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A Web-Based GIS Application for Water Transmission Pipeline Construction Planning Projects in Kelantan using the System Development Life Cycle (SDLC) Framework

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Abstract

This study develops and evaluates a GIS-based web system for water transmission pipeline construction planning in Kelantan. It emphasises comprehensive planning, regulatory compliance, and enterprise GIS adoption to enhance safety. Using the System Development Life Cycle (SDLC), the study involved data collection from industry professionals, user requirement analysis, system testing, and deployment. The system improves visualisation, integrates multiple projects, and supports decision-making. Key features include a user-friendly interface, bookmarks, legend customisation, attribute table interaction, and project summaries. The findings demonstrate the strong potential of GIS web systems to improve efficiency, collaboration, and overall outcomes in infrastructure project management.

Keywords: GIS; Water pipeline; Project planning; Decision support

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1.0 Introduction

Water pipeline construction projects are intricate, extensive endeavours that require meticulous planning, coordinated implementation, and proficient management to ensure timely and cost-effective completion. These projects frequently entail conveying water over vast distances and varied terrain, requiring the segmentation of the construction corridor into manageable portions, or "spreads." Each spread is performed by specialised workgroups with dedicated teams, facilitating a sequential, uninterrupted workflow as crews transfer completed parts to the following teams (Sivakumar et al., 2021). This systematic methodology is crucial for addressing the scale and technical complexity inherent in pipeline construction.

Before physical construction, comprehensive preparatory work is necessary to lay a solid foundation for project success. The activities encompass surveys, feasibility studies, and thorough planning processes that assess social demands, development goals,

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environmental effects, and safety factors. A comprehensive construction plan is developed to synchronise technical specifications with stakeholder expectations, guaranteeing that potential risks and limitations are detected promptly and managed systematically. These preparation phases are essential for reducing uncertainty and facilitating informed decision-making during the project lifecycle.

Efficient oversight and regulation of construction progress are fundamental to successful project management. All stakeholders, including engineers, contractors, and project owners, must have a comprehensive understanding of the project's condition relative to the original plans, timeframes, and budgetary allocations. The general contractor is pivotal in conveying status reports and maintaining transparency among the project team, consultants, and owners. Historically, progress tracking relied heavily on manual data entry, which is laborious, time-consuming, and prone to human error. There is increasing recognition of the need for automated, digital solutions to improve accuracy, efficiency, and real-time oversight in construction monitoring.

In the realm of water pipeline construction projects in Kelantan, the persistent reliance on conventional systems, such as AutoCAD designs, during the pre-contract phase has been recognised as a substantial constraint. These tools offer disjointed, static perspectives on pipeline alignment, hindering planners from fully visualising the construction region. Consequently, projects in Nigeria, as elsewhere, are susceptible to delays, budget overruns, and unexpected technical complications due to design errors (Dosumu, 2018). The lack of a cohesive data management platform hinders the identification of design conflicts, route optimisation, and proper consideration of environmental and social limitations, therefore compromising decision-making (Zhao et al., 2019).

Moreover, drawing-based systems impede efficient collaboration among stakeholders, as information sharing and approval processes are sluggish and disjointed. The absence of integration diminishes productivity and intensifies coordination difficulties among planners, contractors, engineers, and regulatory agencies (Jawdat & Khalid, 2017). The limited capacity of these systems to integrate diverse data sources and conduct sophisticated analysis further limits planners' ability to evaluate feasibility, assess hazards, and optimise resource allocation (Behnam et al., 2016).

The proposed solution to these issues is the implementation of a web-based application utilising Geographical Information System (GIS) technology. This system would facilitate integrated data management, visualisation, and spatial analysis utilising geospatial datasets, including satellite imagery and terrain models, thus enhancing informed planning decisions (Azevedo et al., 2014). The GIS-based system enhances communication, coordination, and analytical capabilities among stakeholders by offering a centralised, collaborative platform with real-time updates and interactive mapping (Yap et al., 2021). Advanced spatial analyses would enhance environmental effect assessment, conflict identification, and route optimisation, resulting in more efficient and sustainable project outputs (Ahmed et al., 2018). The suggested method illustrates GIS technology's ability to enhance pre-contract planning and improve the performance of water pipeline construction projects in Kelantan.

2.0 Literature Review

Pipeline construction projects are widely regarded as complex, interdisciplinary endeavours that encompass planning, design, construction, and testing to ensure the safe transfer of commodities such as oil, natural gas, water, and sewage (Smith, 2018). These projects require specific technical skills, including route planning, ground excavation and preparation, pipeline installation, and system testing. Safety is a significant concern throughout the project lifespan, as hazardous materials and heavy machinery are frequently used, necessitating careful adherence to safety standards and regulatory regulations (Jones, 2016; Johnson, 2019).

Effective monitoring throughout the construction planning stage is critical to ensuring that project activities follow contractual timeframes and minimise delays or disturbances during execution. Pipeline and utility projects in metropolitan areas must consider public impacts, especially during excavation and dredging. Contractors must therefore obtain accurate information from relevant authorities regarding existing underground utilities before construction to avoid service disruptions and associated socioeconomic effects (DOSH, 2017). Planning and design efforts are the foundation of successful pipeline building projects. These steps include establishing the project scope, identifying the necessary resources and materials, and creating precise drawings and technical specifications to guide construction activities (Brown, 2017; Davis, 2018). Architects, engineers, and other domain experts often create such plans, which serve as a strategic roadmap for project implementation (Johnson, 2019).

However, actual studies show that poor planning and management can drastically reduce project performance. Poor coordination, frequent scope changes, design omissions, unclear project objectives, and the adoption of immature or incomplete designs have been cited as important causes of project delays and cost variations (Jawdat & Khalid, 2017; Dosumu, 2018). Furthermore, structural and architectural drawings are frequently the principal sources of design errors, owing to insufficient documentation and limited designer expertise, resulting in inaccuracies in contract documents and decreased project efficiency (Dosumu et al., 2017).

GIS-based systems are sophisticated computerised platforms that acquire, store, manage, analyse, and visualise spatial and geographical data to aid decision-making. These systems are widely used across disciplines, including mapping, urban planning, natural resource management, and environmental analysis. Prior research has shown that GIS-based systems support essential functions such as spatial data acquisition and storage, data manipulation and analysis using specialised tools, and the creation of maps and visual outputs that aid in the interpretation and communication of spatial information. Furthermore, GIS enables geographical analyses, such as distance and area computations, as well as the detection of spatial patterns and trends, which are essential for planning and operational tasks (Jones, 2016; Johnson, 2019).

Data quality is often considered the most important factor in a successful GIS-based system. It encompasses correctness, completeness, consistency, and reliability, all of which directly impact analytical results and decision validity. Kuffer et al. (2021) underlined the need to use high-quality geographic data to avoid analytical errors and misleading findings. As a result, GIS-based systems must include stringent data validation and management protocols. Equally vital is the system's user interface, which should be

intuitive and easy to use to support effective data access and manipulation. An effective interface shortens the learning curve and increases user productivity, thus boosting system usability (Chen & Liu, 2022).

GIS is widely used in water pipeline construction projects to improve planning, design, construction, and monitoring processes. Sivakumar et al. (2021) conducted a thorough review and found that GIS can help with route design, construction activity management, and pipeline maintenance monitoring. Empirical research suggests that using GIS can reduce project length and expenses while increasing efficiency and accuracy. Similarly, GIS-based decision-support systems have been developed to optimise pipeline route selection by incorporating parameters such as terrain, land use, and environmental constraints (Marcolouki et al., 2012).

A recent study has also identified the integration of GIS and Building Information Modelling (BIM) as a possible technique to enhance pipeline construction management. This connection enables more coordinated workflows, enhanced visualisation, and improved information exchange across project stages (Zhao et al., 2019). Despite these advantages, GIS-based systems face challenges such as data integration, data quality, software complexity, and resource constraints, which, if left unaddressed, can impede effective adoption.

Current studies have shown that web-GIS applications are practical for advanced water-pipeline planning, design, and decision support systems (Dongare et al., 2024; Saravani et al., 2024). Looking ahead, GIS-based pipeline construction systems will continue to evolve as new technical trends emerge. These include the integration of remote sensing technologies such as LiDAR, TLS, and aerial imagery (Zhang et al., 2023; Abd Hamid et al., 2024), the use of advanced analytics and machine learning for predictive modelling, the incorporation of real-time data and Internet of Things (IoT) sensors (Chen & Li, 2022), and the expansion of mobile, AI-MCDM-GIS applications (Zaini et al., 2019; Zaij Rashid et al., 2019; Jaafar et al., 2024; Othman et al., 2025). Collectively, these developments position GIS as a game-changing tool for increasing pipeline construction efficiency, productivity, and environmental sustainability.

3.0 Methodology

This study examines the use of GIS technology in water pipeline construction projects in Lati, Mundok, and Repek of Kelantan, Malaysia. The study aims to evaluate the impact of GIS technology on projects and its effectiveness in optimising outcomes and decision-making. The SDLC framework was applied in the study, comprising phases involving specific tasks and activities. The SDLC is consistent and repeatable, involving the creation, review, refinement, and approval of defined work products and documents. The phases were tailored to accommodate unique project aspects, as shown in Fig. 1.

Firstly, conducting requirement analysis and planning through questionnaire distribution. This user requirement analysis aims to capture the perspectives and expectations of various stakeholders, including project planners, engineers, contractors, and regulatory authorities. Through interviews, surveys, and workshops, their valuable input was documented and incorporated into the design and development of the proposed system. These 23 interviews were conducted in a structured manner, ensuring that all relevant topics were covered. Open-ended questions encourage stakeholders to share their insights and provide detailed feedback on the existing challenges they face in the planning phase of water pipeline construction projects.

The questionnaire comprises three sections: A, B, and C. Section A assesses the respondent's profile, while Section B evaluates the existing system for monitoring pipeline projects. Stakeholders provide information about their occupation, experience, and familiarity with GIS. Section B measures satisfaction and opinions using a Likert scale. Section C explores the proposed system, allowing stakeholders to provide detailed responses and insights into its features and potential benefits. The intention is to gather qualitative data and understand stakeholders' expectations, needs, and suggestions for improvement. Secondly is system design and development.

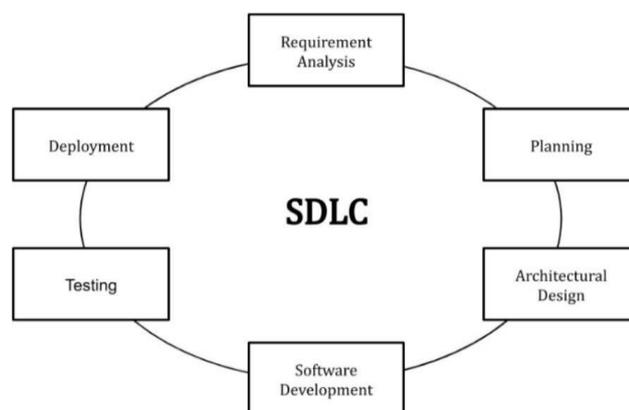


Fig. 1: SDLC Process for the System Development (TutorialsPoint, 2026).

Secondly is system design and development. Based on the gathered user requirements, the study focuses on designing and developing a GIS-based system for water pipeline construction planning. AutoCAD was used to process DWG data and create shapefiles for roads, pipes, and fittings. Web Mapper was used to upload AutoCAD-generated shapefiles into ArcGIS Online projects, while Web AppBuilder was used to build the system, providing a flexible, customisable environment for web applications. The system design considers the unique demands of water pipeline construction planning and incorporates modules, components, and data integration

requirements to meet stakeholder needs. The design process involves mapping functionality and workflows to ensure a seamless user experience. Lastly, system usability testing and deployment were applied to assess the performance and usability of the GIS-based system developed for water pipeline construction projects, and to conduct a comprehensive evaluation. A sample group of stakeholders, including project planners and engineers, participated in the testing phase. Usability tests assess the system's functionality, ease of use, and effectiveness in meeting planning needs. Stakeholders were provided access to the system and guided through tasks related to their roles. They were encouraged to perform tasks such as visualising spatial data, tracking project progress, managing risks, collaborating with stakeholders, and generating reports.

4.0 Result and Discussion

4.1 Examining User Requirements for Developing a Proposed GIS Web-Based System in Water Pipeline Construction Projects

The survey participants represented three primary stakeholder groups in construction projects: the client (AKSB), the contractor, and the consultant, with two respondents identifying as clients. This distribution emphasises clients' prominent involvement in project initiation and decision-making, as well as the value of their viewpoints in evaluating project planning systems. Contractors gave practical insights into project execution, whilst consultants provided professional knowledge in project management, cost control, and quality assurance, providing a balanced evaluation of planning procedures. In terms of experience, 50% of respondents reported 6-10 years in the construction sector, with the remainder having fewer than five years or more than ten years of experience. Notably, all respondents reported using semi-automatic planning tools, indicating a persistent reliance on hybrid manual-digital approaches to project planning.

The questionnaire results reveal that among the six respondents, 33.3% reported using Microsoft Excel as their primary system for project planning (Fig. 2). Microsoft Excel is a widely used spreadsheet program known for its data management and analysis capabilities, making it a popular choice across industries, including construction. Furthermore, one Respondent (16.7%) mentioned utilising M.Excel and ArcGIS in their planning project system. ArcGIS is GIS software that enables users to analyse and visualise spatial data, providing valuable insights into the project's geographical aspects.

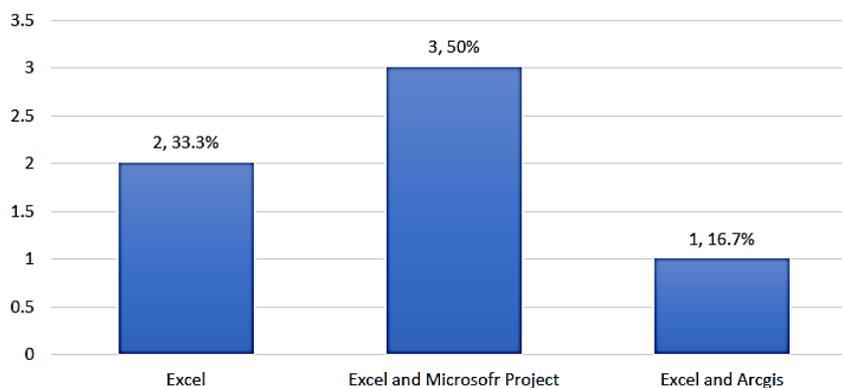


Fig. 2: State the System is Being Used for Planning the Project.

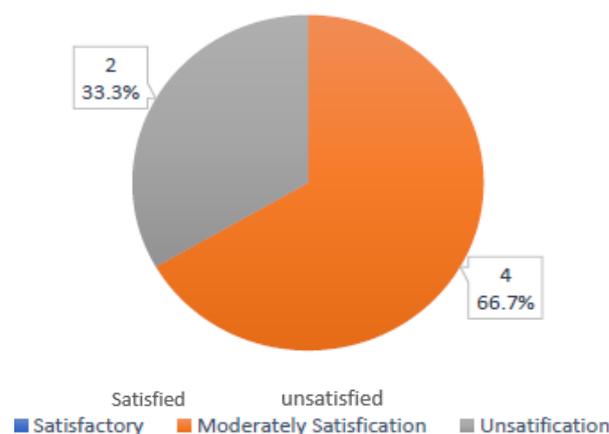


Fig. 3: Satisfaction Level on the Existing System for Planning Project.

Additionally, 50% of respondents used Excel and Microsoft Project for project planning. Microsoft Project is a comprehensive project management software that facilitates planning, scheduling, and tracking of project activities. These individuals can effectively manage

their projects by combining Excel's data management capabilities with Microsoft Project's specialised project planning features. In summary, the results indicate that Excel is the most commonly used project planning tool among respondents. However, additional software tools, such as ArcGIS and Microsoft Project, are also available, reflecting respondents' diverse needs and preferences based on their specific project requirements. Based on respondents' opinions of the existing project planning system, 66.7% of respondents consider it moderately satisfactory. This suggests that they have a certain level of satisfaction with the system. However, they also acknowledge areas for improvement (Fig. 3). On the other hand, 33.3% of respondents find the system unsatisfactory. This indicates they have identified significant issues or shortcomings with the current system that hinder its effectiveness.

Respondents have mixed perceptions of existing project planning systems, with most rating them as moderately satisfactory while acknowledging significant room for improvement. Those dissatisfied identify considerable issues that lead to unmet expectations. The current systems utilise M.Excel for database management and data collection, alongside Microsoft Project for project management. Notably, one respondent's integration with ArcGIS emphasises the need for spatial data and mapping. The feedback gathered indicates a necessity for continuous improvement to adapt to the construction industry's changing needs. The questionnaire on GIS criteria reveals varying levels of GIS integration in these systems, with data quality and user interface being critically assessed.

In contrast, integration with other systems, analysis capabilities, and scalability are less prominent (Fig. 4). These insights suggest crucial areas for improvement to enhance project planning systems and ensure better project outcomes. Regarding the potential application of GIS in the department and the staff's knowledge and skill in GIS applications, the six respondents (100%) had prior theoretical or practical experience with GIS, indicating widespread familiarity with the technology. In terms of proficiency, 50% of respondents claimed a high level of GIS knowledge, while the remaining 50% reported a moderate level, with no respondents indicating low knowledge. This demonstrates a satisfactory level of GIS proficiency among participants. Notably, all respondents (100%) agreed on the importance of GIS for pipeline management, emphasising its critical role in optimising operations, supporting regulatory compliance, and improving informed decision-making.

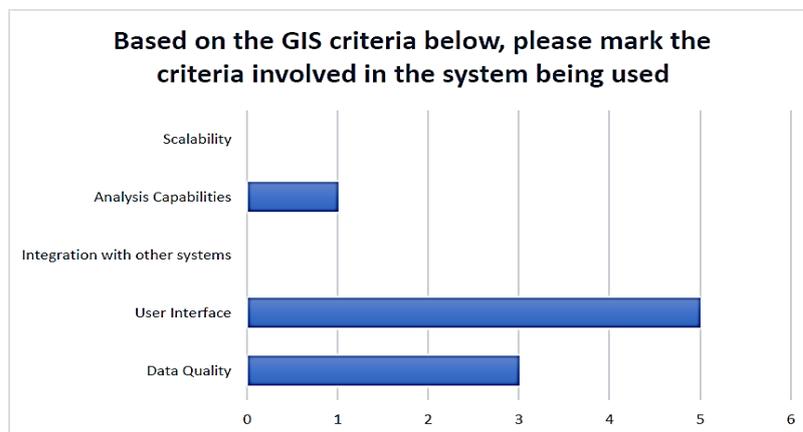


Fig. 4: The GIS Criteria Involved in the System Being Used in the Study Area.

4.2 Designing and Developing a Tested GIS Web-Based System for Water Pipeline Construction Projects

The overall interface of the Web AppBuilder in ArcGIS Online is designed to be user-friendly and easy to navigate (Fig. 5). When you open the interface, you will see a dashboard displaying three main projects: Repek, Mundok, and Lati. These projects are presented as separate tiles or panels on the dashboard, allowing users to quickly identify and select the project they want to work on. The interface is organised and visually appealing, making it easy to manage users' projects. This is a link to enter the Web App Builder: <https://geouitm.maps.arcgis.com/apps/webappviewer/index.html?id=d473bf3ffb9a4820b855671e40feff42>. The system also has a Menu of Bookmarks for specific areas. Bookmarks are pre-defined geographical extents or areas of interest that can be effortlessly accessed with a single command. These bookmarks are established to represent distinct and significant areas within user projects. For instance, within the Repek project, bookmarks may be configured to highlight noteworthy landmarks or specific regions. Similarly, in the Mundok and Lati projects, tailored bookmarks would be available to emphasise their respective areas of focus.

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The Legend feature in ArcGIS Online's Web AppBuilder enables the display and customisation of map elements such as pipes, roads, and pipe fittings for the Repek, Mundok, and Lati project. It offers a visual guide that delineates the symbols and colours used to represent these elements, enabling viewers to identify and understand their meanings easily. The Legend categorises the elements,

each with an icon and description, facilitating quick differentiation among the various data types on the map. The Attribute Table in Web AppBuilder displays fittings such as Scour Valve, Sluice Valve, Hydrant, and S-Bend, allowing users to click a fitting to zoom in on its location on the map. This functionality facilitates easy interaction with the fittings' data for analysis. Additionally, the project summary section of ArcGIS Online's Web AppBuilder provides an overview of the Repek, Mundok, and Lati projects, detailing pipe type, length, budget, and construction duration, which estimates the timeline for pipeline infrastructure completion.



Fig. 5: Overall Interface and Functions of System (Web App Builder in ArcGIS Online).

4.3 Testing the Performance of the Proposed GIS-Based System

This study assesses the usability and functionality of the Web AppBuilder interface using structured comments from two respondents (Respondent 1 and Respondent 2) who were also the original contributors to the user requirements. Their evaluations were based on hands-on experience with the interface and centred on its suitability for managing geospatial projects in Web AppBuilder in ArcGIS Online. The review focused on overall user-friendliness, navigability, the Legend function, and the project summary area, including dashboards showing the Repek, Mundok, and Lati projects.

Key findings indicate high user satisfaction across all tested components. Both respondents assessed the UI as very user-friendly, citing straightforward navigation and easy access to dashboards as important advantages. The project summary section stood out as a handy feature, providing succinct yet comprehensive information on project characteristics and progress, enabling quick situational awareness and informed decision-making. Similarly, the Legend customisation and Attribute Table interaction were commended for boosting data interpretation clarity and facilitating efficient spatial analyses.

Overall, the data show that users have strong positive opinions of the Web AppBuilder interface, which is supported by its visually appealing layout and functional design. Bookmarks, Legend customisation, Attribute Table interaction, and the project summary section were identified as key elements for improving workflow efficiency and analytical capabilities. These findings provide clear recommendations for future user-centred interface upgrades that could improve geospatial project management efficiency within ArcGIS Online-based systems.

5.0 Conclusions

Creating a web-based GIS system for planning water pipeline construction projects provides numerous advantages and breakthroughs, particularly in Kelantan. The findings of this study underscore the usefulness of GIS in planning, particularly for water pipeline construction projects. The results of the user requirement analysis identify GIS criteria that could be modified to increase the efficacy and efficiency of existing water pipeline project planning systems. The suggested method accurately represents geographical data, allowing stakeholders to see project areas, identify conflicts, and optimise route selection. It enables data integration and cooperation among project teams, hence boosting communication and coordination throughout the project's lifecycle. The system's user-friendly interface, bookmark capabilities, legend customisation, attribute table interactivity, and project summaries all help to ease the planning process. GIS and website technology integration enhances data management, visualisation, and analysis, resulting in more effective project planning procedures. Stakeholders can help improve decision-making, optimise resource allocation, and ensure the successful completion of water pipeline building projects. More data integration is recommended, including geotechnical, environmental, and topographic data, to provide a more complete picture of the project site and improve decision-making.

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Paper Contribution to Related Field of Study

This paper demonstrates the effectiveness of a GIS-based web system in improving planning, coordination, and decision-making for water transmission pipeline infrastructure projects in Kelantan, Malaysia.

References

- Abd Hamid, M. A., Saraf, N. M., Razali, M. H., Rasam, A. R. A., & Jalil, A. H. A. (2024). Precise evaluation of 3D building interior using smartphone LiDAR and TLS. *Alam Cipta: International Journal on Sustainable Tropical Built Environment*, 17(2)
- Ahmed, A., Othman, E., Gabr, H., & Hussain, M. A. (2018). Causes and impacts of Poor Communication in The Construction Industry, Sustainable Buildings, and Project Waste Management during the Design and Construction Phase. *View Project. Active travelling to primary school. View project.* <https://www.researchgate.net/publication/330994921>
- Azevedo, R. C. de, Ensslin, L., & Jungles, A. E. (2014). A Review of Risk Management in Construction: Opportunities for Improvement. *Modern Economy*, 05(04), 367–383. <https://doi.org/10.4236/me.2014.54036>
- Behnam, A., Wickramasinghe, D. C., Ghaffar, M. A. A., Vu, T. T., Tang, Y. H., & Isa, H. B. M. (2016). Automated progress monitoring system for linear infrastructure projects using satellite remote sensing. *Automation in Construction*, 68, 114–127. <https://doi.org/10.1016/j.autcon.2016.05.002>
- Brown, G., Rhodes, J., & Dade, M. (2018). An evaluation of participatory mapping methods to assess urban park benefits. *Landscape and Urban Planning*, pp. 178, 18–31. <https://doi.org/10.1016/j.landurbplan.2018.05.018>
- DOSH. (2017). *Guidelines On Ergonomics Risk Assessment at Workplace 2017_July Edited Rev.002.*
- Dongare, P.; Sharma, K.V.; Kumar, V.; Mathew, A. (2024). Water distribution system modelling using GIS, remote sensing, and EPANET for integrated, efficient design. *Journal of Hydroinformatics*, 26(3), 567–588.
- Dosumu, O. (2018). An assessment of the causes, cost effects, and solutions to design-error-induced variations on selected building projects in Nigeria. *Acta Structilia*, 25(1). <https://doi.org/10.18820/24150487/as25i1.2>
- Dosumu, O. S., Idoro, G. I., & Onukwube, H. N. (2017). Causes of Errors in Construction Contract Documents in Southwestern Nigeria. In *JCBM (Issue 2)*. <http://journals.uct.ac.za/index.php/jcbm>
- Jaafar, S. A., Abdul Rasam, A. R., Md Sadek, E. S. S., & Mat Diah, N. (2024). The Role Of Geospatial Artificial Intelligence (GeoAI) In Smart Built Environment Mapping: Automatic Object Detection Of Raster Topographic Maps In Malaysia. *Planning Malaysia*, 22(34). <https://doi.org/10.21837/pm.v22i34.1589>
- Jawdat, F., & Khalid, I. (2017). The Impact of Poor Planning and Management on the Duration of Construction Projects: A Review. In *MECSJ) Electronic Comprehensive Journal for Education And Science Publications Knowledge-Multi ISSUE (Issue 2)*. [www.mecs.com](http://www.mecs.comwww.mecs.com)
- Kuffer, M., Grippa, T., Persello, C., Taubenböck, H., Pfeffer, K., & Sliuzas, R. (2021). We are mapping the Morphology of urban deprivation: the role of remote sensing in developing a Global Slum Repository. In *Urban Remote Sensing: Monitoring, Synthesis, and Modeling in the Urban Environment, Second Edition (pp. 305–323)*. Wiley. <https://doi.org/10.1002/9781119625865.ch14>
- Marcoulaki, E. C., Papazoglou, I. A., & Pixopoulou, N. (2012). Integrated framework for the design of pipeline systems using stochastic optimisation and GIS tools. *Chemical Engineering Research and Design*, 90(12), 2209–2222. <https://doi.org/10.1016/j.cherd.2012.05.012>
- Othman, A. N., Idris, M. A. A., Hashim, N., Abdul Rasam, A. R., & Abd Hamid, A. (2025). GIS-based Analytical Hierarchical Process for Ecotourism Site Suitability Assessment. *Built Environment Journal*, 22(1). <https://doi.org/10.24191/bej.v22i1.1032>
- Saravani, M.J.; Saadatpour, M.; Shahvaran, A.R. (2024). A web GIS-based integrated water resources assessment tool for Javeh Reservoir. *Expert Systems with Applications*, 252, 124198
- Sivakumar, V. L., Nallanathel, M., Ramalakshmi, M., & Veeraswamy, G. (2021). Optimal route selection for natural gas transmission through pipelines in Tiruchengode Taluk using GIS - A preliminary study. *Materials Today: Proceedings*, 50, 576–581. <https://doi.org/10.1016/j.matpr.2021.01.028>
- Zaini, M. F., & Rasam, A. R. (2019). Water loss meter tracking GIS mobile application. *International Journal of Engineering and Advanced Technology*, 9(1), 5923–5928. doi:10.35940/ijeat.a3029.109119
- TutorialsPoint. (2026). SDLC – Overview. In *Software Development Life Cycle (SDLC) tutorial*. Retrieved February 1, 2026, from https://www.tutorialspoint.com/sdlc/sdlc_overview.htm
- Zain Rashid, A. H., Abdul Rasam, A. R., Idris, A. N., Adnan, N. A., & Othman, F. (2019). Online mapping and GIS mobile healthcare systems to enhance accessibility in low- and middle-income communities. *IOP Conference Series: Earth and Environmental Science*, 385(1), 012038. doi:10.1088/1755-1315/385/1/012038
- Zhang, L., Zhao, Y., & Chen, M. (2023). Integration of LiDAR and aerial imagery with GIS for pipeline route optimisation. *Remote Sensing*, 15(6), 1582.
- Zhao, L., Liu, Z., & Mbachu, J. (2019). An Integrated BIM–GIS Method for Planning of Water Distribution System. *ISPRS International Journal of Geo-Information*, 8(8), 331. <https://doi.org/10.3390/ijgi8080331>