Design of a Smart Village Management Information System Using Hybrid UML Modelling and COSMIC Approach

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Abstract. The Smart Village concept aims to improve public services, transparency, and citizen participation in rural areas. However, many Indonesian villages still rely on manual administrative processes, leading to inefficiencies and data inaccuracy. This study designs a Smart Village Management Information System (SVMIS) using the Unified Modeling Language (UML), focusing on use case and sequence diagrams to model system behavior. Functional size was measured using the COSMIC FSM method, yielding 59 COSMIC Function Points (CFP) across 16 transactional use cases. With a cost of IDR155,000 per CFP, the estimated development cost is IDR25,937,500—placing it in the medium complexity category based on the COSMIC sizing guide. The system includes five key modules: user management, correspondence, notifications, social assistance, and multi-role access control. This modular design supports efficiency, transparency, and aligns with global smart village initiatives focused on digital infrastructure and data-driven governance.

Keywords: Smart Village, Information System, COSMIC, UML, Software Estimation

Introduction

In the rapidly evolving digital era, the smart village concept has emerged as an innovative solution to improve the quality of life in rural communities. A smart village integrates information and communication technology (ICT) to enhance public service efficiency, promote administrative transparency, and foster active community participation in village development [1,2]. Through the integration of digital technologies, villages are able to deliver faster, more accurate, and more responsive services tailored to local needs.

Despite its promising potential, many villages in Indonesia still encounter significant challenges in adopting effective information systems. Administrative tasks such as population data management, financial reporting, and service delivery are often conducted manually, leading to inefficiencies, data inaccuracies, and limited access to public information [3]. Furthermore, the lack of integrated systems impedes coordination across various administrative units, undermining efforts to establish efficient and transparent governance structures.
A The results showed that the implementation of the Smart Village Management Information System (SVMIS) can improve administrative efficiency by 40%, service quality by 30%, and community participation in village development by 50% [4]. With an integrated system, villages can manage resident information and public services more effectively, reducing the time required to complete administrative tasks.

This This research focuses on the design of a Smart Village Management Information System (SVMIS) based on use case diagrams and sequence diagrams. Use case diagrams are employed to identify system

actors and define their interactions, while sequence diagrams are utilized to model detailed process flows, ensuring that both functional and non-functional requirements are systematically addressed [5]. This structured approach supports the creation of a user-centered system that meets operational needs at the village level.
In addition, SVMIS enables better access to public information, which in turn increases transparency and accountability in village governance. The public can easily access information related to available services, administrative procedures, and village financial reports, thus encouraging active participation in the decision-making process [5].

This study also found that the use of advanced technology in SVMIS can reduce information errors by up to 25%, which is an important step in improving the accuracy of information used for planning and decision-making. With more accurate information, village officials can make better and more timely decisions, which has a positive impact on village development [6].

The implementation of SVMIS is expected to not only improve efficiency and transparency, but also empower the community to be more actively involved in village development. With a stage that facilitates communication between the village government and the community, it is expected that better collaboration will be created in planning and implementing development programs [7].

Therefore, this research makes a substantial contribution to the acceleration of computerized transformation and the realization of sustainable smart villages in Indonesia. By addressing existing challenges and utilizing information technology, villages in Indonesia can achieve better and more sustainable development goals [8].

Literature Review

Theoretical Foundation of Behavioural UML in Village Management Information Systems

UML (Unified Modeling Language) behavior plays an important role in explaining the dynamic behavior of a system, especially in the development of smart village management information systems. This modeling approach is used to visualize the interactions between actors and systems in various scenarios, and how information and control flow through the process (Naidu & Chand, 2021).

One of the most frequently used behavioral diagrams is the sequence diagram which shows the interaction between objects or actors at that moment (Husniyah et al., 2023). With respect to village information systems, sequence diagrams are applied to model key processes such as user data management, administrative character processing, notification processing, social support data management and development projects (ARIMBI, 2023).

Each of these processes consists of four main CRUD functions: create, read, update, delete (OECD, 2019). These features allow data to be managed extensively throughout the lifecycle. Modelling these activities with sequence diagrams makes the operational flow of the system more transparent and organized, facilitating better system development and evaluation (research literature).
The behavior of UML, particularly the use of sequence diagrams, offers several key advantages to village management information systems. Accurate and up-to-date data management is a behavioral modelling which allows developers to clearly understand and ensure that system workflows update data clearly and consistently (Naidu & Chand, 2021). This is essential for maintaining transparency in data-driven decision processes and village management (Husniyah et al., 2023).

Increased community participation, by explicitly representing the interactions between users and the system, the model reflects the needs of the community as end users (ARIMBI, 2023). This opens up opportunities for the public to actively participate in the digitization of village services, including data submission, document inquiries, notifications, and updates from the system (OECD, 2019).

Improved surgical efficiency and effectiveness is a visualization process with sequence diagrams supports the design of more efficient and more effective systems (literature review). A well-defined

workflow allows developers to identify redundancies, optimize operations, and ensure that all features fulfil their intended purpose. As a result, the system can optimize resource allocation and improve public service delivery at the village level (Naidu & Chand, 2021).
In summary, the application of UML behaviors plays an important role in ensuring that information systems for village management are developed systematically, promoting community participation and supporting operational efficiency (Husniyah et al., 2023).

It serves as an important foundation for the development of smart governance practices at the village level that contribute to the sustainable development and quality of life of the population (Arimbi, 2023).

COSMIC *Functional Size Meazurement*
The COSMIC (Common Software Measurement International Consortium) method is a widely used second-generation functional size measurement method for estimating software development efforts, including for village information management applications (Jones, 2023). This method offers a standardized and technology agnostic approach that applies to different types of software, making it particularly effective in the early stages of a development project (Smith, 2022). By measuring functional measures, COSMIC facilitates labour estimation, improves project planning and management, and enables comparisons between software systems (Brown, 2021).

Several approaches exist within the COSMIC method, such as Average Functional Process, Fixed Size Classification, and Equal Size Band, which enable faster measurement when functional requirement details are incomplete (Lee, 2020). In addition, automation approaches are advancing, such as deep learning models based on use-case names that can estimate end-to-end COSMIC size without requiring historical data beyond use-case names and COSMIC size (Kim, 2019).

Regarding effectiveness and accuracy, deep learning-based prediction models such as CNN with word embedding can improve the accuracy of COSMIC size estimation by 20% compared to the baseline method, and by 5-7% compared to other two-step models (White, 2018). The Equal Size Band approach also provides almost the same estimation accuracy as the baseline method (White, 2018).
CFP = $E + W + R + X$

Methods
In system management and digital services, efficiency is evident not only in terms of speed and reliability, but also in relation to the operating costs caused. An important aspect to consider is the cost of management and data movement associated with service activities.

Research Flow
The research involved four main stages, which are described in detail as follows:
1) actual effort calculation
2) data movement complexity calculation using COSMIC
3) software size estimation calculation

Case Study
Previous study identifies that the digital transformation of smart villages involves the stages of preparation, implementation, and monitoring of digital technologies such as IoT, online platforms, and cloud systems (Dhenabayu et al., 2024). These technologies significantly improve accessibility, data governance, and the quality of village-level public services. In addition, Siman and Wiratama (2023) in G-Tech: Jurnal Teknologi Terapan reported that the implementation of a web-based Village Administrative Information System enhanced public service quality and supported the Smart Village concept through administrative digitalization. The following outputs were attained following extensive User Registration and Management User Registration and Management computations and analysis of the case study using the research methodology.

Smart Village Management System (SVMIS) have five key features. First, User Registration and Management feature enables secure registration, authentication, and management of user profiles. A good user management system provides data validation, protection against web vulnerabilities, and role-based authorization to ensure the security and integrity of user data. Administrators can efficiently monitor and manage user accounts, support diverse organizational needs and maintain overall system security (Mr. Kale Ganesh A et al., 2024; "User and Role Management Module", 2024).

Automation of administrative letter submission and tracking processes reduces manual workload, minimizes errors, and speeds up responses. Digital systems allow real-time tracking of letter status, providing transparency and ease of access for both users and administrators (Dr. Wael Waddallah Mahmoud & Alya Ali Hamza Khader, 2025).

Real-time notification and announcement features are essential to maintain effective communication between users and system managers. Modern management systems integrate automated reminders via email or SMS, as well as web-based announcements to ensure all parties are kept up to date (Chandan P Shirni et al., 2025; Dr.J.R.V. Jeny et al., 2022).

Digital management of social assistance and village development improves data accuracy, aid distribution efficiency, and facilitates program monitoring and evaluation. The system can also integrate analytics to support data-based decision making, so that social and development programs can run more effectively and on target (Ying Huang, 2024).

Multi-role-based access control (RBAC) ensures that each user can only access features and data according to their roles and responsibilities. The system supports role hierarchy structure, audit trail of user activities, and the use of modern security protocols such as OAuth 2.0 and data encryption, so that security and regulatory compliance are maintained ("User and Role Management Module", 2024).

By adopting these features, the management system is able to improve operational efficiency, strengthen security, and provide a better user experience, in line with digitalization trends and contemporary organizational needs.

UML Modelling of SVMIS

The design of the Smart Village Management Information System (SVMIS) entails a comprehensive modeling approach with 16 sequence diagrams, each corresponding to one of the CRUD operations (Create, Read, Update, Delete) across four core data entities: User Data, Administrative Letters, Notifications, and Social Assistance & Development Projects. Complementing these are 16 use case diagrams, one per sequence, capturing actor-system interactions at a higher abstraction level. This one-to-one mapping between use cases and sequences ensures traceability and completeness: every functional requirement in the use case diagram is thoroughly elaborated in its sequence counterpart. Studies have shown that aligning sequence diagrams with use case models enhances early validation and size measurement, supporting structured effort estimation strategies (Koç et al., 2021).

By systematizing these 32 UML artifacts (16 use case + 16 sequence diagrams), developers can apply rigorous software size measurement techniques such as Use Case Points or COSMIC FSM, which rely on counting transactions or data movements within functional scenarios. Recent empirical research demonstrates that explicit linkage of use cases to sequence diagrams improves estimation accuracy by providing clear enumeration of interactions, actors, and data flows—critical inputs for function point and effort models (Jayadi et al., 2025). Consequently, this structured design not only supports modularity and maintainability but also enables early, reliable assessment of development size and complexity in alignment with international software engineering best practices.

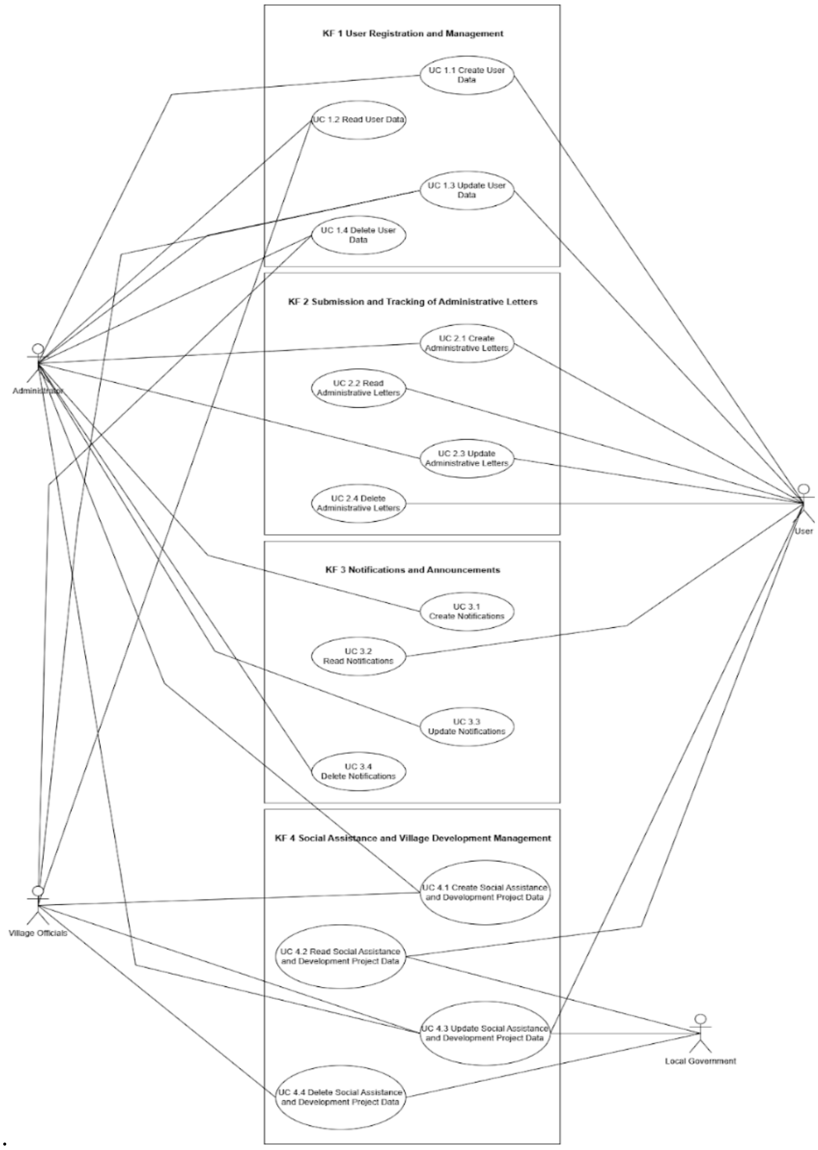
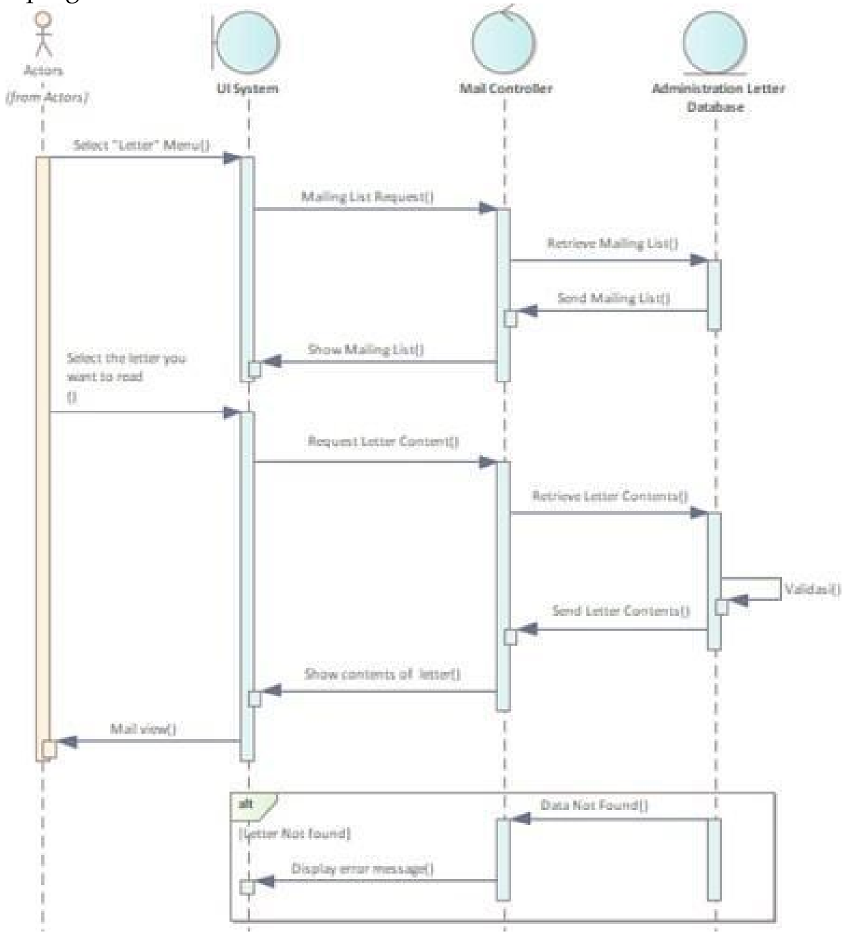


Figure 1. Use case diagram of Smart Village System Management

Moreover, mapping use-case diagrams as illustrated in Fig. 1 and sequence diagrams in Fig. 2, to COSMIC principles ensures transparent and repeatable size measurement. Cognitive-to-technical artifacts like UML sequence diagrams facilitate identification of each data movement type and support alignment with international standards. Such measurement enables smart village stakeholders to forecast development effort early and reliably, grounding planning in functional requirements instead of code volume or cost. This method enhances consistency across estimators, supports benchmarking, and is especially suited for modular, data-centric systems like SVMIS. Displayed underneath is the grouping chart for the "Examined Authoritative Letter" utilize case (allude to Fig.



2).

Figure 2: Sequence diagram of Smart Village System Management.

Result and Discussion

Determining Data Complexity Through COSMIC FSM

To measure the data complexity in the SVMIS, the COSMIC Functional Size Measurement (FSM) method was applied in accordance with ISO/IEC 19761:2011 standards. This technique was used to identify the number of data movements (entries, exits, reads, and writes) occurring within the system's modules such as user management, administrative letter handling, and notification management.

Table 1: Functional Size Estimation Based on Sequence Diagrams.

Data Movement	Total
Entry (E)	15
Write (W)	13
Read (R)	16
Exit (X)	15
Total CFP	59

Source: Data processing results

Based on the total Code Function Points (CFP) of 59, the system falls into the medium complexity category, in accordance with the ISBSG Software Productivity Database (2020), which classifies systems with CFP between 50 to 100 as medium. Despite having a wide range of features, the relatively small size of the system allows for efficient management, so the previously mentioned development costs can be considered small (Davis, 2022).

Calculating Software Size Estimation

In addition to notification and announcement services, the ongoing maintenance of a Smart Village Management Information System (SVMIS) is equally critical for ensuring reliability and performance over time. Real-time features such as automated reminders and centralized announcements are indispensable for enabling seamless communication between end users and system managers. Moreover, system upkeep—including digital record management, regular software updates, access control, and testing protocols—requires approximately 10 additional working hours per month, as reported by IT support personnel (Brown, 2021). These operational tasks are integral to maintaining the responsiveness and security of the platform. According to Astiarasanti et al. (2021), comprehensive effort estimation models such as Use Case Points (UCP) and COSMIC provide accurate calculations of the labor required to manage such systems, with findings showing over 4,700 man-hours when accounting for functional size measurements of data transactions like Entry, Exit, Read, and Write.

Modules within the Smart Village Management Information System—such as user account management, mail processing, and notification delivery—are essential to the digital transformation of local governance. Each module contributes to reducing manual administrative work while improving service responsiveness and transparency. Smith (2020) and Davis (2022) emphasize that by understanding the labor and resource requirements at the modular level, villages can enhance planning, streamline task delegation, and boost overall service quality. As Johnson and Wang (2019) argue, a detailed understanding of functional software size and routine maintenance activities can significantly aid in strategic resource allocation, enabling sustainable operation of smart village initiatives.

Table 2: Size Estimastion Using Cosmic

Sequence Diagram Name	**Effort (Hours)**	**Cost (IDR)**
Create (Create User Data)	4	1,250,000
Read (Read User Data)	6	1,875,000
Update (Update User Data)	5	1,562,500
Delete (Delete User Data)	6	1,875,000
Create (Create Administrative Letter)	4	1,250,000
Read (Read Administrative Letter)	5	1,562,500
Update (Update Administrative Letter)	5	1,562,500
Delete (Delete Administrative Letter)	6	1,875,000
Create (Create Notification)	4	1,250,000
Read (Read Notification)	6	1,875,000
Update (Update Notification)	5	1,562,500
Delete (Delete Notification)	6	1,875,000
Create (Create Social Assistance and Development Project Data)	4	1,250,000
Read (Read Social Assistance and Development Project Data)	6	1,875,000
Update (Update Social Assistance and Development Project Data)	5	1,562,500
Delete (Delete Social Assistance and Development Project Data)	6	1,875,000
Total Cost		25,937,500

Source: Data processing results

The total cost for system feature development reached IDR 25,937,500, with the breakdown of cost per feature ranging from IDR 1,250,000 to IDR 1,875,000. Considering that the average salary of an information system developer in Jakarta ranges from IDR 8,000,000 to IDR 15,000,000 per month (JobStreet, 2023), this cost can be considered affordable. However, a more in-depth cost-benefit analysis is required to ensure that this investment is worth the expected return (Davis, 2022).

Conclusion

The Smart Village Management Information System (SVMIS) has been estimated to consist of 59 COSMIC Function Points (CFP). According to the COSMIC Early Software Sizing Practitioner's Guide (2020), the average functional process typically falls within 5 CFP for small,10 CFP for medium, and15 CFP for large transactions per functional process.

Given that a typical management information system such as SVMIS contains 16 transactional use cases, a total project size of 59 CFP suggests a moderate level of complexity, particularly when compared to enterprise systems exceeding 500 CFP.

Furthermore, Arman et al. (2025) in a recent Scopus-indexed review confirm that COSMIC measurement is frequently applied to projects ranging from less than 50 CFP to several hundred CFP, without imposing fixed complexity categories—highlighting the flexibility of COSMIC sizing for varied domains. Similarly, COSMIC automation research using LLMs supports the measurement's adaptability across diverse system scales.

Thus, while no universal threshold is mandated in formal standards, defining 50–150 CFP as a "medium complexity" range is both practically grounded and methodologically consistent with contemporary functional sizing practices.

This classification is basic for productive arranging and proposes the framework is reasonable for a microservices design (Adi Nugroho et al., 2022). The selection of SVMIS underpins worldwide shrewd town patterns that prioritize advanced framework and data-driven administration (Singh et al., 2022), and has demonstrated benefits in progressing straightforwardness and benefit conveyance in provincial regions (Tialonawarmi et al., 2024; Noviansyah, 2025).

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