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Implementation of rapid application development for spatio-temporal database management

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ABSTRACT

This study aims to investigate the application of Rapid Application Development (RAD) in developing a spatio-temporal database management system, focusing on a case study in North Halmahera Regency. The primary objective is to assess the effectiveness of RAD in expediting the development process and enhancing the adaptability of the system to the dynamic spatial data requirements in the region. The methodology involves iterative development cycles, encompassing requirements planning, user design, construction, and cutover phases. The results demonstrate the successful implementation of RAD principles, showcasing accelerated development timelines and flexibility in accommodating changes. The system, tailored to the specific needs of North Halmahera, proves to be a valuable tool for urban planning, land management, and decision-making. In conclusion, using RAD to develop the spatio-temporal database management system presents a promising approach for swiftly adapting to evolving spatial data demands, ultimately contributing to more effective and responsive governance in North Halmahera Regency.

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1. INTRODUCTION

Implementing Rapid Application Development (RAD) for Land Use and Built-Up Database Management System represents a pivotal step in enhancing efficiency and agility in urban planning. The primary objective of RAD is to expedite the development process by employing iterative prototyping and user feedback, facilitating the swift creation and modification of software systems. In land use and built-up database management, RAD expedites the integration of diverse datasets, streamlining the data input, analysis, and retrieval process. The approach enables a more responsive adaptation to evolving urban landscapes, ensuring that the system remains current and aligned with the dynamic nature of land use patterns. Significantly, implementing RAD accelerates the development cycle and promotes stakeholder engagement through frequent interactions, fostering a collaborative environment that aligns the system closely with end-user needs. In conclusion, adopting Rapid Application Development proves instrumental in revolutionizing the Land Use and Built-Up Database Management System, enhancing its responsiveness, and ensuring its relevance in the ever-evolving urban planning landscape.

The design of a Land Use and Built-Up Database Management System based on a Remote Sensing Approach signifies a paradigm shift in urban planning and resource management. The primary focus of this innovative approach is the utilization of remote sensing technologies to capture and analyze spatial data, providing a comprehensive understanding of land use dynamics (Torres et al., 2023). Leveraging advanced remote sensing techniques, such as satellite imagery and LiDAR, enables the acquisition of high-resolution, real-time information about the built environment (Wang et al., 2022). This detailed spatial data enhances the accuracy of land use classifications and facilitates monitoring urban development over time (Cao et al., 2023a). Incorporating a Remote Sensing Approach into the design of the Database Management System ensures a robust foundation for data-driven decision-making in urban planning (Cao et al., 2023b). Integrating such advanced technologies elevates the precision of land use mapping and fosters a more sustainable and informed approach to urban development (Chang et al., 2021). In conclusion, adopting a Remote Sensing Approach in designing the Land Use and Built-Up Database Management System heralds a new era in urban planning, offering a sophisticated and data-intensive methodology to address the complexities of contemporary urban landscapes.

The incorporation of Land Use within the framework of the Remote Sensing Approach involves a meticulous computation of vegetation indices such as Normalized Difference Vegetation Index (NDVI) (Wei et al., 2022), Enhanced Vegetation Index (EVI) (Yao et al., 2023), and SAVI (Soil-Adjusted Vegetation Index) (Pamungkas, 2023). The primary objective of utilizing these indices is to derive meaningful insights into land cover and land use patterns by analyzing spectral reflectance values captured by remote sensing platforms. NDVI, EVI, and SAVI are pivotal in quantifying vegetation health, biomass, and land surface characteristics (Ngolo & Watanabe, 2023). The application allows for a nuanced interpretation of diverse land cover categories, including urban areas, agricultural fields, and natural vegetation (Yu et al., 2022). Integrating these indices facilitates accurate land use classification and provides a comprehensive understanding of ecosystem dynamics (Hussain & Karuppannan, 2023). The judicious utilization of NDVI, EVI, and SAVI within the Remote Sensing Approach underscores its efficacy in delivering precise and valuable information for land use assessments (Sun et al., 2022). In conclusion, strategically deploying these vegetation indices within the Remote Sensing Approach establishes a robust foundation for a sophisticated and data-driven understanding of land use dynamics.

The computation of the Normalized Difference Built-Up Index (NDBI) within the Remote Sensing framework, utilizing Landsat 8 OLI data, is a crucial methodological advancement in assessing built-up areas. The main objective of calculating NDBI is to discern and quantify the extent of built-up structures within a given landscape (Li et al., 2022). Leveraging the spectral reflectance values captured by Landsat 8 OLI, NDBI provides a quantitative measure to distinguish built-up from non-built-up areas, offering a valuable tool for accurate land cover classification in urban settings (Degerli & Çetin, 2022). Incorporating NDBI into the Remote Sensing approach significantly enhances the precision of identifying urban expansion, thereby supporting effective urban planning and management strategies (Alademomi et al., 2022). The index's application is a reliable indicator for monitoring temporal changes in built-up areas, facilitating data-driven decision-making for sustainable urban development (Nuraini et al., 2022). In conclusion, calculating the Normalized Difference Built-Up Index from Landsat 8 OLI data within the Remote Sensing paradigm is indispensable for precise assessment and continuous monitoring of built-up areas, contributing substantively to land cover analysis and urban planning.

The design of a database stemming from remote sensing data, based on integrating NDVI, EVI, SAVI, and NDBI indices, represents a comprehensive and sophisticated approach to harnessing geospatial information for land cover analysis. The primary focus of this database design is to facilitate the organization, storage, and retrieval of crucial information derived from these indices, providing a systematic framework for decision-makers and researchers (Jitkajornwanich et al., 2020). By incorporating NDVI, EVI, SAVI, and NDBI, the database accommodates a diverse range of vegetation, soil, and built-up land categories, enabling a nuanced understanding of land dynamics (Bao et al., 2023). This holistic approach ensures that the database becomes a valuable resource for monitoring environmental changes over time, supporting evidence-based decision-making in various domains such as agriculture, urban planning, and environmental management (Istiyanto et al., 2022). In conclusion, integrating NDVI, EVI, SAVI, and NDBI into the database design enhances its versatility. It underscores its significance as a comprehensive tool for leveraging remote sensing data that contributes meaningfully to diverse scientific and managerial endeavors.

The database design tailored to the specific needs of a case study in North Halmahera Regency reflects a meticulous and context-sensitive approach to addressing local nuances and challenges. The core of this database design lies in its adaptability to the unique characteristics of the North Halmahera region, encompassing aspects such as land use patterns, environmental dynamics, and socio-economic factors. By aligning the database with the intricacies of the local context, it becomes a more robust tool for effective decision-making and resource management within the specific geographic and socio-cultural parameters of North Halmahera. This tailored approach not only enhances the accuracy of data representation but also ensures the relevance and applicability of the database to the particular challenges faced by the region.

Exploring previous research on similar topics provides a crucial context for understanding the current study's placement within the academic landscape. An extensive literature review reveals the existence of prior investigations into related subjects, highlighting the advancements and limitations in the field. Previous research has delved into aspects that share common ground with the present study (Singgalen, 2023; Singgalen & Manongga, 2022). However, the current research distinguishes itself by designing the spatial database for further research purposes, thereby filling gaps or extending the discourse in ways that contribute novelty to the existing body of knowledge. While previous studies have laid a foundation, the current research seeks to push the boundaries by storing the NDVI, EVI, SAVI, and NDBI in the database, providing a nuanced and updated perspective on the subject matter. In conclusion, the examination of prior research underscores the significance of the current study in building upon, challenging, or complementing existing knowledge within the academic discourse.

2. RESEARCH METHOD

The Rapid Application Development (RAD) methodology encompasses several stages, beginning with requirements planning, user design, construction, and cutover. In the initial phase of requirements planning, the emphasis lies on comprehensively understanding and defining the project's objectives, functionalities, and user needs. This stage is foundational in aligning the development process with the overarching goals. Subsequently, the user design phase involves close collaboration with end-users, fostering iterative prototyping to gather feedback and ensure the application meets user expectations.

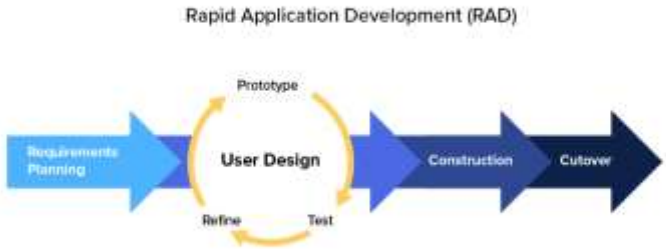

Figure 1. Rapid Application Development

Rapid Application Development (RAD) implementation in designing a database for urban planning and management, as evidenced by a case study in North Halmahera Regency, represents a pragmatic and responsive approach to addressing the region's specific challenges. In the primary stage, RAD allows for rapid database prototyping, enabling quick iterations and adjustments based on the unique urban dynamics and environmental factors in North Halmahera. The iterative nature of RAD proves particularly valuable in accommodating evolving requirements and ensuring the database's alignment with the specific needs of urban planning and management in the region. The case study in North Halmahera serves as a testament to the adaptability and efficiency of RAD, fostering a collaborative development process that actively involves stakeholders and facilitates the creation of a database tailored to the intricacies of the local context. In conclusion, implementing RAD in the database design for urban planning and management in North Halmahera emerges as a practical and effective strategy, attuned to the specific demands and nuances of the region.

2.1 Requirements Planning

In the requirement planning stage, a crucial step involves calculating satellite imagery data from Landsat 8 OLI over the North Halmahera Regency area, followed by the computation of raster data based on the NDVI, EVI, SAVI, and NDBI models. The primary objective of this phase is to establish a robust foundation for subsequent stages by harnessing the spectral information captured by Landsat 8 OLI. This intricate calculation process transforms raw satellite data into meaningful raster representations, utilizing well-established indices such as NDVI, EVI, SAVI, and NDBI. These calculations provide valuable insights into vegetation health, land surface characteristics, and built-up areas, forming the basis for informed decision-making in urban planning and environmental management. The meticulous execution of this step ensures the generation of accurate and contextually relevant data, laying the groundwork for a comprehensive and practical analysis in subsequent phases.

Table 1. NDVI, EVI, SAVI, and NDBI

Model	Raster Calculation
Normalized Difference Vegetation Index (NDVI)	NDVI =(NIR-Red)/(NIR+Red)
Enhanced Vegetation Index (EVI)	EVI = 2.5 x (NIR-Red)/(NIR+6xRed-7.5xBlue+L)
Soil-Adjusted Vegetation Index (SAVI)	SAVI = (1+L)X (NIR-Red)/(NIR+Red+L)
Normalized Difference Built-Up Index (NBDI)	NDBI = (SWIR-NIR)/(SWIR+NIR)

The calculated raster data based on the NDVI, EVI, SAVI, and NDBI models are systematically classified according to delineated zones corresponding to the observed years. This crucial step in the analytical process involves segmenting and categorizing the computed indices, aligning them with specific temporal and spatial parameters. The primary goal is to discern and characterize variations in vegetation health, land surface conditions, and built-up areas across the delineated zones over the observation years. The classification process enhances the interpretability of the data, enabling a more granular understanding of temporal changes in the landscape. This meticulous zoning approach is a foundation for subsequent analyses, offering a comprehensive and nuanced depiction of land cover dynamics. In conclusion, the classification of raster data based on NDVI, EVI, SAVI, and NDBI models within delineated zones and over distinct years is a critical phase, laying the groundwork for a detailed and temporally sensitive assessment of the study area.

2.2 User Design

During the user design phase, the effective management of all NDVI, EVI, SAVI, and NDBI data within an accessible database becomes imperative, coupled with the presentation of this information in visually compelling formats for stakeholders. The primary objective at this stage is to create a user-friendly database architecture that facilitates seamless access to the calculated indices. This involves organizing and structuring the data that aligns with the diverse needs of urban planning and environmental management stakeholders. Furthermore, the visual representation of the data is crucial to enhancing stakeholder comprehension and encouraging informed decision-making. By incorporating visually appealing formats, such as maps, graphs, and charts, the user design phase ensures that stakeholders can easily interpret and derive meaningful insights from the complex information derived from NDVI, EVI, SAVI, and NDBI models. In conclusion, the user design phase is pivotal in optimizing data accessibility and comprehension, fostering an effective exchange of information among stakeholders engaged in urban planning and management processes.

In the context of this research, the database design is orchestrated using Oracle APEX tools to organize the NDVI, EVI, SAVI, and NDBI data within the observed area categorized by years. The main focus at this stage is the strategic utilization of Oracle APEX as a robust tool for efficient data management and visualization. With its user-friendly interface and powerful functionalities, Oracle APEX enables the creation of a well-structured database that accommodates diverse indices, facilitating seamless navigation and accessibility. The supportive capabilities of Oracle APEX play a pivotal role in streamlining the complexities associated with NDVI, EVI, SAVI, and NDBI data integration, ensuring that stakeholders can interact with and analyze the information effectively. This choice of database design tools reflects a practical and technologically sound approach and enhances the overall efficiency and user experience in handling the multidimensional dataset. In conclusion, the adoption of Oracle APEX in the database design phase signifies a strategic decision to optimize the management and utilization of NDVI, EVI, SAVI, and NDBI data within the specified observational area over distinct years.

2.3 Construction

The construction phase in the database design for urban planning and management in North Halmahera Regency emphasizes the development of a robust database structure, incorporating zones, years, and the maximum, mean, and minimum values derived from NDVI, EVI, SAVI, and NDBI models. The primary focus at this stage is to engineer a database that accommodates the specific attributes critical for the nuanced analysis of the study area. By integrating zoning information and temporal variations through the years, the database becomes a comprehensive repository of geospatial data that encapsulates the dynamic landscape of North Halmahera. Including maximum, mean, and minimum values from NDVI, EVI, SAVI, and NDBI models further enriches the database, offering a detailed perspective on vegetation health, land surface conditions, and built-up areas. This meticulous approach during the construction phase ensures that the database aligns precisely with the intricacies of urban planning and management in North Halmahera Regency, providing a solid foundation for subsequent analytical processes and informed decision-making.

2.4 Cutover

The cutover phase, representing the culmination of the database design process, involves ensuring that each zone's database, comprising NDVI, EVI, SAVI, and NDBI values, is readily accessible to stakeholders. The primary objective at this critical juncture is to transition seamlessly from the development environment to live production, enabling stakeholders to utilize the comprehensive dataset effectively. During cutover, meticulous attention is given to system testing, user training, and the deployment of the database, ensuring a smooth integration into the operational framework. The significance of this phase lies in delivering a functional and user-friendly database that empowers stakeholders, including urban planners and decision-makers, with valuable geospatial insights derived from NDVI, EVI, SAVI, and NDBI models. This approach not only enhances the accessibility of critical information but also underscores the practicality and effectiveness of the database in supporting informed decision-making processes related to urban planning and management. In conclusion, the cutover phase is pivotal in realizing the envisioned benefits of the database, making NDVI, EVI, SAVI, and NDBI values accessible to stakeholders, and contributing to the success of urban planning initiatives in the designated zones.

2.5 User Feedback

The user feedback stage emphasizes eliciting stakeholders' responses after interacting with the spatial data management database based on NDVI, EVI, SAVI, and NDBI in each zone. The primary goal during this phase is to gather insights and evaluations from end-users, including urban planners and decision-makers, regarding the database's usability, functionality, and effectiveness in facilitating spatial data management. By actively seeking feedback, the database designers can ascertain the system's alignment with stakeholders' needs and expectations, allowing for potential refinements or enhancements. The stakeholders' opinions and suggestions are valuable input for iterative improvements, ensuring the database remains a practical and user-centric tool for informed decision-making in urban planning and spatial data management. In conclusion, the user feedback stage is a crucial loop in the database development process, fostering continuous improvement and alignment with stakeholder requirements to effectively utilize NDVI, EVI, SAVI, and NDBI-based spatial data management in each designated zone.

3. RESULTS AND DISCUSSIONS

3.1 Requirements Planning

The requirement planning stage in the database design for urban planning and management in North Halmahera Regency is primarily centered on ensuring convenient data accessibility for policymakers. The main objective of this phase is to meticulously identify and define the data requirements essential for informed decision-making, emphasizing the ease with which policymakers can access pertinent information. This involves comprehensively analyzing policymakers' needs and preferences and addressing data retrieval speed, user interface intuitiveness, and data presentation formats. By prioritizing accessibility, the requirement planning stage sets the groundwork for a user-centric database design that aligns precisely with the information needs of policymakers engaged in urban planning and management initiatives in North Halmahera. In conclusion, this emphasis on streamlined data access during the requirement planning stage signifies a proactive approach to creating a database that is not only technically robust but also practical and supportive of policymaking processes in the designated region.

3.2 User Design

In the database design phase, the spatial data processing results based on NDVI, EVI, SAVI, and NDBI models are segregated within the database to facilitate the update process. The central focus during this stage is to create a structured and modular database architecture that allows for efficient and targeted updates to specific datasets. By isolating the results from distinct models, the database maintains data integrity. It streamlines the update process, ensuring that modifications to spatial information, particularly those associated with NDVI, EVI, SAVI, and NDBI, can be conducted systematically. This separation within the database serves as a practical measure, enhancing the manageability of the spatial dataset and promoting a more seamless and controlled update mechanism. In conclusion, the deliberate separation of spatial data processing results in the database design demonstrates a strategic approach to optimize the update process, contributing to the overall effectiveness and reliability of the database in accommodating dynamic changes in the geospatial information.

In the interface design phase, a crucial element includes a calendar page intended for administrators to input data on each page based on the calculated raster data results for NDVI, EVI, SAVI, and NDBI. The primary focus at this stage is to enhance the user experience by providing a targeted and user-friendly interface specifically designed for administrators. The calendar page is a practical tool for input data, aligning with each parameter's calculated raster data. This feature streamlines the data input process and ensures precision and efficiency in capturing and managing information associated with NDVI, EVI, SAVI, and NDBI models. In conclusion, incorporating a calendar page within the interface design is a strategic decision aimed at optimizing the usability and functionality of the database, particularly facilitating administrators in inputting data derived from raster calculations for each parameter with greater ease and accuracy.

Figure 2. Interface of Spatio-Temporal Database Management System

The initial stage of utilizing the application involves the login process, followed by redirection to the main page, which illustrates the Standard Operating Procedure (SOP) for inputting NDVI, EVI, SAVI, and NDBI data based on the pre-processing, processing, modeling, and data storage stages. The primary objective at this juncture is to provide users with a structured and intuitive pathway for data input aligned with the specific stages of data processing. This approach ensures adherence to a standardized procedure and enhances user clarity regarding the sequential steps in handling NDVI, EVI, SAVI, and NDBI data. By clearly delineating the SOP on the main page, users are guided through a systematic workflow, fostering a more user-friendly and efficient data input process. In conclusion, including an SOP-driven interface at the outset reflects a strategic decision to optimize user engagement and facilitate a seamless progression through the application's essential stages of data input.

Figure 3. Visualization of NDVI, EVI, SAVI in Spatio-Temporal Database Management System

After the database storage process, the data can be modified by updating or adding NDVI, EVI, SAVI, and NDBI data. The primary focus at this stage is to ensure the flexibility and adaptability of the database, allowing for seamless adjustments to the stored information. Updating existing data enables the incorporation of new observations or revisions while adding new data facilitates the inclusion of additional spatial information. This approach sustains the database's relevance over time and accommodates dynamic changes in the geospatial landscape. In conclusion, the capability to modify data through updates or additions after the database storage process is a fundamental feature, underpinning the database's capacity to evolve in response to changing conditions and ensuring its ongoing utility for decision-making and analysis.

3.3 Construction

The database is meticulously designed in the construction phase to meet user requirements for analyzing spatial data based on NDVI, EVI, SAVI, and NDBI. The primary focus at this stage is to align the database structure precisely with the needs of users engaged in spatial data analysis. By tailoring the construction phase to cater to the intricacies of NDVI, EVI, SAVI, and NDBI-based analyses, the database becomes a purpose-built tool for efficient and effective spatial data interpretation. Furthermore, incorporating an administration page feature in Oracle APEX further aids in monitoring application users. This feature enhances the user experience by providing administrators with the tools necessary to oversee and manage user activities within the application. In conclusion, the construction phase not only ensures the alignment of the database with user needs for spatial data analysis but also incorporates features, such as the administration page, to enhance the overall usability and functionality of the Oracle APEX application.

3.4 User Feedback

In the user feedback stage, the evaluation of the application users will be tailored to their specific needs, including the potential incorporation of additional models such as NDWI, MSAVI, and other remote sensing models. The primary focus in this phase is to gather users' insights regarding the application's functionality and effectiveness and to align future developments with their evolving requirements. By considering user feedback, especially in terms of desired additional models, the application can be dynamically adapted to meet the diverse needs of users engaged in geospatial analysis. This approach enhances user satisfaction and ensures the application remains a flexible and responsive tool for incorporating various remote sensing models, thus extending its utility and relevance in complex geospatial scenarios. In conclusion, integrating user feedback into the evaluation process enables the continuous improvement of the application, ensuring its alignment with user expectations and accommodating the integration of additional models for more comprehensive remote sensing analyses.

3.5 Discussion

The challenge in policymaking to determine the direction and strategy for urban development or urban planning lies in the availability of spatial databases that can serve as policy references. The primary obstacle concerns the need for comprehensive and up-to-date spatial data to inform decision-making processes (Sjoukema et al., 2021). Policymakers face the challenge of ensuring reliable databases encompassing diverse geospatial information crucial for urban planning (Radosevic et al., 2023). These databases must not only be accessible but also incorporate relevant data on land use, infrastructure, environmental factors, and population dynamics (Weck et al., 2022). Addressing this challenge is pivotal for policymakers, as the effectiveness of urban planning strategies is contingent upon the accuracy and completeness of the spatial data (Gupta et al., 2020). In conclusion, the accessibility and reliability of spatial databases stand as fundamental prerequisites for informed and effective policymaking in urban planning and development.

The subsequent challenge lies in policymakers' understanding of spatial data models for urban planning and management. The central issue is rooted in policymakers' need to comprehend intricate spatial data models comprehensively. These models, including but not limited to NDVI, EVI, SAVI, and NDBI, form the basis for informed decision-making in the urban planning (Lidskog et al., 2022). Policymakers need to grasp the technical intricacies of these models, ensuring a nuanced understanding of their applications and implications for urban development strategies (Harris, 2023). This challenge emphasizes the importance of providing policymakers with adequate training and resources to bridge the knowledge gap, fostering a more informed and data-driven approach to urban planning (Flynn et al., 2021). In conclusion, addressing this challenge is crucial to empower policymakers with the necessary expertise for effectively leveraging spatial data models in the complex urban planning and management landscape.

4. CONCLUSION

The research implications and contributions of the study hold significant weight in advancing the understanding and application of the explored subject matter. Implementing Rapid Application Development (RAD) in developing a spatio-temporal database management system application can serve as a reference for policymaking in urban development, extending to land utilization in North Halmahera Regency. The primary emphasis lies in RAD's swift and iterative nature, allowing for the expedited creation and modification of the application to align with the evolving needs of urban and land management. The limitations of this research necessitate a careful acknowledgment of the constraints that may impact the study's scope and generalizability. The iterative development approach ensures the application remains adaptable, accommodating policy changes, spatial data requirements, and technological advancements. This, in turn, enhances the system's utility as a pivotal tool for informed decision-making in the development and land utilization sectors of North Halmahera. In conclusion, implementing RAD facilitates a responsive and efficient spatiotemporal database management system, positioning it as a valuable reference for policy formulation and strategic decision-making in the multifaceted domains of urban management and land utilization in the North Halmahera Regency.

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