at creating a futuristic city that integrates advanced technolo-

gies and sustainable living. AI is used in NEOM for infrastructure management, cyber security, and education (Alismail, Faridi, 2021; DARRAJ, 2019). At the same time, Saudi Arabia is facing challenges such as rapid urbanization, a growing young population, and demand for sustainable growth, public facilities, housing, and infrastructure (Abubakar, Aina, 2018; B. S. Alotaibi et al., 2024). Furthermore, In Saudi Arabia, various case studies highlight the application of AI to address socio-cultural. AI is enhancing e-learning experiences, particularly for women, thereby improving access to quality education. In healthcare, AI optimizes dental care and medication management, increasing accessibility and safety. Additionally, AI is utilized in disaster-resilient architectural designs that respect cultural heritage and in forensic science to strengthen justice systems. These initiatives demonstrate how AI can effectively tackle socio-cultural issues while promoting sustainable development in the region (Almajed et al., 2024; Luppicini, Walabe, 2021).

However, the limited research on SDGs, socio-cultural challenges, AI, and sustainability in Saudi Arabia is insufficient. For example, research shows explicitly that SDGs 1 and 3 are particularly relevant for addressing social challenges in Saudi Arabia (Guermazi, Gharbi, 2024). Also, studies collectively emphasize the importance of AI in driving sustainable practices in various sectors of Saudi Arabia, which aligns with the country's strategic goals for economic diversification and environmental stewardship (N. S. Alotaibi, Alshehri, 2023; Mutambik, 2024). However, Saudi Arabia has a significant research gap regarding the role of AI in implementing SDGs and solving socio-cultural challenges. In this regard, a narrative review method with a critical approach can be useful because increasing understanding, improving decision-making, promoting responsibility, and advancing knowledge in various fields is vital, and these are possible with the help of a narrative review method.

In light of these developments, this study explores the utilization of AI to address socio-cultural challenges in Saudi Arabia by promoting SDGs. The following goals guide this study: Identify the most important socio-cultural challenges in Saudi Arabia, analyze which SDGs would help address these challenges, review AI applications that would help achieve these SDGs, and summarize AI applications that may contribute to overcoming current socio-cultural challenges in Saudi Arabia. By clearly defining these goals, the study ensures coherence among the research objectives, methodology, results, and conclusions. This study adopts a theoretical framework that posits AI as a facilitator in achieving SDGs, thereby mitigating socio-cultural challenges. This framework is grounded in the theory that technological advancements can drive significant socio-cultural transformations when aligned with sustainable development policies. Furthermore, this study has opened up a fresh perspective in this area by exploring the feasibility of AI applications based on the unique traits and principles of Saudi society and culture. Given the similarities among Islamic nations, particularly in the Middle East, this new perspective could hold significant value in establishing a solid groundwork for AI utilization in nations such as Saudi Arabia. With the rapid advancement of smart city initiatives in Saudi Arabia, propelled by numerous ongoing projects, the comprehensive insight offered by this research into the potential of AI applications could prove crucial for future progress.

Methodology

This narrative review employs a structured four-step approach to analyze literature relevant to its main goals. Given that the topics in this area are still developing and lack integrated literature, a narrative review was deemed appropriate. Such reviews are significant in academic research as they offer a comprehensive overview of existing literature, allowing researchers to contextualize their findings and identify knowledge gaps. Unlike systematic reviews, which adhere to strict methodologies for literature selection, narrative reviews prioritize understanding the topic through extensive reading, fostering deeper insights that facilitate better literature synthesis. They also enhance accessibility for a broader audience, encourage engagement with complex subjects, and stimulate scholarly discourse by challenging existing assumptions and highlighting emerging trends (Orben, 2020).

This study incorporates specific criteria and processes in each step of the narrative review to ensure methodological rigor and transparency.

Step 1: Identification of Socio-Cultural Challenges

The first step involves identifying and extracting the most significant socio-cultural challenges facing Saudi Arabia. This is achieved through conducting a thorough review of existing literature on socio-cultural issues in Saudi Arabia, including recent studies and official documents like Saudi Vision 2030. We used this search string on the All Fields section of Scopus database on 20 July 2024:

("socio-cultural challenges" OR "cultural issues" "cultural challenges" OR "social dynamics" OR "social challenges" OR "social issues" OR "social problems" OR "cultural problems") AND ("Saudi Arabia" OR "Kingdom of Saudi Arabia" OR "Saudi")

We found 141 articles and after analyzing and reading the title and abstract of them we found 5 main socio-cultural challenges in Saudi Arabia: Gender equality, Cultural preservation and heritage protection, Increasing Youth Population, Rapid Urbanization, and Climate change.

Step 2: Analysis of SDGs

In the second phase, we designed a search string for each socio-cultural challenge we identified in the previous step. By applying these search strings in the Title section of the Scopus database we identified suitable documents for connecting SDGs to our socio-cultural challenges. The search strings are:

Gender equality: ("Sustainable Development Goals" OR "SDGs" OR "UN SDGs" OR "2030 Agenda" OR "global goals") AND ("gender equality" OR "gender equity" OR "women's empowerment" OR "gender parity" OR "gender rights" OR "women's rights" OR "gender issues" OR "gender discrimination" OR "female empowerment" OR "equal opportunities for women" OR "gender balance")

Cultural preservation and heritage protection: (“Sustainable Development Goals” OR “SDGs” OR “UN SDGs” OR “2030 Agenda” OR “global goals”) AND (“cultural preservation” OR “heritage protection” OR “cultural heritage conservation” OR “cultural sustainability” OR “heritage conservation” OR “cultural safeguarding” OR “cultural legacy protection” OR “preservation of cultural heritage” OR “intangible cultural heritage” OR “tangible cultural heritage”)

Increasing Youth Population: : (“Sustainable Development Goals” OR “SDGs” OR “UN SDGs” OR “2030 Agenda” OR “global goals”) AND (“increasing youth population” OR “growing youth demographic” OR “youth bulge” OR “youth growth” OR “young population” OR “youth expansion” OR “demographic transition” OR “youth development” OR “population growth among youth” OR “young people”)

Rapid Urbanization: (“Sustainable Development Goals” OR “SDGs” OR “UN SDGs” OR “2030 Agenda” OR “global goals”) AND (“rapid urbanization” OR “accelerated urban growth” OR “urban expansion” OR “urban sprawl” OR “urban development” OR “fast urbanization” OR “urban migration” OR “urbanization trends” OR “urban population growth”)

Climate change: (“Sustainable Development Goals” OR “SDGs” OR “UN SDGs” OR “2030 Agenda” OR “global goals”) AND (“climate change” OR “global warming” OR “climatic change” OR “climate crisis” OR “climate variability” OR “climate disruption” OR “environmental change” OR “atmospheric changes” OR “climate impacts”)

Step 3: Identification of AI Applications

The third step focuses on identifying and categorizing the most significant AI applications that can be utilized to implement and strengthen the relevant SDGs. In this regard, the global literature is reviewed to find successful AI applications that tackle similar socio-cultural challenges and promote sustainable development. We applied a relevant search string on Title section of Scopus database:

Step 4: Discussion of Results and Recommendations

In the final phase, the study will discuss the findings from the third step, focusing on the effectiveness and necessary conditions for promoting the identified AI applications in the context of Saudi Arabia. This will include an analysis of cultural context considerations, examining how Saudi Arabia’s socio-cultural characteristics — such as traditional values and ongoing projects like NEOM — impact the adoption of these AI technologies. Additionally, a needs assessment will be conducted to identify the resources, training, and infrastructure required for effective implementation of the AI applications. Finally, the study will propose actionable policy recommendations aimed at facilitating the integration of AI in promoting relevant SDGs while addressing socio-cultural challenges in Saudi Arabia.

Additionally, this step involves critically evaluating potential barriers to AI implementation, such as data privacy concerns, ethical considerations, and resistance to tech-

nological change. Strategies to mitigate these barriers are also discussed to ensure AI solutions' successful adoption and sustainability.

Inclusion and Exclusion Criteria

To enhance the transparency and reproducibility of the narrative review, specific inclusion and exclusion criteria have been established. The inclusion criteria specify that publications must be from the last five years to ensure the incorporation of recent developments and trends. Only peer-reviewed journal articles, conference papers, and official government reports will be considered. Additionally, studies must focus on AI applications, SDGs, and socio-cultural challenges in Saudi Arabia or comparable contexts in the Global South. Research providing empirical evidence, case studies, or comprehensive reviews relevant to the research goals will also be included. Conversely, the exclusion criteria indicate that publications older than five years will be excluded unless they are seminal works essential for foundational understanding. Studies that do not directly relate to Saudi Arabia's socio-cultural challenges or AI applications will also be omitted. Furthermore, opinion pieces, editorials, and non-peer-reviewed sources lacking substantial evidence or analysis will not be included in the review.

Quality Assessment

To ensure the reliability and validity of the included studies, a quality assessment was conducted based on several criteria. First, relevance was considered, meaning that the study must directly address one or more of the research goals. Methodological rigor was also essential; the study should employ robust and appropriate data collection and analysis methodologies. Additionally, credibility was evaluated by checking whether the study was published in reputable journals or by recognized institutions.

The strength of evidence was another critical factor, requiring that the study provide solid empirical evidence or a comprehensive theoretical analysis. Finally, bias minimization was assessed by examining whether the study demonstrated efforts to minimize bias through transparent reporting and acknowledgment of limitations. Each study included in the review was evaluated against these criteria, and only those meeting the majority of the standards were incorporated into the final analysis.

Addressing Potential Biases

Recognizing the inherent limitations of narrative reviews, this study proactively addresses potential biases through several strategies. First, it diversifies sources by incorporating a variety of materials from different disciplines and perspectives to provide a balanced view. The selection process is also made transparent by clearly documenting the inclusion and exclusion criteria, ensuring a systematic and unbiased approach to selecting studies.

Additionally, the study engages in critical appraisal, actively critiquing the strengths and weaknesses of each included study to avoid over-reliance on any single source or

perspective. Finally, reflexivity is emphasized by acknowledging the researcher's biases and perspectives while striving to maintain objectivity throughout the review process.

Literature review

Saudi Arabia Socio-Cultural Challenges

As the birthplace of Islam, Saudi Arabia is a country steeped in religious and cultural values, and its unique economic, religious, political, and socio-cultural characteristics have made this country an influential country in the Middle East and the world. Nevertheless, Saudi Arabia is modernizing at a high speed, and at the same time, it is facing important socio-cultural challenges. Identifying socio-cultural challenges in a country is very important to promote social justice, preserve cultural heritage, strengthen social cohesion, improve quality of life, and support economic development. By addressing these challenges, countries can strive to create a more just, inclusive, and prosperous society for all (S.K. Yadav, 2023). Therefore, we will discuss the most important recent socio-cultural challenges of Saudi Arabia.

Gender Equality

Researchers consider gender equality in Saudi Arabia as one of the most important socio-cultural challenges in Saudi Arabia. The 2020 Global Gender Gap Index report shows Saudi Arabia's low ranking in terms of gender equality, with women making up only 16% of the workforce. (Alnufaie, Beghum, 2021). Despite some progress in empowering women and changing the dynamics of the work environment, Saudi women still face challenges such as gender segregation and lack of representation in the workforce (Aldossari, Calvard, 2022). The country's cultural climate, under the influence of male guardianship laws and conservative norms, creates an unfriendly environment for women and affects their movement and interaction. (Alasmari, 2023; Alsharif, Ulrich-Schad, 2019). While recent efforts have been made for gender equality and women's empowerment in Saudi Arabia, there is still a long way to go to remove systemic barriers and promote equal opportunities for women in various areas of society (Al-Nasrallah, 2023).

Recent studies emphasize the intersectionality of gender with other socioeconomic factors, highlighting how AI can be leveraged to promote gender equality by enhancing women's access to education, employment, and healthcare (Mishra et al., 2023; Olubiyi et al., 2022). Additionally, AI-driven initiatives can help monitor and enforce gender-related policies, thereby facilitating a more equitable workforce (Baena-Morales et al., 2020).

Cultural Preservation and Heritage Protection

Saudi Arabia is rich in cultural and historical sites, with a diverse population and important cultural and behavioral values. Despite the development of the non-religious tourism industry and the rapid modernization of cities, cultural and heritage protection

remains a challenge. Research highlights the importance of local assessment criteria for cultural heritage values and conservation, focusing on identifying and emphasizing the importance of places through their values (Albaqawy et al., 2023). Initiatives in Saudi Arabia emphasize the preservation of historical heritage, ancient materials, and adaptive reuse methods to maintain social values and promote sustainable conservation approaches (MAZZETTO, 2022). The Saudi National Vision 2030 emphasizes the importance of preserving heritage sites and the local environment to strengthen national identity and Arab values (MAZZETTO, 2022). Remote sensing and geographic information systems are used to produce risk maps for World Heritage sites, helping decision-makers develop proactive conservation programs (Ramadan et al., 2022). Interventions such as university expansion and airport renovations align with the country's goal of achieving a sustainable economy and tourism. More comprehensive policies and strategies are needed to effectively safeguard both tangible and intangible aspects of Saudi Arabia's cultural legacy (Aldegeishem, 2024; Alshehaby, 2024; Altassan, 2023).

AI technologies, notably Computer Vision and Geospatial AI, play a pivotal role in cultural preservation by enabling accurate 3D modeling of heritage sites, monitoring environmental changes, and facilitating virtual tourism (Fomin et al., 2022; Roa, Triana, 2021). These applications not only aid in preserving physical structures but also in maintaining the intangible cultural heritage by documenting and analyzing traditional practices and community interactions (Brown Dr et al., 2019).

Increasing Youth Population

Saudi Arabia's rapidly growing youth population, over 60% under 30, has pressured public services and infrastructure, particularly in urban areas (Alasmari, 2023; Alsharif, Ulrich-Schad, 2019). Prioritizing urban development should focus on urban facilities, urban economy, health, housing, and third places to meet the needs of the young generation. However, this population also presents challenges such as high unemployment rates, potential social unrest, and limited educational and employment opportunities. Issues such as job discrimination, lack of appropriate workforce preparation curriculum, and women's reluctance to join the workforce are prevalent (Al-Otaibi, Mansour, 2021). Vision 2030 aims to address youth unemployment through strategic development initiatives, but progress remains a challenge (Asem et al., 2024). Adolescents in Saudi Arabia face health risks like smoking, traffic accidents, and drug abuse, which can impact their well-being and prospects. A limited understanding of youth education and employment pathways after high school complicates the situation, highlighting the need for comprehensive reforms and support systems. The government must address these challenges to support and benefit from the growing youth population in Saudi Arabia (Algarni et al., 2023; Alqahtany, Aravindakshan, 2022; Khateb, Alkhaibari, 2023).

AI applications, such as Predictive Analytics and Natural Language Processing, can significantly enhance educational outcomes by personalizing learning experiences and predicting student performance, thereby addressing educational disparities (Milicevic et

al., 2024; Okulich-Kazarin et al., 2023). Furthermore, AI-driven job matching platforms and career counseling tools can help reduce youth unemployment by aligning educational outcomes with labor market demands (Dawana et al., 2024; Yue et al., 2021).

Rapid Urbanization

Urban development in Saudi Arabia, particularly in the Al-Ahsa Urban Area, has led to significant demographic challenges and environmental consequences (Alqahtany, 2023). The rapid growth has resulted in pollution, water resource degradation, urban heat island effect, and urban sprawl, which negatively impact the environment and public health (Almulhim, Cobbinah, 2023). Unsustainable urbanization practices, particularly in Riyadh and Jeddah, contradict sustainability principles, emphasizing the need for sustainable urban policies. The trade-off between heritage site protection and increased urbanization complicates cultural heritage management (Alqahtany, Aravindakshan, 2022). The rapid growth of urban populations has led to a housing supply gap, hindering the government's goal of increasing home ownership to 70% by 2030 (Alhamoudi, 2024). Traffic congestion and accidents in cities like Abha and Bisha are also a concern. The rapid urbanization and ambitious development policies in cities like "Buraydah" have disrupted traditional environments, leading to a loss of local identity. Key challenges include data management infrastructure, construction industry regulations, uncertain housing delivery policies, and resistance to change (Abuhasel, 2023). In this regard, the Saudi government has launched initiatives like the Saudi Vision 2030 to increase home ownership and promote sustainable urban development. However, successful implementation requires a comprehensive strategy that addresses the various urbanization challenges facing the country (Al-Ansi et al., 2023; Alhamoudi, 2024).

AI-driven smart city technologies, including IoT, machine learning, and Geospatial AI, are essential in managing urban growth sustainably (Karpov et al., 2023; Kumar et al., 2023). These technologies enable efficient resource allocation, traffic management, and environmental monitoring, thereby mitigating the adverse effects of rapid urbanization (Maraju et al., 2023; Pandey et al., 2024). Additionally, AI can facilitate the integration of green spaces and optimize energy consumption in urban infrastructure, aligning with sustainability goals (Meng et al., 2018; Tawfik et al., 2024).

Climate Change

Saudi Arabia faces significant challenges due to climate change, particularly in Dammam. Despite 90% of respondents being aware of climate change, 33% were unaware of its causes and impacts. This highlights the need for increased public awareness and education on climate change in the country (Almulhim, 2021). Climate change is also linked to geopolitical risks in Saudi Arabia, with a solid bidirectional causal relationship between the country's geopolitical risk index and critical climate change factors (Dhifaoui et al., 2023). This suggests that climate change is exacerbating regional instability. Climate change also threatens Saudi Arabia's food system security, with factors like temperature

increases, greenhouse gas emissions, population growth, and economic development contributing to vulnerabilities (Al Jaafreh, Allouzi, 2023; Almulhim, 2021; Dhifaoui et al., 2023). To ensure long-term food security, policymakers must address these complex challenges. A multi-faceted approach involving public education, risk management frameworks, and policy interventions is required. Sustainable urban planning, capacity-building programs for farmers, and climate change mitigation and adaptation policies are essential for a resilient national food system and safe roads for all (Abubakar, Dano, 2020; Azeem, Alhafi Alotaibi, 2023).

AI applications, such as Predictive Analytics, Machine Learning, and Geospatial AI, are instrumental in climate change mitigation and adaptation strategies (Dube et al., 2024; Hamdan et al., 2024). These technologies enable accurate climate modeling, early warning systems, and optimized resource management, which are crucial for addressing the multifaceted impacts of climate change (Sen et al., 2021; Sen et al., 2021). Additionally, AI can enhance agricultural practices by predicting weather patterns, optimizing irrigation systems, improving crop resilience, and supporting food security initiatives (Elufioye et al., 2024; Sakapaji, Puthenkalam, 2023).

Related SDGs and AIs

The SDGs integrate economic, social, and environmental concerns, emphasizing human rights and good governance (Kannengießer, 2023). They are essential in promoting global health and aligning with social entrepreneurship models to address vulnerable populations (Yi, 2023). Implementing the SDGs positively impacts society, including economic development and competitiveness, and can help reduce socio-cultural challenges in Saudi Arabia (Del-Aguila-Arcentales et al., 2022; Surmeli et al., 2022). As Table 1 shows, by reviewing the relevant literature, SDGs that were directly related to solving these challenges were identified for each of the five main challenges. It was found that 10 of the 17 SDGs are directly related to the socio-cultural challenges of Saudi Arabia. On the other hand, a deeper examination of the research showed that for the implementation of the SDGs, AI could be a suitable tool for providing innovative solutions and data-based insights due to its efficiency in the implementation and promotion of the SDGs (Ziesche et al., 2023). Despite the fragmented nature of AI implementation, techniques such as machine learning and explainable AI enable policymakers to measure SDG indicators and make informed decisions effectively (Tuğaç, 2023). As Table 1 shows, as a result of further literature studies and valuable experiences in AI and SDGs, there are direct connections between the two fields. Table 1 identifies key AI applications and models to implement and strengthen the ten main SDGs, which are crucial for Saudi policymakers and designers considering the rapid development of smart cities. The AI models and methods are categorized into six broad areas:

- Predictive Analytics and Forecasting: Includes forecasting analytics and classification tasks for predicting future outcomes or classifying data (Nagahisarchoghaei et al., 2023; Zhang et al., 2020).

- Optimization and Decision Support: Covers optimization tasks, recommendation systems, and reinforcement learning applications for decision-making and optimization (Ma et al., 2023).
- Natural Language Processing: Focuses on understanding, interpreting, and generating human language (İpek et al., 2023).
- Computer Vision: Involves processing and analyzing visual data (Karpov et al., 2023).
- Generative AI: Includes applications that create new content (Mohammadi & Kalhor, 2021).
- Geospatial AI: Focuses on analyzing and interpreting geographic and spatial data (Karpov et al., 2023).

Table 1. Related SDGs, AI, models and methods

SDG Area	AI Applications	Key AI Models and Methods
SDG 4: Quality Education	<ul style="list-style-type: none"> • Enhance learning outcomes and personalize learning experiences (Milicevic et al., 2024) • Develop future skills using intelligent tutoring systems and advanced methods (Okulich-Kazarin et al., 2023) 	<ul style="list-style-type: none"> • Natural Language Processing (Zhang, 2024) • Generative AI (gshayish, 2023) • Large Language Models (Arruda, 2024) • Computer Vision (Okulich-Kazarin, 2023) • Recommendation Systems (Okulich-Kazarin, 2023)
SDG 5: Gender Equality	<ul style="list-style-type: none"> • Promote women's political participation and address gender violence (Mishra et al., 2023) • Develop machine learning models for gender equality policies and governance structures (Olubiyi et al., 2022) • Empower women through ICT and wearable technologies for breastfeeding support (Shah & Krishnan, 2024) • Address gender stereotypes in educational content and media (Baena-Morales et al., 2020) 	<ul style="list-style-type: none"> • Natural Language Processing (Azmi, 2020) • Sentiment Analysis (Baena-Morales et al., 2020) • Forecasting Analytics (Olubiyi et al., 2022) • Recommendation Systems (Nurmila et al., 2021) • Reinforcement Learning (Kathambi & Obiero, 2022) • Computer Vision (Mishra & Mishra, 2023) • Large Language Models (Shah & Krishnan, 2023) • Generative AI (Baena-Morales et al., 2020)
SDG 6: Clean water and sanitation	<ul style="list-style-type: none"> • Implement smart water management systems and enhance water governance (Maroju et al., 2023) • Improve wastewater treatment and water desalination processes (S. Pandey et al., 2022) • Monitor and assess water quality and sanitation facilities (Maroju et al., 2023) 	<ul style="list-style-type: none"> • Optimization models (Maroju, 2023;) • Classification models (Maroju, 2023) • Large language models (Maroju, 2023) • Forecasting Analytics (Maroju, 2023) • Computer Vision (Maroju, 2023) • Generative AI (Pandey et al., 2022) • Reinforcement Learning (Saboori & Mehrjerdi, 2022)

<p>SDG 7: Affordable and clean energy</p>	<ul style="list-style-type: none"> Optimize energy consumption in smart homes and manage energy in smart green ports (Tawfik et al., 2024) Enhance energy forecasting and optimization in buildings and grids (Meng et al., 2018) Improve power management in IoT devices (A. K. Pandey et al., 2024) 	<ul style="list-style-type: none"> Optimization models (Tawfik, 2024) Forecasting Analytics (Kumar et al., 2023)
<p>SDG 8: Decent work and economic growth</p>	<ul style="list-style-type: none"> Analyze labor markets and economic growth (Yu et al., 2019) Enhance productivity in manufacturing and secure IoT environments (Yue et al., 2021) Utilize Augmented Reality and AI for interactive learning experiences (Dawana et al., 2024) 	<ul style="list-style-type: none"> Forecasting Analytics (Yue et al., 2021) Classification models (Yue et al., 2021)
<p>SDG 11: Sustainable cities and communities</p>	<ul style="list-style-type: none"> Develop transport operations, urban planning, and smart city initiatives (Marji et al., 2024) Conduct sentiment analysis towards urban initiatives and monitor infrastructure (Ametepey et al., 2024) Promote green AI practices and community development (Arruda & Arruda, 2024) Address ethical considerations in AI use (Theodorou et al., 2022) 	<ul style="list-style-type: none"> Forecasting Analytics (Marji et al., 2024) Classification models (Ametepey et al., 2024) optimization models (Cirianni et al., 2023) natural language processing (Ametepey et al., 2024) Sentiment analysis (Ametepey et al., 2024) Computer vision (Ametepey et al., 2024) Generative AI (Hasas et al., 2024)
<p>SDG 12: Responsible consumption and production</p>	<ul style="list-style-type: none"> Forecast consumer trends and optimize production processes (Hannan et al., 2021) Categorize products by environmental impact and understand consumer sentiments (Matsui et al., 2022) Enhance supply chain management and design sustainable packaging solutions (Kurnia et al., 2023) 	<ul style="list-style-type: none"> Forecasting Analytics (Hannan et al., 2021) Classification models (Bjola, 2022) Natural language processing (Matsui et al., 2022) sentiment analysis (Matsui et al., 2022) Optimization models (Kurnia et al., 2023) Computer vision (Okulich-Kazarin et al., 2023) Generative AI (Pigola et al., 2021)
<p>SDG 13: Climate action</p>	<ul style="list-style-type: none"> Mitigate climate change and develop sustainable solutions (Hamdan et al., 2024) Forecast solar photovoltaic power and improve renewable energy efficiency (Iheanetu, 2022) Enhance climate resilience, weather forecasting, and water resources management (Dube et al., 2024) Promote climate-resilient agricultural practices and food security (Sakapaji & Puthenkalam, 2023) 	<ul style="list-style-type: none"> Forecasting Analytics (Hamdan et al., 2024) classification models (Sen et al., 2021) optimization models (Sakapaji & Puthenkalam, 2023)

<p>SDG 14: Life below water</p>	<ul style="list-style-type: none"> • Predict marine conservation trends and identify risks (Joel et al., 2024) • Conserve marine biodiversity and forecast marine traffic dynamics (Molina-Molina et al., 2021) • Predict ocean dynamics and extreme events (Dong et al., 2022) 	<ul style="list-style-type: none"> • Forecasting Analytics (Nzeako et al., 2024) • Geo AI (Molina-Molina et al., 2021)
<p>SDG 15: Life on land</p>	<ul style="list-style-type: none"> • Monitor the environment, conserve biodiversity, and detect land cover changes (Chisom et al., 2024) • Optimize agricultural supply chains and forecast species abundances (Elufoye et al., 2024) • Predict habitat quality under climate change scenarios and manage inventories (Nzeako et al., 2024) 	<ul style="list-style-type: none"> • Geo AI (Chisom et al., 2024) • Forecasting Analytics (Nzeako et al., 2024) • classification models (Limberger et al., 2024) • natural language processing (Kass et al., 2022) • computer vision (Kass et al., 2022)

AI's role in supporting SDGs extends beyond mere implementation; it actively contributes to formulating strategies that align with sustainable and inclusive growth. For instance, Natural Language Processing (NLP) can be utilized to analyze public sentiment and feedback on gender policies, thereby facilitating more effective and responsive governance (Baena-Morales et al., 2020). Similarly, Computer Vision technologies can monitor and preserve cultural heritage sites by detecting real-time structural changes or potential threats, ensuring timely interventions (Fomin et al., 2022). Furthermore, the integration of AI in urban planning through Geospatial AI allows for the creation of more resilient and adaptable infrastructure, which is essential for managing the challenges posed by rapid urbanization and climate change (Karpov et al., 2023; Maroju et al., 2023). These AI-driven solutions address immediate socio-cultural challenges and contribute to long-term sustainable development by fostering innovation, efficiency, and inclusivity in Saudi Arabia's smart cities.

Additionally, it is important to consider the ethical implications and sustainability of AI applications. AI's water footprint, which refers to the amount of water consumed during the training and operation of AI models, poses significant environmental concerns, especially in water-scarce regions like Saudi Arabia (Chen et al., 2023). Addressing this issue requires the development of more efficient algorithms and adopting green AI practices to minimize environmental impact while maximizing the benefits of AI technologies (Mashhood et al., 2023).

Moreover, recent studies have highlighted the importance of incorporating local cultural contexts into AI applications to ensure their relevance and effectiveness. By tailoring AI solutions to Saudi Arabia's unique socio-cultural dynamics, policymakers can enhance the acceptance and success of these technologies in achieving the SDGs (Olubiya et al., 2022; Samarin, Al-Asfour, 2023).

In summary, the interplay between AI and SDGs in the context of Saudi Arabia's socio-cultural challenges is multifaceted and dynamic. The following sections will delve deeper into specific AI applications and their contributions to each identified SDG, com-

prehensively analyzing how AI can drive sustainable and inclusive development in Saudi Arabia's smart cities.

Results and Discussion

In general, Saudi Arabia is struggling with various socio-cultural challenges, and the sustainability of the society depends on solving these challenges. This is also emphasized in the Saudi 2030 Vision document. Therefore, this research *provides an overview* of the most important challenges in Saudi Arabia. This study first identifies the most likely SDGs to solve these problems and then the most important AI applications *used to implement and promote these SDGs*.

Saudi Arabia is implementing ambitious smart city projects such as NEOM, which can have trans-regional impacts. On the other hand, AI is considered an important tool in smart cities. Integrating AI technologies into various urban systems is a key factor in developing smarter, more efficient, and livable smart cities (Napolitano, 2023; Rebahi et al., 2023). As a result, this integration should align with the socio-cultural challenges and characteristics of Saudi Arabia to drive sustainability and enhance the quality of life. Nevertheless, we see that the Neom project, which is the most prominent project of the smart city, has followed the emphasis on solving some socio-cultural challenges to a lesser extent. In general, this project has emphasized goals such as biophilic design (Alhefnawi, 2022), technology (AlDoaies, Almagwashi, 2018), geothermal and renewable energy (Aboud et al., 2023), urban investment bonds, and geological and environmental considerations (Chang, 2024), which can be in line with the challenges of rapid urbanization, climate change, and increasing youth population. However, the two difficulties of gender equality and Cultural preservation and heritage protection do not play a central role in the Neom project. At the same time, there are some criticisms of this project. For example, the researchers believe the NEOM site is located near an active geological fault, which is risky. The researchers also believe disruption to local ecosystems and habitats is possible due to the large-scale construction and development of NEOM (Alhefnawi, 2022; Bashir, Alsalman, 2023). Therefore, despite the concrete emphasis of Saudi 2030 vision on socio-cultural challenges, the priority of some of these challenges cannot be identified, at least in the NEOM project. There is a need to review the tools, policies, and technologies in NEOM and other Saudi smart city projects, which this research saw in the appropriate use of AI. In this regard, Figure 1 was designed, which shows the close relationship between Saudi socio-cultural challenges with SDGs and AI applications, and this can be considered an important perspective for researchers and policymakers in the field of smart cities in Saudi Arabia.

Gender Equality

Gender equality is a significant socio-cultural challenge in Saudi Arabia, aligning with SDG 5. AI applications have been developed to improve women's economic and political

participation (Mishra et al., 2023), gender equality policies (Olubiyi et al., 2022), and address gender stereotypes in content and educational media (Baena-Morales et al., 2020). These applications use Natural Language Processing, Predictive Analytics, Forecasting, Optimization and Decision Support, Computer Vision, and Generative AI models. In smart cities, AI should be designed and implemented with the help of women to maximize efficiency in gender equality. AI-driven initiatives can facilitate monitoring gender-related policies and analyzing workforce data to identify and address disparities (Baena-Morales et al., 2020). Additionally, Natural Language Processing can be employed to analyze public discourse and media content to identify and mitigate gender biases, thereby fostering a more inclusive environment (Mishra et al., 2023).

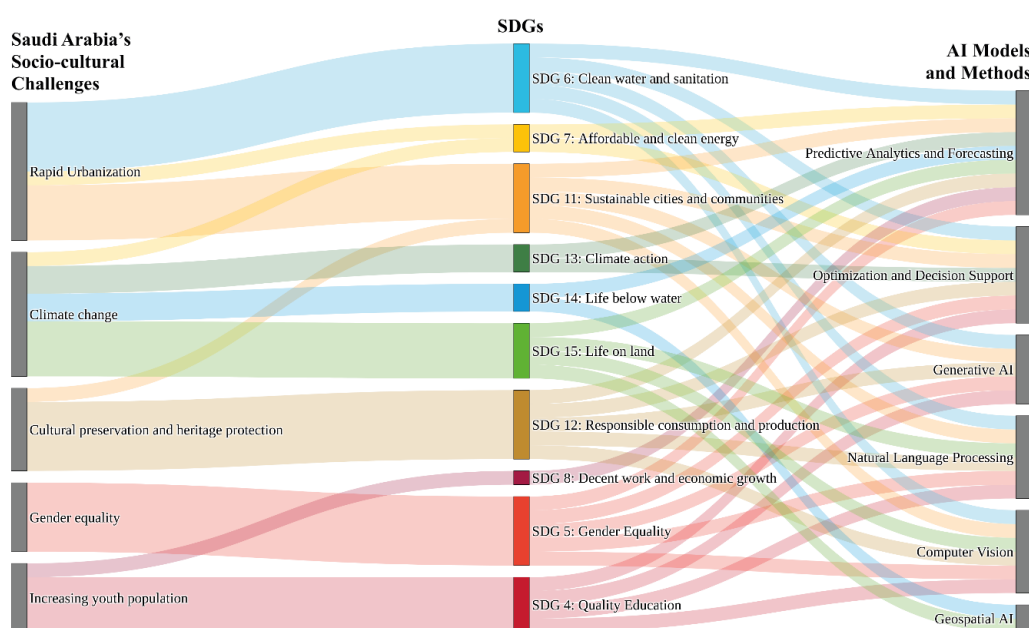


Figure 1. Final overview of SDGs in relation to Saudi Arabia's socio-cultural challenges with AI models and methods

Cultural Preservation and Heritage Protection

Related to SDG 11, the preservation and protection of cultural heritage are also crucial, encompassing not only ancient architecture and urban planning but also the identity, cultural heritage, and social values of Saudi Arabia. AI models can be used to create accurate 3D models of heritage sites and artifacts, monitor and document them (Roa, Triana, 2021), track changes in their condition (Brown Dr et al., 2019), and analyze environmental data to predict potential threats (Yildirim et al., 2019). Virtual reality and augmented reality can improve tourism by optimizing visitor flow, monitoring crowd density, and providing personalized recommendations (Barbosa et al., 2022). In SDG 12, AI applica-

tions can be used for heritage conservation, including digital documentation, condition monitoring, restoration, and interaction with visitors (Fomin et al., 2022). These capabilities contribute to responsible consumption and production of natural resources, reduce waste, and promote sustainable practices. However, there are negative points to consider when preserving and protecting cultural heritage using AI. It is essential to ensure that AI systems respect cultural sensitivities, intellectual property rights, and autonomy of local communities and that AI-based cultural preservation initiatives are accessible and inclusive for diverse communities. As Saudi Arabia is a significant pilgrimage destination for Muslims and a form of Islamic cultural crystallization, it is crucial to preserve the authenticity and accurate representation of cultural practices and identities, avoiding simplification or misinterpretation in AI applications and smart cities.

AI technologies such as Computer Vision and Geospatial AI play a pivotal role in cultural preservation by enabling the creation of detailed 3D models of heritage sites, facilitating real-time monitoring, and predicting potential risks from environmental changes (Fomin et al., 2022; Roa, Triana, 2021). These technologies ensure that cultural heritage is accurately documented and preserved for future generations while enhancing tourism through immersive virtual experiences (Barbosa et al., 2022).

Increasing Youth Population

The increasing youth population in Saudi Arabia requires a focus on promoting SDGs 4 and 8 in smart cities. AI applications can accelerate SDG 4 by improving learning outcomes and personalizing experiences, enabling the development of future skills (Milicevic et al., 2024; Okulich-Kazarin et al., 2023). The young society also needs a dynamic economy and job opportunities aligned with SDG 8. Predictive Analytics and Forecasting models can analyze labor market and economic growth, increase productivity in production, and create safe environments for the Internet of Things (Dawana et al., 2024; Yu et al., 2019; Yue et al., 2021). AI-powered educational platforms can personalize learning experiences to better cater to the diverse needs of the youth, thereby enhancing educational outcomes and reducing dropout rates (Milicevic et al., 2024). Furthermore, AI-driven job matching systems can bridge the gap between graduates and employment opportunities, addressing high unemployment rates and aligning workforce skills with market demands (Yue et al., 2021).

Rapid urbanization

Rapid urbanization is a comprehensive challenge in Saudi Arabia, requiring sustainable city planning, water and urban waste management, and access to clean energy. AI applications can play a crucial role in promoting SDG 6 by implementing smart water management systems, strengthening water governance, improving wastewater treatment and water desalination processes, and monitoring and evaluating water and sanitary facilities (Maroju et al., 2023; Mraz et al., 2021; S. Pandey et al., 2022). AI applications can also op-

timize energy consumption in smart homes, smart green ports, buildings and networks, and Internet of Things devices, promoting and implementing SDG 7 (Kumar et al., 2023; Meng et al., 2018; A. K. Pandey et al., 2024; Tawfik et al., 2024). SDG 11 is the most important SDG related to the challenge of rapid urbanization in Saudi Arabia and should be taken seriously. Successful AI experiences at the global level can be considered a suitable tool for creating sustainable smart cities in Saudi Arabia.

AI-driven smart water management systems utilize machine learning algorithms to predict water demand, detect leaks, and optimize distribution networks, ensuring efficient water resource use (Maroju et al., 2023). Similarly, AI applications in energy management can optimize consumption patterns in smart homes and buildings, significantly reducing energy wastage and promoting the use of renewable energy sources (Kumar et al., 2023). These AI solutions are essential for managing the complexities of rapid urbanization and ensuring sustainable growth in Saudi Arabia's smart cities.

Climate Change

The climate change challenge in Saudi Arabia is closely linked to SDGs 7, 13, 14, and 15. The NEOM project emphasizes the importance of overcoming this challenge for the future of smart cities in Saudi Arabia. AI applications have proven successful in addressing SDG 13 by reducing climate change, creating sustainable solutions, forecasting solar photovoltaic power, improving renewable energy efficiency, increasing climate flexibility, weather forecasting, water resource management, and promoting agricultural practices resistant to climate and food security (Dube et al., 2024; Hamdan et al., 2024; Iheanetu, 2022; Sakapaji, Puthenkalam, 2023; Sen et al., 2021). Saudi Arabia's wide border with the Arabian Gulf and the Red Sea is also related to SDG 14, and its strengthening is crucial. AI applications can help promote SDG 14 by predicting sea protection trends, preserving marine biodiversity, predicting marine traffic dynamics, and predicting ocean dynamics and extreme events (Dong et al., 2022; Joel et al., 2024; Molina-Molina et al., 2021; Mooney et al., 2020). AI applications can also help improve and implement SDG 15 by monitoring the environment, preserving biodiversity, identifying land cover changes, optimizing the agricultural supply chain, predicting species abundance, and managing inventory (Chisom et al., 2024; Elufioye et al., 2024; Limberger et al., 2024; Nzeako et al., 2024; Requena-Mullor et al., 2017). Given Saudi Arabia's special and sensitive climatic conditions, future smart cities can use AI to effectively fight climate change challenges and achieve SDGs 7, 13, 14, and 15.

AI technologies such as Predictive Analytics and Machine Learning enable accurate climate modeling and weather forecasting, which is critical for developing effective climate change mitigation and adaptation strategies (Sen et al., 2021; Hamdan et al., 2024). Geospatial AI assists in monitoring environmental changes and predicting extreme weather events, thereby enhancing the resilience of infrastructure and communities (Dong et al., 2022; Molina-Molina et al., 2021). Additionally, AI-driven agricultural technologies can optimize irrigation, improve crop yields, and promote sustainable farming practices, ad-

addressing both food security and environmental sustainability (Sakapaji, Puthenkalam, 2023; Elufioye et al., 2024). Although limited, other studies have also attempted identify suitable AI technologies for addressing the socio-cultural challenges of Saudi Arabia.

Conclusion

The study explores the utilization of AI to address socio-cultural challenges in Saudi Arabia by promoting SDGs. A narrative review method was used in four steps to achieve this goal. Saudi Arabia's most important socio-cultural challenges were gender equality, increasing youth population, rapid urbanization, and climate change. Ten SDGs were identified as critical for addressing Saudi Arabia's most important socio-cultural challenges using proper AI applications, models, and methods.

Therefore, this study demonstrates that AI applications can play a crucial role in addressing sociocultural challenges by implementing SDGs in various ways based on extensive literature reviews and successful global case studies. However, this research argues that for the correct use of AI in Saudi Arabia, it is necessary to prioritize social, religious, and cultural characteristics and values and that AI should be highly compatible with Saudi society. AI can enhance sustainability in Saudi Arabia's smart cities and contribute to achieving the SDGs, so investing in developing and implementing AI-based solutions is essential to address the identified challenges and foster sustainable development. Policy-makers, urban planners, and technology experts must collaborate to leverage AI's potential for maximizing positive societal impact. By doing so, Saudi Arabia can create smart, sustainable communities that improve its residents' and future generations' quality of life.

To translate these findings into actionable strategies, several practical recommendations are proposed. First, establishing national frameworks is essential to guide the integration of AI technologies in smart city projects, ensuring alignment with SDGs and socio-cultural values. Additionally, fostering partnerships among government agencies, private sector entities, academic institutions, and local communities will drive inclusive and culturally sensitive AI initiatives. Implementing educational programs and training workshops is also crucial for building AI literacy and expertise among the youth and workforce, thereby supporting SDG 4 (Quality Education) and SDG 8 (Decent Work and Economic Growth). Furthermore, developing and enforcing ethical guidelines for AI deployment will address data privacy, security, and ethical concerns, ensuring that AI applications respect cultural and societal norms. Lastly, providing funding for research and development in AI technologies tailored to Saudi Arabia's unique socio-cultural context will foster innovation and sustainable solutions.

Despite the significant potential of AI, this study acknowledges several limitations. One notable challenge is the implementation of AI solutions, which may encounter barriers such as inadequate infrastructure, limited access to quality data, and resistance to technological change. Additionally, data privacy and ethical concerns are paramount; ensuring the privacy and security of data used in AI applications is particularly critical in culturally sensitive contexts. Furthermore, the generalizability of the findings is a limita-

tion to consider. While the study focuses on Saudi Arabia, the insights gained may not be applicable to other regions in the Global South due to differing socio-cultural dynamics.

Future research should focus on several key areas to address existing limitations and further explore the role of AI in sustainable development. One area of investigation is the implementation barriers that hinder AI adoption in Saudi Arabia's smart cities. Conducting empirical studies to identify and analyze these obstacles will be crucial for developing effective strategies to overcome them. Another important area is the exploration of ethical frameworks. There is a need to develop comprehensive ethical guidelines that address data privacy, security, and the responsible use of AI in culturally diverse settings. This will help ensure that AI technologies are implemented in ways that respect individual rights and societal norms. Assessing the long-term impacts of AI integration is also vital. Evaluating the social, economic, and environmental consequences of AI in smart cities will help ensure that its benefits are sustained and aligned with SDGs. Also, promoting inclusive AI development is essential. Research should focus on methods to involve diverse stakeholders, including marginalized communities, in the design and implementation of AI technologies to ensure inclusivity and equity. This collaborative approach will enhance the relevance and effectiveness of AI initiatives within various socio-cultural contexts.

In conclusion, this study underscores AI's transformative potential in advancing sustainable development and addressing socio-cultural challenges in Saudi Arabia's smart cities. By prioritizing culturally aligned AI applications and fostering collaborative efforts among key stakeholders, Saudi Arabia can harness AI to achieve its Vision 2030 goals, creating resilient and inclusive communities for future generations.

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Искусственный интеллект в продвижении умных городов Саудовской Аравии: обеспечение целей устойчивого развития в процессе ответа на социокультурные вызовы

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Исследование посвящено использованию искусственного интеллекта (ИИ) для решения социокультурных проблем в Саудовской Аравии и содействия достижению целей устойчивого развития (ЦУР). Рост ИИ значительно повлиял на различные области, включая науки об обществе и городе, что делает его универсальным инструментом для анализа сложных социальных явлений, понимания человеческого поведения и оптимизации городской инфраструктуры. Саудовская Аравия, сталкиваясь с уникальными социокультурными вызовами, стремится к устойчивому развитию, опираясь на концепцию «Видение 2030» и различные проекты умных городов, подчеркивая важность решения таких проблем, как гендерное равенство, сохранение культуры, рост молодежного населения, быстрая урбанизация и изменение климата.

В статье рассматриваются ИИ-приложения и модели, используемые для решения этих проблем и продвижения соответствующих ЦУР. Приложения, применяемые в сферах обработки естественного языка, компьютерного зрения и предиктивной аналитики, могут принести пользу в таких областях, как гендерное равенство, сохранение культуры, а также образование и трудоустройство молодежи. Аналогично, ИИ может оптимизировать управление водными ресурсами, потребление энергии и городское планирование в целях решения проблем быстрой урбанизации и изменения климата. Согласовав развитие технологий ИИ с целями устойчивого развития, Саудовская Аравия может раскрыть потенциал ИИ в вопросе создания устойчивых, адаптивных и инклюзивных «умных городов», эффективно отвечающих на социокультурные вызовы. Результаты этого исследования имеют значение не только для Саудовской Аравии, и для других стран региона, но и за его пределами, подчеркивая важность интеграции ИИ для достижения целей устойчивого развития и повышения качества жизни.

Ключевые слова: ИИ; ЦУР; Социокультурные вызовы; Умные города; Саудовская Аравия; Видение Саудовской Аравии 2030; NEOM