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(REVIEW ARTICLE)

Driving efficiency: The role of Artificial Intelligence (AI) in enhancing municipal operations in Saudi Arabia

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Abstract

As the Kingdom of Saudi Arabia continues its journey towards economic diversification and technological advancement, the adoption of Artificial Intelligence (AI) has emerged as a critical driver of innovation across various sectors. This paper investigates the potential benefits of integrating AI technologies in municipal services within the Saudi context.

Drawing upon a comprehensive literature review and examining existing initiatives, this paper explores the potential benefits of using AI. It reviews the Application and development of AI in municipalities in Saudi Arabia. This research identifies areas where AI can enhance municipal operations, improve citizen engagement, and revolutionize municipal operations. These include urban planning, intelligent infrastructure management, traffic optimization, waste management, and citizen services.

Overall, this paper contributes to the literature on AI adoption in the public sector, offering valuable insights for policymakers, urban planners, and technology developers seeking to harness the transformative potential of AI in enhancing municipal services and improving the quality of life for citizens in Saudi Arabia.

Keywords: Municipalities; Machine learning; Artificial Intelligent; Economic diversification

1. Introduction

The Kingdom of Saudi Arabia is undergoing a significant transformation towards economic diversification and technological advancement, driven by the Vision 2030 agenda. This vision recognizes the pivotal role of Artificial Intelligence (AI) in driving innovation and efficiency across various sectors, including municipal governance. Municipalities play a crucial role in delivering essential services to urban populations, making them prime candidates for benefiting from the integration of AI technologies. AI has emerged as a disruptive force capable of revolutionizing traditional approaches to service delivery, resource management, and citizen engagement. Its potential to automate routine tasks, analyze vast amounts of data, and optimize decision-making processes presents unprecedented opportunities for municipalities to enhance efficiency, reduce costs, and improve service quality.

However, integrating AI into municipal operations in Saudi Arabia faces obstacles such as data privacy concerns, regulatory limitations, workforce preparedness, and institutional barriers. Overcoming these hurdles is essential to unlock the full potential of AI-driven innovation. Despite these challenges, the imperative for Saudi Arabian municipalities to embrace AI is clear. AI can streamline processes, optimize resource allocation, and provide citizens with more tailored and responsive services. Additionally, AI empowers municipalities to address emerging challenges like rapid urbanization and environmental sustainability proactively.

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This paper explores the prospects associated with AI adoption in Saudi Arabian municipal governance. A comprehensive literature review and empirical analysis provide valuable insights for policymakers, urban planners, and municipal administrators on leveraging AI's transformative potential to create more innovative, sustainable, and resilient cities for the future.

In Saudi Arabia, municipalities are responsible for urban development plans, maintaining crucial local infrastructure, and delivering essential services. However, they need more resources, aging infrastructure, rapid urbanization, fiscal sustainability, and technological disparities. Addressing these challenges requires municipalities to identify municipal projects and establish criteria for prioritization methodically. Furthermore, enhancing public engagement mechanisms is crucial for effectively aligning municipal initiatives with citizens' needs and demands.

According to Wirtz et al., 2019 [1], the most common AI applications in government agencies are as follows:

- AI-based knowledge management software;
- AI process automation systems;
- chatbots/virtual agents;
- predictive analytics and data visualization;
- identity analytics;
- cognitive robotics and autonomous systems;
- recommendation systems;
- intelligent digital assistants;
- speech analytics, and;
- cognitive security analytics and threat intelligence.

Local government agencies are increasingly recognizing the advantages of AI. As stated by the International City/County Management Association (ICMA) Yigitcanlar et al., 2021 [2], these advantages encompass (a) enhanced operational efficiency for local governments; (b) a heightened ability for local governments to concentrate on their residents; (c) substantial reduction of bias within local governments, and; (d) the capacity for local governments to make data-informed decisions, providing an added advantage to under-resourced departments.

Presently, AI is not only integrating into the operations and services of local governments but also exerting influence on and shaping the future of our cities and societies Yigitcanlar et al. (2020) [3]. As many municipalities across various countries worldwide have experience in implementing artificial intelligence technologies in some of their services, we will discuss some of these initiatives in this paper and present them in detail.

2. Literature review

El Hoummaidi et al. (2021) [4] use deep learning with the corporation of Dubai municipality by collaborating with Dubai municipality employing unmanned aerial systems and deep learning for agricultural mapping in Dubai. They create an accurate agriculture database that contributes to the decision-making process in determining areas suitable for crop growth. They used the object detection method and geospatial analysis as an integrated workflow to detect individual crops.

Mikalef et al. (2019) [5] shed some light on the use and intended use of AI within public administration, particularly in Norwegian municipalities; they found that the most popular applications of AI for municipalities in Norway include intelligent interaction agents with citizens, real-time translations for meetings, including speech-to-speech and speech-to-text, as well as request processing and applications handling and automatizing data entry.

Kimari et al. (2023) [6] studied the effects of artificial intelligence on service delivery in South African local municipalities; they found that the use of artificial intelligence would promote transparency, accountability, and inclusivity, which are needed for delivering adequate services that meet people's expectations

[7] This paper examines the experiences of pioneers who have adopted the Application of Robotized Process Automation, a type of narrow AI, in financial assistance, known as the "Trelleborg model.", which involves utilizing automated software robots to streamline and optimize processes related to financial assistance programs.

Son et al. (2023) [8] thoroughly examine the urban planning domains where AI technologies are considered or utilized. It explores how AI technologies currently bolster or have the potential to bolster intelligent and sustainable development initiatives.

Matthews et al. (2020) [9] explain the Belgian Flemish region and the Netherlands and accurate and complete spatial databases for mapping maintenance hole covers using deep learning networks.

Ayeleru et al. (2021) [10] conducted a study to predict municipal solid waste (MSW) production in the City of Johannesburg (CoJ), South Africa, utilizing ongoing guesstimates for the projection period by using a machine learning approach.

Andreasson et al. (2019) [11] wrote a report concerning how selected Nordic regions work with artificial intelligence; some municipalities used artificial intelligence for less complex citizen-facing tasks such as sorting citizen inquiries or answering questions using chatbots. Several have tested whether the technology could be used as decision support in more complex case processing, including processing planning applications and the labor market. However, they still needed to start using artificial intelligence to do this.

Kazakov et al. (2020) [12] delve into the Application of machine learning to address challenges in managing a contemporary urban economy. The authors examine the extent to which machine learning can be utilized in resolving urban issues and making managerial decisions to oversee the socio-economic development of a region, particularly in forecasting critical socio-economic indicators.

3. Methodology

Conduct a comprehensive review of existing literature on adopting Artificial Intelligence (AI) in municipal services worldwide, examining existing initiatives and best practices. Identify relevant studies highlighting the potential benefits of AI integration in various municipal operations. The databases used for the search were Scopus, Web of Science, and Google Scholar.

4. Results and Data Analysis

To explore how municipalities in Saudi Arabia can benefit from artificial intelligence (AI), it is essential to consider several potential areas of Application:

4.1. Smart Infrastructure Management

AI can optimize the management of municipal infrastructure such as roads, bridges, utilities, and public transportation systems. Geographic information systems (GIS) and artificial intelligence (AI) techniques were employed to create an intelligent asset management system to optimize road and bridge maintenance. Through data analysis and predictive modeling, AI can help identify potential issues, optimize maintenance schedules, and improve efficiency. Japan has integrated AI technology to anticipate maintenance needs for municipal infrastructure (Katayama, 2021) [13]. Tokdemir et al. (2000) [14] employed artificial neural networks (ANN) and genetic algorithms (GA) to create predictive models for bridge sufficiency ratings, utilizing current geometrical, age, traffic, and structural attributes as explanatory variables. Ranyal et al. (2022) [15] conducted a comprehensive literature review of road condition monitoring (RCM) technologies from 2017 to 2022. it emphasizes next-gen sensors, including contact and non-contact methods, while discussing challenges in AI advancement and suggesting future research directions. Chun et al. (2020) [16] propose using uncrewed aerial vehicle (UAV) technology, artificial intelligence (AI) technology, and telecommunications technology in bridge inspection in Japan. Alsugair and Al-Judah (1998) [17] demonstrate the successful implementation of artificial neural networks (ANN) to recommend suitable maintenance and repair (M&R) actions. To accurately diagnose M&R actions, the ANN must be trained in correctly diagnosed M&R actions, represented by pavement condition data obtained from comprehensive visual inspection on the Riyadh Road network in Saudi Arabia. Each training set includes pavement condition data, deduct values for each distress in the pavement and the corresponding recommended M&R action. The associated M&R actions were determined based on consulting human expertise and M&R actions recommended by M&R software. The study's findings indicate that ANN is suitable for identifying appropriate M&R actions based on the provided data and training sets, showcasing its potential for practical implementation in this context.

4.2. Waste Management

In today's world, municipal solid waste (MSW) management is considered the primary issue in protecting the surrounding environment. AI can help municipalities optimize waste collection routes, reduce landfill usage, and improve recycling rates. By analyzing data on waste generation patterns, AI systems can identify areas with high waste production and allocate resources more effectively. Abbasi et al. (2016) [18] developed a model to predict monthly waste generation in Queensland, Australia's Logan City Council region. Results showed that artificial intelligence models have good prediction performance and could be successfully applied to establish municipal solid waste forecasting models. Xia Wet al. (2022) [19] summarizes the Machine Learning methods used to predict Municipal Solid Waste generation in many countries such as the USA, Denmark, South Africa, Canada, and China. Chhay et al. (2018) [20] tried different methods for forecasting municipal solid waste in China, and they found that ANN is the most acceptable model for forecasting municipal solid waste in China. Zhang et al. (2022) [21] found that AI, IoT, and 5G technologies will be widely and deeply used for waste generation prediction, waste collection route optimization, waste management facility positioning, and waste resource recovery process modeling. Ninghui Li et al. (2023) [22] introduce CNN and Graph-LSTM, two advanced deep-learning methods that identify everyday waste items as they move along a conveyor belt in waste management systems. The CNN-based model is trained to classify six object categories: cardboard, metal, glass, plastic, paper, and organic waste.

4.3. Generate revenue

There are dedicated administrations for investing in municipalities called the Investment and Revenue Development Management. Their goal is to propose investment projects that can generate income for municipalities by offering designated municipalities lands to the private sector to invest in various areas, whether constructing a commercial complex, private hospital, private school, etc. Artificial intelligence can determine the suitable choice for the proposed investment project's nature in any neighborhood within the city. Also, AI is utilized to assess investment opportunities and determine suitable project locations. AI-driven decision-making processes are used to identify investment opportunities and make informed decisions about project locations. Conway (2010) [23] explores using machine learning and artificial intelligence for analysis, prediction, and automation within the real estate sector. He concludes that Machine learning and artificial intelligence have the capacity and will be harnessed to enhance real estate investment across various domains, encompassing property management, investment strategies, and development procedures. This integration promises to revolutionize the real estate sector into a more streamlined and data-centric industry. Also, AI can be used for predicting real estate prices Pinter et al. (2020) [24]. Property location significantly influences its value, yet automated evaluations lack in assessing this aspect. Stang et al. (2023) [25] present the SHAP location score, a novel approach integrating machine learning with the Shapley Additive Explanations method. Addressing location complexities enhances real estate assessment based on econometric modeling and hedonic pricing theory.

4.4. Urban Planning and Development

Between 1970 and 1986, Saudi Arabia underwent a significant wave of urbanization, leading to rapid annual growth rates for its cities, averaging over 6.4% Al-Hathloul, (2004) [26]. This heightened growth spurred demand for expanding extensive areas to accommodate various purposes, including housing, commercial ventures, industrial activities, and other land uses. Consequently, the imperative for sustainable urban planning has become increasingly urgent, necessitating concerted efforts from governmental bodies and municipal authorities like Al-But'hie and Eben Saleh (2002) [27]. On the other hand, using effective urban planning methods in municipalities naturally leads to sustainable city planning, which may entail significant costs and require substantial efforts to rectify later on. Conventional analytical approaches such as statistical analysis, geographic information systems (GIS), and literature review are now inadequate for comprehending the vast amount of data and reports accessible by Peng et al. [28]. AI-powered geospatial analysis can provide insights into spatial patterns and relationships within the city area. Geographic Information Systems (GIS) combined with machine learning algorithms can help identify areas with high needs or vulnerabilities, optimize resource allocation, and plan infrastructure projects effectively. Gao & S. (2021) [29] wrote bibliographical highlights of up to ten significant recent works, accompanied by brief annotations detailing their relevance across a spectrum of GeoAI topics. These topics encompass fundamental spatial representation learning, spatial predictions, and advancements in cartography, earth observation, social sensing, and geospatial semantics.

Artificial Intelligence (AI) can be crucial in avoiding ineffective urban planning methods and promoting sustainable city planning in municipalities. Urban artificial intelligence refers to artificial intelligence integrated into urban environments and infrastructure Yigitcanlar et al. (2020) [30]. The emergence of urban big data presents fresh possibilities for enhancing various facets of urban life. This wealth of data underscores its potential utility in facilitating informed decision-making for resource optimization. Moreover, technological advancements like the Internet of Things,

artificial intelligence, and machine learning can significantly enhance this endeavor, enabling researchers and planners to conduct comprehensive and precise urban analyses Kamrowska-Załuska, Dorota. 2021 [31]. [31] explores the potential of AI-based tools and urban big data to bolster city design and planning. Additionally, it offers a conceptual contribution by examining the role of urban big data analytics using AI-based tools in modeling urban transformations.

AI can support urban planners in making informed decisions regarding land use, zoning regulations, and infrastructure development. By analyzing demographic data, economic trends, and environmental factors, AI systems can help municipalities plan for sustainable growth and development. Machine learning algorithms have been implemented in the preliminary design of various engineering structures. These methods aid current engineering practices by extracting insights from existing engineering design projects alongside expert knowledge My et al. (2001) [32]. Jootoo, A & Lattanzi, D (2017) [33].

AI algorithms have the capacity to analyze extensive volumes of data related to urban development, including population demographics, infrastructure usage, transportation patterns, and environmental factors. By processing this data, AI can provide insights into current and future urban needs, enabling better-informed decision-making in urban planning. AI can gather the following data for urban design and planning: Regional linkages and polycentric spatial structure analyses, Urban spatial structure and dynamic analyses, Urban flows analyses, Urban morphology analyses, and Analyses of the behavior and opinion of urban dwellers Kamrowska-Załuska, Dorota. 2021 [31]. In Ho Chi Minh City (HCMC), Vietnam, machine learning algorithms autonomously identify and categorize various land cover and land use types over different periods, producing insightful analytics and visualizations. This supervised machine learning method involves training computers to recognize specific features in satellite imagery using reference or training data. [34]

AI-powered predictive modeling can forecast future trends and scenarios, helping planners anticipate challenges and opportunities in urban development. This proactive approach allows municipalities to implement preventive measures and adapt their plans to mitigate potential risks, promoting sustainability. AI can sift through extensive datasets from diverse outlets and pinpoint trends and optimal locations for forthcoming land-use planning endeavors. This process involves evaluating potential sites for designated land uses, factoring in infrastructure, transportation, environmental implications, and local regulations. Additionally, AI facilitates the modeling and prediction of nonlinear urban land dynamics. AI can propose zoning recommendations by analyzing traffic flow, population density, and economic goals.

Furthermore, it can forecast future urban expansion patterns and economic shifts, ensuring the viability of future zoning strategies. AI-driven simulations offer insights into the probable outcomes of proposed zoning modifications. AI can predict the effects of modifications to zoning regulations or enhancements in public transportation on housing affordability or traffic patterns Yan, Liu, and Zhao (2020) [35]. Additionally, AI is utilized to anticipate land-use shifts Aburas et al. (2019) [36]. AI can support urban planners in examining various scenarios for future urban growth. For example, it can produce virtual simulations of potential development initiatives, assisting planners in envisioning the consequences of these projects on the neighboring environment Liang et al. (2018) [37]. Furthermore, planners can utilize AI methodologies such as computer-aided design and digital twins to simulate alternative scenarios, enhancing urban planning and design while emphasizing sustainability and resilience (Deng et al. (2021) [38]; Quan et al. (2019) [39].

4.5. Predicting the Productivity of Municipality Workers

Bijalwan et al. (2024) [40] propose a machine learning approach to predict and evaluate the productivity of municipality workers of Uttarakhand state in India. Corbett et al. (2023) [41] explore the Danish municipality initiative to create an algorithmic tool aiming to enhance the efficiency of public job placement services. They perceived the current process as subjective and needing measurable success metrics. The algorithm aims to provide concrete value metrics, aiding caseworkers in decision-making for improved outcomes.

4.6. Traffic Management

AI-powered systems can analyze real-time traffic data to optimize traffic flow, reduce congestion, and improve road safety. This can include implementing intelligent traffic signal control systems, dynamic routing algorithms, and predictive maintenance for traffic infrastructure. Singapore's Land Transport Authority (LTA) has effectively utilized data analytics and artificial intelligence to forecast traffic flow and precisely anticipate congestion by utilizing sensors, cameras, and GPS devices that actively monitor real-time traffic conditions. A dynamic traffic signal control system adjusts timings in response to the prevailing traffic conditions Huiling & Goh (2017) [42].

4.7. Public Input and Engagement

Rather than employing traditional data collection methods, municipalities can utilize a modern approach—namely, social media analysis. Social media platforms, continually evolving spaces where individuals share their thoughts and opinions, have emerged as a novel source of qualitative data Kankanamge et al. (2019) [43]. Increasingly, this method has become the primary data source for numerous studies, providing an opportunity to engage with broader audiences in an impartial environment Kankanamge et al. (2020) [44]. Nordic municipalities used AI to communicate with citizens, such as sorting inquiries or answering questions using chatbots [45]. Sentiment Analysis is the computationally identifying and categorizing opinions expressed in a text. Ravi et al. (2015) [46] Utilize sentiment analysis algorithms to process data from social media, surveys, and community feedback. This can provide insights into public sentiment, concerns, and priorities, aiding in developing citizen-centric strategic plans. Rauscher, M. (2021) [47] answers the question of How municipalities can benefit by using IoT and AI with geodata to enhance their services. In his research in the City of Vienna, he found that implementing AI in municipalities yields numerous advantages, including enhanced efficiency, improved data quality and completeness, increased accuracy in forecasts, facilitated data-driven decision-making, standardized processes, and significant time savings.

Artificial Intelligence (AI) is revolutionizing the finance industry by automating processes, enhancing decision-making, and improving customer experiences. AI algorithms analyze vast amounts of financial data at speeds impossible for humans, enabling accurate predictions, risk assessments, and fraud detection. AI revolutionizes accounting with automated data entry, expense management, and financial forecasting. It detects fraud, automates audits, and streamlines tax preparation. AI tools generate financial reports, manage cash flow, and assess credit risk. Continuous accounting processes are accelerated through AI, improving efficiency and accuracy. AI transforms accounting, enabling faster decision-making and compliance while reducing manual effort and errors in financial tasks. [48-51]

5. Conclusions and Recommendations

This paper explores the potential benefits of using AI in municipalities in Saudi Arabia. This research identifies areas where AI can enhance municipal operations, improve citizen engagement, and revolutionize municipal operations. Integrating artificial intelligence (AI) technologies in municipal services within Saudi Arabia offers significant potential benefits. The document emphasizes the transformative impact of AI on service enhancement, delivery, and community empowerment in the context of Saudi Arabian society. It identifies areas where AI can enhance municipal operations, improve citizen engagement, and revolutionize municipal operations, including intelligent infrastructure management, traffic optimization, waste management, and citizen services. The study also underscores the imperative for municipalities in Saudi Arabia to embrace AI despite challenges related to data privacy concerns, regulatory constraints, workforce readiness, and institutional barriers. The paper provides valuable insights for policymakers, urban planners, and municipal administrators on harnessing the transformative potential of AI to create more innovative, sustainable, and resilient cities for the future.

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