World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Review Article)

GIS in healthcare facility planning and management: A review

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World Journal of Advanced Research and Reviews, 2024, 21(01), 012–019

Publication history: Received on 20 November 2023; revised on 28 December 2023; accepted on 30 December 2023

Article DOI: https://doi.org/10.30574/wjarr.2024.21.1.2682

Abstract

This paper explores the transformative role of Geographic Information Systems (GIS) in healthcare facility planning and management. Tracing the historical evolution, theoretical frameworks, applications, benefits, and challenges of GIS reveals its pivotal contribution to spatially informed decision-making. GIS optimizes resource allocation, enhances accessibility, and streamlines facility management. The integration with emerging technologies, including AI and IoT, propels healthcare infrastructure into an era of predictive modelling and real-time analytics. Addressing challenges such as data quality, privacy, and integration complexities requires comprehensive policies. Looking ahead, GIS in healthcare promises innovations like augmented reality and advanced remote sensing technologies, fostering resilient, patient-centric healthcare ecosystems. This abstract encapsulates the journey of GIS in healthcare, emphasizing its potential to revolutionize the spatial frontier of healthcare planning and management.

Keywords: Geographic Information Systems; Healthcare Facility Planning; Spatial Analysis

1. Introduction

The healthcare landscape is dynamic, marked by evolving demographic patterns, technological advancements, and the ever-increasing demand for accessible, efficient, and high-quality healthcare services (Coughlin, 2021; Tabish & Nabil, 2015). The strategic planning and management of healthcare facilities play a pivotal role in meeting these demands and ensuring the delivery of optimal patient care(Ginter, Duncan, & Swayne, 2018; Organization, 2018). Geographic Information Systems (GIS) have emerged as a transformative tool in this context, offering a spatially informed approach to healthcare facility planning and management (M. N. K. Boulos, 2004). This review seeks to explore and analyze the role of GIS in healthcare facility planning and management, shedding light on its historical evolution, theoretical underpinnings, applications, benefits, challenges, and future trends.

As populations grow and age, the pressure on healthcare systems intensifies, necessitating the strategic allocation of resources to meet diverse and complex healthcare needs (Hanlon & Halseth, 2005; McMaughan, Oloruntoba, & Smith, 2020). Healthcare facility planning involves the strategic assessment of locations for new facilities, the optimization of existing infrastructure, and the equitable distribution of healthcare resources (Mitropoulos, Mitropoulos, Giannikos, & Sissouras, 2006; Zhang, Cao, Liu, & Huang, 2016). Effective facility management, on the other hand, requires a nuanced understanding of spatial dynamics to enhance workflow efficiency, optimize resource allocation, and ensure the seamless delivery of healthcare services (Hardin & McCool, 2015; Rane, 2023a). Historically, healthcare facility planning relied on conventional methods that often lacked the spatial precision required to make informed decisions. The advent

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of GIS technology marked a paradigm shift in this field, providing a spatially intelligent framework for understanding the geographical nuances of healthcare provision. GIS facilitates the integration of diverse data sets, including demographic information, transportation networks, and environmental factors, enabling healthcare professionals and planners to make well-informed decisions based on a comprehensive spatial analysis.

The primary objective of this review is to comprehensively examine the role of GIS in healthcare facility planning and management. By delving into the existing body of literature, we aim to trace the historical evolution of GIS in healthcare, explore theoretical frameworks underpinning GIS in healthcare, examine applications in healthcare facility planning, and evaluate GIS in healthcare facility management. While this review aims to provide a comprehensive overview of GIS in healthcare facility planning and management, it is important to acknowledge its limitations. The scope is primarily focused on existing literature and may not encompass the latest developments in the field. Additionally, the review may not cover every subdomain of healthcare facility planning and management but rather aims to provide a broad understanding of the role GIS plays in this context.

In the subsequent sections, we will delve into the historical evolution of GIS in healthcare, explore the theoretical underpinnings, and analyze its applications in both facility planning and management. The review will also address the benefits and challenges associated with GIS implementation in healthcare settings, offering a nuanced perspective on the transformative potential of this technology.

2. Literature Review

2.1. Historical Evolution of GIS in Healthcare Facility Planning and Management

The intersection of Geographic Information Systems (GIS) and healthcare facility planning has undergone a significant evolutionary journey, mirroring the technological advancements and changing paradigms in both GIS and healthcare. In the early stages, GIS applications were primarily confined to cartography and geographical analysis. However, with the increasing need for sophisticated tools to address complex healthcare challenges, the adoption of GIS in the healthcare sector has gained momentum.

In the 1980s and 1990s, GIS technology started to find applications in healthcare facility planning (Drummond & French, 2008; Khashoggi & Murad, 2020). Its early use was characterized by basic mapping and analysis functionalities, providing healthcare professionals with tools to visualize the geographical distribution of healthcare facilities and patient populations. This laid the foundation for more advanced applications in subsequent decades (M. K. Boulos, Roudsari, & Carson, 2001; Davenhall & Kinabrew, 2012).

The 2000s witnessed a notable shift toward the integration of GIS into broader healthcare information systems. The emphasis moved beyond mere spatial representation to incorporating data analytics, allowing for more robust decision-making in healthcare facility planning and management. GIS became an essential component in assessing the geographical accessibility of healthcare services and optimizing resource allocation. In recent years, the evolution of GIS in healthcare has been propelled by advancements in data collection technologies, such as remote sensing and the integration of real-time data streams. This has enabled healthcare planners to make more informed decisions based on dynamic and up-to-date spatial information (Blaschke, Hay, Weng, & Resch, 2011; Safari Bazargani, Sadeghi-Niaraki, & Choi, 2021; Weng, 2010).

2.2. Theoretical Frameworks Underpinning GIS in Healthcare

Several theoretical concepts and frameworks underpin the integration of GIS in healthcare facility planning and management. One fundamental framework is the Spatial Analysis in Health Geography model, which emphasizes the spatial relationships between healthcare facilities and their catchment areas. This model provides a foundation for understanding how GIS can be used to analyze spatial patterns of diseases, identify healthcare service gaps, and plan for optimal facility locations.

The Andersen Behavioral Model of Health Services Utilization is another relevant theoretical framework (Von Lengerke, Gohl, & Babitsch, 2013; Yang & Hwang, 2016). It considers individual, environmental, and healthcare system factors influencing healthcare utilization. GIS, when integrated with this model, facilitates a spatial understanding of these factors, contributing to more effective healthcare facility planning. Additionally, the Ecological Model, which recognizes the interplay between individual, interpersonal, organizational, community, and policy factors, can be applied to GIS in healthcare. By incorporating these layers into spatial analyses, GIS helps identify multi-level determinants affecting healthcare facility planning and management (Babitsch, Gohl, & Von Lengerke, 2012; Phillips, Morrison, Andersen, & Aday, 1998; SoleimanvandiAzar et al., 2020).

2.3. Applications of GIS in Healthcare Facility Planning

GIS has revolutionized healthcare facility location analysis and selection by offering a spatially informed approach. By integrating demographic data, disease prevalence, and accessibility factors, GIS aids in identifying optimal locations for new healthcare facilities. For example, GIS can help determine areas with underserved populations, high disease burdens, or inadequate healthcare infrastructure. GIS optimizes resource allocation by providing a comprehensive understanding of the geographical distribution of healthcare resources . Through spatial analysis, healthcare planners can identify areas with resource deficiencies and allocate resources more equitably. Furthermore, GIS enhances accessibility by analyzing travel times, transportation networks, and geographic barriers, ensuring that healthcare services are geographically accessible to diverse populations (Neutens, 2015; Verma & Dash, 2020; Yerramilli & Fonseca, 2014).

GIS plays a vital role in healthcare facility management by enhancing operational efficiency. For maintenance, GIS helps track the spatial distribution of assets, schedule maintenance tasks, and monitor equipment conditions. In terms of security, GIS enables the mapping of security incidents, surveillance camera locations, and emergency response plans, contributing to a safer healthcare environment. Workflow optimization is facilitated through spatial analysis of patient flows, enabling better organization of spaces and resources for efficient healthcare delivery (Lee et al., 2015; Vissers, 2005).

The synergy between GIS and other cutting-edge technologies is reshaping healthcare facility planning and management. The integration of the Internet of Things (IoT) with GIS allows real-time monitoring of medical equipment, patient vital signs, and environmental conditions. Big Data analytics, when combined with GIS, provides a deeper understanding of healthcare trends and supports evidence-based decision-making. Artificial Intelligence (AI) enhances GIS capabilities by automating spatial analyses, predicting healthcare resource needs, and optimizing facility workflows (Babitsch et al., 2012; Rane, 2023a, 2023b).

In conclusion, the historical evolution of GIS in healthcare facility planning and management has been marked by a transformative journey from basic mapping applications to sophisticated spatial analytics. The theoretical frameworks that underpin GIS applications in healthcare provide a conceptual foundation for understanding spatial dynamics and their impact on healthcare utilization. The diverse applications of GIS, ranging from facility location analysis to resource optimization and facility management, highlight its integral role in the healthcare sector. Moreover, the integration of GIS with other technologies, such as IoT, Big Data, and AI, propel healthcare facility planning and management into a new era of data-driven decision-making. As GIS continues to evolve and integrate with emerging technologies, its potential to address complex healthcare challenges and enhance patient outcomes becomes increasingly evident. This review sets the stage for a deeper exploration of specific case studies and methodologies, which will further illuminate the practical implications of GIS in healthcare facility planning and management.

3. Benefits and Challenges

GIS have emerged as powerful tools in healthcare facility planning and management, offering numerous benefits while presenting certain challenges that require careful consideration.

3.1. Benefits

GIS empowers healthcare professionals with spatial analysis tools, enabling them to make well-informed decisions. By overlaying various spatial data layers, such as population distribution, disease prevalence, and environmental factors, planners gain valuable insights into the geographical nuances influencing healthcare facility planning. This spatial intelligence facilitates strategic decision-making in selecting optimal locations for new facilities and allocating resources efficiently.

One of the primary advantages of GIS in healthcare is its ability to optimize resource allocation. By integrating demographic data and healthcare service utilization patterns, GIS assists in identifying areas with underserved populations (Khashoggi & Murad, 2020; Robin et al., 2019). This ensures that healthcare resources, including personnel and equipment, are strategically distributed to address the specific needs of different communities, ultimately improving overall healthcare accessibility. GIS contributes to improved accessibility by analyzing travel times, transportation networks, and geographic barriers. Planners can identify areas with limited access to healthcare facilities and devise strategies to enhance accessibility. This is particularly crucial in rural or remote areas where geographical factors may pose challenges to healthcare service delivery. GIS facilitates the development of efficient transportation routes and helps bridge gaps in healthcare access(Clift, Scott, Johnson, & Gonzalez, 2014; Li, Vo, Randhawa, & Fick, 2017; E. Ukwajunor & Akarawak, 2018; Walsh, Page, & Gesler, 1997).

In facility management, GIS plays a crucial role in enhancing operational efficiency. By mapping and tracking the spatial distribution of assets, such as medical equipment and facilities, GIS assists in maintenance scheduling and asset management. It also contributes to security measures by mapping surveillance camera locations, emergency response plans, and incidents, ensuring a safe healthcare environment. Workflow optimization is achieved through spatial analysis of patient flows, leading to more effective and organized healthcare delivery (Mokgalaka, 2015). GIS integration with emerging technologies, such as the Internet of Things (IoT), Big Data, and Artificial Intelligence (AI), amplifies its capabilities. IoT allows real-time monitoring of medical equipment and environmental conditions, while Big Data analytics provides deeper insights into healthcare trends. AI enhances GIS by automating spatial analyses, predicting resource needs, and optimizing facility workflows. This integration propels healthcare facility planning and management into a more advanced and data-driven era.

3.2. Challenges

The effectiveness of GIS is highly dependent on the quality and standardization of data. Inconsistencies, inaccuracies, or lack of standardized formats in spatial datasets can compromise the reliability of analyses and decision-making. Maintaining data accuracy and ensuring interoperability between different data sources remain ongoing challenges. The initial cost of implementing GIS infrastructure and providing training for healthcare professionals can be a substantial barrier. Small healthcare facilities or those with limited budgets may find it challenging to invest in GIS technology. Additionally, ongoing training is essential to keep healthcare staff updated on GIS applications and methodologies, adding to the overall cost.

The integration of GIS with healthcare data raises privacy and ethical considerations. The mapping of patient data and healthcare facilities requires robust security measures to protect sensitive information. Striking a balance between utilizing GIS for improved healthcare outcomes and safeguarding patient privacy remains a critical challenge. While GIS provides powerful spatial analysis tools, the complexity of these analyses can be a challenge for healthcare professionals who may not have extensive training in GIS methodologies. Simplifying the user interface and providing user-friendly tools are essential to ensuring widespread adoption and effective use. Integrating GIS with existing healthcare information systems can be challenging due to differences in data formats, standards, and software compatibility. Seamless integration is crucial for a cohesive and efficient healthcare ecosystem (Beirão, Patrício, & Fisk, 2017; Eunice E Ukwajunor, Akarawak, & Abiala, 2021).

In conclusion, the benefits of GIS in healthcare facility planning and management are substantial, ranging from informed decision-making to optimized resource allocation and enhanced accessibility. However, addressing challenges related to data quality, implementation costs, privacy concerns, spatial analysis complexity, and system integration is vital to maximizing the potential of GIS in the healthcare sector. As technology continues to advance, finding innovative solutions to these challenges will be crucial for realizing the full benefits of GIS in shaping the future of healthcare facility planning and management.

4. Future Trends and Innovations

The landscape of Geographic Information Systems (GIS) in healthcare facility planning and management is poised for transformative advancements driven by emerging technologies and evolving healthcare needs. Several future trends and innovations are expected to shape the way GIS is utilized in optimizing healthcare infrastructure. The future of GIS in healthcare lies in the integration of real-time spatial analytics. This entails the continuous monitoring and analysis of dynamic spatial data, allowing healthcare professionals to respond swiftly to changing conditions. Real-time GIS can enhance situational awareness during public health crises, natural disasters, or disease outbreaks, enabling effective and timely decision-making.

The integration of predictive modelling and artificial intelligence (AI) with GIS will play a pivotal role in forecasting healthcare resource needs. AI algorithms, fueled by large datasets and historical patterns, can predict future healthcare demands. This integration facilitates proactive planning, enabling healthcare facilities to anticipate and address emerging challenges. Augmented Reality is poised to revolutionize the design and navigation of healthcare facilities. By overlaying digital information onto the physical environment, AR can aid architects and planners in visualizing and optimizing the layout of healthcare facilities. Additionally, AR applications can enhance navigation within healthcare facilities, providing patients and staff with interactive and intuitive guidance.

The integration of blockchain technology addresses critical concerns related to data security and interoperability. Blockchain ensures the integrity and security of spatial data by creating an immutable and transparent ledger. This technology can streamline data sharing among different healthcare entities, promoting interoperability while maintaining the privacy and security of sensitive information. Mobile GIS applications will become increasingly prevalent for field data collection and real-time updates. Healthcare professionals can utilize mobile devices to collect spatial data on-site, improving the accuracy and efficiency of data collection. This enhances the responsiveness of healthcare systems to changing conditions and facilitates more agile decision-making (Montella, Chiaradonna, Criscuolo, & De Martino, 2019; Omar & Nehdi, 2016).

The concept of digital twins, creating virtual replicas of physical spaces, will find application in healthcare facility planning. This technology allows planners to simulate and optimize various scenarios before implementing changes in the physical environment. Digital twins enable a more thorough understanding of how alterations will impact workflows, resource allocation, and overall facility functionality. Continued advancements in remote sensing technologies, such as satellite imagery and aerial drones, will provide a wealth of spatial data for healthcare planning. These technologies can offer insights into environmental factors, population dynamics, and disease patterns, contributing to a more holistic understanding of the spatial context in healthcare facility planning (E. Ukwajunor, Akarawak, Abiala, & Adebayo, 2020; Eunice Egonmwan Ukwajunor, Adebayo, & Gayawan, 2023).

In the future, the convergence of these trends and innovations is likely to propel GIS in healthcare facility planning and management to new heights. The ability to harness real-time data, predictive modelling, and advanced technologies will empower healthcare professionals to create more resilient, adaptable, and patient-centric healthcare infrastructures. As these innovations continue to unfold, the synergy between GIS and emerging technologies will shape the future of healthcare facility planning, optimizing resources and improving healthcare outcomes on a global scale.

4.1. Policy Implications

The integration of Geographic Information Systems (GIS) into healthcare facility planning and management necessitates careful consideration of policy implications to maximize the benefits and address potential challenges. Policies play a crucial role in shaping the framework for the effective utilization of GIS in the healthcare sector.

Data Governance and Standards: Policies should establish robust data governance frameworks to ensure the quality, integrity, and interoperability of spatial data. Standardization of data formats and sharing protocols is essential to facilitate seamless collaboration among different healthcare entities. Clear policies regarding data ownership, consent, and security are imperative to safeguard patient information and maintain public trust (Papoutsi et al., 2015).

Privacy and Ethical Guidelines: Given the sensitive nature of healthcare data, policies must articulate clear privacy and ethical guidelines governing the use of GIS. Mechanisms for de-identification, informed consent, and secure data storage should be defined to protect patient confidentiality. Policies should also address potential biases in spatial analyses to ensure equitable healthcare planning and resource allocation (Tsofa, Molyneux, Gilson, & Goodman, 2017).

Capacity Building and Training: To harness the full potential of GIS, policies should emphasize capacity building and training programs for healthcare professionals. Ensuring that staff members are proficient in GIS methodologies and technologies is essential for successful implementation. Continuous training programs can help healthcare professionals stay updated on evolving GIS applications and best practices (Collins & Mitchell, 2019).

Interagency Collaboration: Policies should encourage and facilitate interagency collaboration to enhance the sharing of spatial data and promote a holistic approach to healthcare facility planning. Collaboration between health departments, planning authorities, and technology agencies can foster a comprehensive understanding of spatial dynamics and improve the overall efficiency of healthcare systems (Kidd, 2007).

Accessibility and Equity: Policies should prioritize accessibility and equity in healthcare facility planning. This involves addressing disparities in healthcare access and resource distribution. GIS can be a powerful tool for identifying underserved populations and areas lacking adequate healthcare infrastructure. Policies should guide the use of GIS to promote equitable access to quality healthcare services (Rosero-Bixby, 2004).

Regulatory Framework for Emerging Technologies: As GIS integrates with emerging technologies like IoT, AI, and Blockchain, policies should establish a regulatory framework to govern their implementation. This includes ensuring data security, preventing misuse, and promoting transparency in the deployment of these technologies in healthcare facility planning and management (Yao, Chu, & Li, 2012).

Community Engagement and Communication: Policies should encourage community engagement in healthcare planning processes facilitated by GIS. Transparent communication about the use of spatial data, its implications, and the benefits to the community fosters trust and ensures that the public is well-informed and involved in decision-making processes.

In conclusion, well-crafted policies are essential to guide the ethical, secure, and equitable utilization of GIS in healthcare facility planning and management. By addressing data governance, privacy, capacity building, collaboration, accessibility, and the regulatory framework for emerging technologies, policymakers can create an enabling environment for GIS to contribute positively to the future of healthcare infrastructure.

5. Conclusion

The integration of GIS into healthcare facility planning and management marks a significant stride towards a more informed, efficient, and patient-centric healthcare landscape. The journey through the historical evolution, theoretical frameworks, applications, benefits, challenges, and future trends reveals the transformative potential of GIS in shaping the future of healthcare infrastructure. GIS has evolved from basic mapping applications to sophisticated spatial analytics, offering healthcare professionals a comprehensive toolkit for strategic decision-making. The theoretical underpinnings, including spatial analysis models and ecological frameworks, provide a conceptual foundation for understanding the complex interplay of spatial dynamics in healthcare utilization.

The benefits of GIS are manifold, ranging from optimized resource allocation and enhanced accessibility to efficient facility management. As GIS integrates with emerging technologies like AI, IoT, and Blockchain, it opens new frontiers for predictive modelling, real-time analytics, and secure data interoperability. However, the journey is not without challenges. Data quality, privacy concerns, and integration complexities require careful consideration. Policy implications become paramount to guide ethical GIS use, ensuring equity, accessibility, and community engagement. Looking forward, GIS in healthcare holds the promise of real-time spatial analytics, augmented reality for facility design, and advanced remote sensing technologies. These innovations, coupled with robust policies, will further empower healthcare professionals to create resilient, adaptable, and patient-centric healthcare infrastructures.

In conclusion, GIS is not merely a technology; it is a dynamic force shaping the future of healthcare. As we navigate this spatial frontier, the judicious application of GIS, informed by robust policies and ethical considerations, holds the key to a healthcare ecosystem that is not only responsive to current needs but anticipates and addresses the challenges of tomorrow.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Babitsch, B., Gohl, D., & Von Lengerke, T. (2012). Re-revisiting Andersen's Behavioral Model of Health Services Use: a systematic review of studies from 1998–2011. *GMS Psycho-Social-Medicine, 9*.

[2] Beirão, G., Patrício, L., & Fisk, R. P. (2017). Value cocreation in service ecosystems: Investigating health care at the micro, meso, and macro levels. *Journal of Service Management, 28*(2), 227-249.

[3] Blaschke, T., Hay, G. J., Weng, Q., & Resch, B. (2011). Collective sensing: Integrating geospatial technologies to understand urban systems—An overview. *Remote Sensing, 3*(8), 1743-1776.

[4] Boulos, M. K., Roudsari, A. V., & Carson, E. R. (2001). Health geomatics: an enabling suite of technologies in health and healthcare. *Journal of Biomedical Informatics, 34*(3), 195-219.

[5] Boulos, M. N. K. (2004). Towards evidence-based, GIS-driven national spatial health information infrastructure and surveillance services in the United Kingdom. *International Journal of Health Geographics, 3*, 1-50.

[6] Clift, K., Scott, L., Johnson, M., & Gonzalez, C. (2014). Leveraging geographic information systems in an integrated health care delivery organization. *Perm J, 18*(2), 71-75.

[7] Collins, L., & Mitchell, J. T. (2019). Teacher training in GIS: what is needed for long-term success? *International Research in Geographical and Environmental Education, 28*(2), 118-135.

[8] Coughlin, J. (2021). Accessible Health: An Evidenced Based Approach to Improve User Experience and Clinical Sustainability within Rural Healthcare.

[9] Davenhall, W. F., & Kinabrew, C. (2012). GIS in health and human services. *Springer handbook of geographic information*, 557-578.

[10] Drummond, W. J., & French, S. P. (2008). The future of GIS in planning: Converging technologies and diverging interests. *Journal of the American Planning Association, 74*(2), 161-174.

[11] Ginter, P. M., Duncan, W. J., & Swayne, L. E. (2018). *The strategic management of health care organizations*: John Wiley & Sons.

[12] Hanlon, N., & Halseth, G. (2005). The greying of resource communities in northern British Columbia: implications for health care delivery in already-underserviced communities. *Canadian Geographer/Le Géographe canadien, 49*(1), 1-24.

[13] Hardin, B., & McCool, D. (2015). *BIM and construction management: proven tools, methods, and workflows*: John Wiley & Sons.

[14] Khashoggi, B. F., & Murad, A. (2020). Issues of healthcare planning and GIS: a review. *ISPRS International Journal of Geo-Information, 9*(6), 352.

[15] Kidd, S. (2007). Towards a framework of integration in spatial planning: an exploration from a health perspective. *Planning Theory & Practice, 8*(2), 161-181.

[16] Lee, E. K., Atallah, H. Y., Wright, M. D., Post, E. T., Thomas IV, C., Wu, D. T., & Haley Jr, L. L. (2015). Transforming hospital emergency department workflow and patient care. *Interfaces, 45*(1), 58-82.

[17] Li, Y., Vo, A., Randhawa, M., & Fick, G. (2017). Designing utilization-based spatial healthcare accessibility decision support systems: A case of a regional health plan. *Decision Support Systems, 99*, 51-63.

[18] McMaughan, D. J., Oloruntoba, O., & Smith, M. L. (2020). Socioeconomic status and access to healthcare: interrelated drivers for healthy aging. *Frontiers in public health, 8*, 231.

[19] Mitropoulos, P., Mitropoulos, I., Giannikos, I., & Sissouras, A. (2006). A biobjective model for the locational planning of hospitals and health centers. *Health Care Management Science, 9*, 171-179.

[20] Mokgalaka, H. (2015). *GIS-based analysis of spatial accessibility: an approach to determine public primary healthcare demand in metropolitan areas.* University of Cape Town,

[21] Montella, A., Chiaradonna, S., Criscuolo, G., & De Martino, S. (2019). Development and evaluation of a web-based software for crash data collection, processing and analysis. *Accident Analysis & Prevention, 130*, 108-116.

[22] Neutens, T. (2015). Accessibility, equity and health care: review and research directions for transport geographers. *Journal of Transport Geography, 43*, 14-27.

[23] Omar, T., & Nehdi, M. L. (2016). Data acquisition technologies for construction progress tracking. *Automation in Construction, 70*, 143-155.

[24] Organization, W. H. (2018). *Delivering quality health services: A global imperative*: OECD Publishing.

[25] Papoutsi, C., Reed, J. E., Marston, C., Lewis, R., Majeed, A., & Bell, D. (2015). Patient and public views about the security and privacy of Electronic Health Records (EHRs) in the UK: results from a mixed methods study. *BMC medical informatics and decision making, 15*, 1-15.

[26] Phillips, K. A., Morrison, K. R., Andersen, R., & Aday, L. A. (1998). Understanding the context of healthcare utilization: assessing environmental and provider-related variables in the behavioral model of utilization. *Health services research, 33*(3 Pt 1), 571.

[27] Rane, N. (2023a). Integrating Building Information Modelling (BIM) and Artificial Intelligence (AI) for Smart Construction Schedule, Cost, Quality, and Safety Management: Challenges and Opportunities. *Cost, Quality, and Safety Management: Challenges and Opportunities (September 16, 2023)*.

[28] Rane, N. (2023b). Role of ChatGPT and Similar Generative Artificial Intelligence (AI) in Construction Industry. *Available at SSRN 4598258*.

[29] Robin, T., Khan, M. A., Kabir, N., Rahaman, S. T., Karim, A., Mannan, I. I., . . . Rashid, I. (2019). Using spatial analysis and GIS to improve planning and resource allocation in a rural district of Bangladesh. *BMJ Global Health, 4*(Suppl 5), e000832.

[30] Rosero-Bixby, L. (2004). Spatial access to health care in Costa Rica and its equity: a GIS-based study. *Social science & medicine, 58*(7), 1271-1284.

[31] Safari Bazargani, J., Sadeghi-Niaraki, A., & Choi, S.-M. (2021). A survey of gis and iot integration: Applications and architecture. *Applied Sciences, 11*(21), 10365.

[32] SoleimanvandiAzar, N., Kamal, S. H. M., Sajjadi, H., Harouni, G. G., Karimi, S. E., Djalalinia, S., & Forouzan, A. S. (2020). Determinants of outpatient health service utilization according to Andersen's Behavioral Model: A systematic scoping review. *Iranian Journal of Medical Sciences, 45*(6), 405.

[33] Tabish, S., & Nabil, S. (2015). Future of healthcare delivery: Strategies that will reshape the healthcare industry landscape. *International Journal of Science and Research, 4*(2), 727-758.

[34] Tsofa, B., Molyneux, S., Gilson, L., & Goodman, C. (2017). How does decentralisation affect health sector planning and financial management? a case study of early effects of devolution in Kilifi County, Kenya. *International journal for equity in health, 16*(1), 1-12.

[35] Ukwajunor, E., & Akarawak, E. (2018). MODEL SELECTION TECHNIQUES WITH APPLICATION TO PREDICTING THE DELIVERY WEEK OF A CURRENT PREGNANCY. *UNILAG Journal of Medicine, Science and Technology, 6*(2), 125-134.

[36] Ukwajunor, E., Akarawak, E., Abiala, I., & Adebayo, S. (2020). Weighted Logistic Regression Modelling of Prevalence and Associated Risk Factors of Malaria in Nigeria. *Annals of Statistical Theory and Applications (ASTA), 3*, 126-141.

[37] Ukwajunor, E. E., Adebayo, S. B., & Gayawan, E. (2023). Spatio-temporal modelling of severity of malnutrition and its associated risk factors among under five children in Nigeria between 2003 and 2018: Bayesian multilevel structured additive regressions. *Statistical Methods & Applications*, 1-35.

[38] Ukwajunor, E. E., Akarawak, E. E., & Abiala, I. O. (2021). Mathematical modeling of the impact of temperature variations and immigration on malaria prevalence in Nigeria. *International Journal of Biomathematics, 14*(08), 2150067.

[39] Verma, V. R., & Dash, U. (2020). Geographical accessibility and spatial coverage modelling of public health care network in rural and remote India. *Plos one, 15*(10), e0239326.

[40] Vissers, J. (2005). *Health operations management: patient flow logistics in health care*: Routledge.

[41] Von Lengerke, T., Gohl, D., & Babitsch, B. (2013). Re-revisiting the Behavioral Model of Health Care Utilization by Andersen: a review on theoretical advances and perspectives. *Health care utilization in Germany: theory, methodology, and results*, 11-28.

[42] Walsh, S. J., Page, P. H., & Gesler, W. M. (1997). Normative models and healthcare planning: network-based simulations within a geographic information system environment. *Health services research, 32*(2), 243.

[43] Weng, Q. (2010). *Remote sensing and GIS integration*.

[44] Yang, P. Q., & Hwang, S. H. (2016). Explaining immigrant health service utilization: a theoretical framework. *Sage Open, 6*(2), 2158244016648137.

[45] Yao, W., Chu, C.-H., & Li, Z. (2012). The adoption and implementation of RFID technologies in healthcare: a literature review. *Journal of medical systems, 36*, 3507-3525.

[46] Yerramilli, S., & Fonseca, D. G. (2014). Assessing geographical inaccessibility to health care: Using GIS network based methods. *Public Health Research, 4*(5), 145-159.

[47] Zhang, W., Cao, K., Liu, S., & Huang, B. (2016). A multi-objective optimization approach for health-care facility location-allocation problems in highly developed cities such as Hong Kong. *Computers, Environment and Urban Systems, 59*, 220-230.