Journal of Artificial Intelligence and Engineering Applications

Website: https://ioinformatic.org/

June 2026. Vol. 5. No. 3; e-ISSN: 2808-4519

Designing the Foundation of a Multi-Tenant and Surrogate Key-Based Nusa Praja Village Government System on the Nusa Eka Platform

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Abstract

Village government administration in Indonesia is still largely manual, resulting in service inefficiencies and the potential loss of sensitive population data. The purpose of this research is to create the architectural foundation of a village government information system called NUSA PRAJA, which is part of the NUSAEKA multi-tenant Software as a Service (SaaS) platform. This research applies the Multi-Tenant Isolation concept to ensure data security and separation between villages, as well as the Surrogate Key concept to protect residents' National Identification Number (NIK) data from leaks. The research method used is Waterfall with the stages of requirements analysis, system architecture design, and database design. The results of the research are a multi-tenant system architecture design based on a shared database with tenant_id filters, an Entity Relationship Diagram (ERD) design with 14 main tables, and a flowchart design for three user roles. This project is expected to be a strong foundation for building a secure, scalable, and easy-to-use digital village system for village governments throughout Indonesia.

Keywords: *E-Government; Multi-Tenant; Surrogate Key; System Design*

1. Introduction

Village governments in Indonesia are centers of public service that directly connect with the community. However, many villages still use manual processes to issue administrative correspondence and store population data. This situation causes various problems such as data redundancy, delays in service processes, the risk of damage or loss of physical documents, and increased challenges in managing citizen data [1], [2].

Various studies have been conducted to address these issues through web-based information systems. According to Mulyanto and Supriatiningsih [3], an effective population administration system can be accessed via the internet and improve service efficiency. Romadhon and Maryam [4] used Laravel to create an information system for village administration services. However, these systems are not scalable for massive implementation across thousands of villages in Indonesia because they are typically standalone and serve a single village.

NUSAEKA's digitalization solution for village services, based on a hybrid Software as a Service (SaaS) architecture, enables multiple villages to be served by a single platform [5]. The NUSA PRAJA module is a key component of this platform, which will function as an electronic correspondence system and population master data. This research focuses on the architectural foundation design stage of two main concepts, namely Multi-Tenant Isolation and Surrogate Key.

The security of sensitive data such as the Population Identification Number (NIK) is a major concern in developing a population system. Agustina and Suhirman [6] investigated the use of encryption to protect village demographic data. Surrogate Key theory [7], which separates NIK storage from inter-table relationships, was used in this study. This allows the impact of security incidents to be minimized.

Based on this background, this study aims to design the foundation of a multi-tenant NUSA PRAJA village government system on the NUSAEKA platform. The design was carried out by constructing a multi-tenant system architecture, constructing a secure database structure using the surrogate key concept, and designing system flows for each user role.

2. Literature Review

2.1. Village Administration Information System

In recent years, research has focused on the digitalization of village administration. Piski et al. [8] developed a web-based village data processing application using the waterfall method. This method includes village profiles and head of household data management features. Rosmasari et al. [9] created an e-mail system for Handil Terusan Village using the WDLC method. Applicants can access services from various locations. The mail service and population data management system developed by Adhi and Adhi [1] successfully addressed the problems of long queues and data duplication.

Mardinata et al. [10] examined the digital transformation of villages through the Village Information System (SID) and concluded that digitalization significantly improves the quality of public services and community welfare. Meizary and Amnah [11] developed a village website to improve access to information and population data in the digital era. These studies formed the basis for the system requirements designed in this study.

2.2. Population Information System Security

Population data security is a critical aspect in designing village information systems. Ratuliu and Hidayasari [12] applied the Secure Software Development Life Cycle (SSDLC) approach with Role-Based Access Control (RBAC) for a village mail service system. Agustina and Suhirman [6] implemented the Data Encryption Standard (DES) algorithm for population data encryption and successfully secured population data from leaks.

The Surrogate Key concept [7] is a database architecture approach that uses a surrogate key without business significance as the primary key. Asuni [7] explains that the Reversible Numeric Composite Key (RNCK), as an extension of the surrogate key, can improve query performance while securing sensitive data. The application of Surrogate Keys to National Identity Number (NIK) data aims to separate sensitive data storage from inter-table relationships, thereby minimizing the blast radius of data leaks.

2.3. Multi-Tenant SaaS Architecture

Software as a Service (SaaS) is a software distribution model in which applications are hosted by a service provider and made available to customers over the internet [13]. SaaS implementations use a multi-tenant architecture, where a single application instance serves multiple customers (tenants) with strict data isolation. Zhang et al. [14] found that logical data isolation between tenants is a major issue in multi-tenant cloud systems and proposed a hybrid isolation framework to address it. Li et al. [5] examined the security mechanisms of data isolation and sharing in a blockchain-based multi-tenant cloud. This study used a shared database approach with row-level isolation using tenant_id because it is more efficient and easier to implement at the village government scale.

3. Methodology

3.1. Design Method

The system development method used in this research is the Waterfall method. This method was chosen because the system's needs and scope had been clearly defined from the initial research stage [1], [4]. The stages in the Waterfall method in this research include system requirements analysis, architecture and database design, and system design evaluation. Each stage produces a design document that is used as a basis for the next stage.

3.2. Needs Analysis

The needs analysis was conducted by studying the literature on various studies related to village information systems [1], [3], [8], [9], the needs analysis was conducted to identify the functional requirements of the system. The results of the analysis showed that the system requires several main functions, such as population data management which includes education history, employment, and family cards. In addition, the system is designed to support electronic correspondence services through flows such as submission, verification, digital signing, and printing of documents [9], [12]. The system also supports user account management through role-based access control (RBAC), user activity audit trails, and multi-tenant mechanisms to ensure data isolation between villages [5], [14].

3.3. Multi-Tenant Architecture Design

To design a multi-tenant architecture, the tenant_id column is used as a foreign key for the tenants table of each table in the database. A shared database approach with row-level isolation is used through the tenant_id column. The Global Scope mechanism in the Laravel framework is designed to ensure that each query is automatically filtered based on the active user's tenant_id, thereby automatically ensuring data isolation between tenants without the need for manual filtering in each query [14]. Furthermore, flowcharts for three user roles: Village Admin, Registered Resident, and Outside Resident have been included in the design. The flowcharts cover login, resident data management, letter submission, verification, signing, and logout. To maintain data isolation at every level of the system, each activity is designed to always include the tenant_id context.

3.4. Database Design

The database design resulted in an ERD that includes 14 main tables: tenants, admin, residents, family_card, education_history, employment_history, letter_type, letter_template, letter, visitor_account, roles, permissions, log_audit_data, and log_audit_system. The

Surrogate Key concept is applied to the residents table by using an auto-increment integer id column as the primary key replacing the National Identification Number (NIK). The NIK is stored only in the nik_encryption column in an encrypted state.

In conventional systems, the NIK is used directly as a foreign key in the letter, family_card, and other tables, so that if a leak occurs in one of these tables, the NIK is immediately exposed. In the NUSA PRAJA system, all relational tables store only internal IDs (Surrogate Keys), so a leak in the relational tables does not expose residents' NIKs.

4. Results and Discussion

4.1. Multi-Tenant Architectural Design

The resulting NUSA PRAJA system architecture design is a single-panel approach with row-level isolation and a shared database. The system architecture consists of several layers: a presentation layer, a business layer with a Laravel Controller, a data layer with an Eloquent Model with Global Scope, and a database layer with MySQL.

Laravel's Global Scope mechanism is used in the data layer to automatically add a tenant_id filter to every Eloquent query. This mechanism is designed to ensure that data from each village remains secure and cannot be accessed by other tenants. This method aligns with the concept of logical isolation in multi-tenant systems outlined by Zhang et al. [14]. Furthermore, as stated by Li et al. [5], data isolation mechanisms are a crucial part of maintaining the security of multi-tenant systems.

The village table stores tenant information such as village code, administrative area, contact information, and system configuration. The tenant_id column, a char(36) type, is used to link each record to a specific village within the NUSAEKA platform.

4.2. Database Design with Surrogate Key

The ERD structure of the NUSA PRAJA system consists of 14 main tables with a structure designed to optimize NIK data security.

Table 1: List of Tables for NUSA PRAJA Database Design

Table Name	Function	Security Features
tenants	Village master data	Multi-Tenant master table
admin	System admin account	tenant_id isolation
warga	Population master data	surrogate key + NIK encryption
kartu_keluarga	Family member relationship	FK to resident ID (not NIK)
riwayat_pendidikan	Resident education history	FK to resident ID (not NIK)
riwayat_pekerjaan	Resident employment history	FK to resident ID (not NIK)
jenis_surat	Letter category master	tenant_id isolation
template_surat	Letter HTML template	tenant_id isolation
surat	Letter submission data	FK to resident ID (not NIK)
akun_pengunjung	External resident accounts	tenant_id isolation
peran	User roler master	RBAC
izin_akses	Access rights master	RBAC
log_audit_data	Data change log	Audit trail
log_audit_sistem	Login activity log	Audit trail

The Surrogate Key implementation is used in the citizen table, where the auto-increment integer ID column is the sole identifier used in all inter-table relationships. Citizens' National Identification Numbers (NIK) are stored encrypted in the nik_encryption column of the citizen table. Internal identities are stored only in the family card, education history, employment history, or mail history tables. This security design ensures that citizens' NIKs will not be disclosed if data is leaked into these tables.

4.3. System Flow Design

The system flow design resulted in a flowchart for three user roles: Village Administrator, Registered Resident, and Outside Resident.

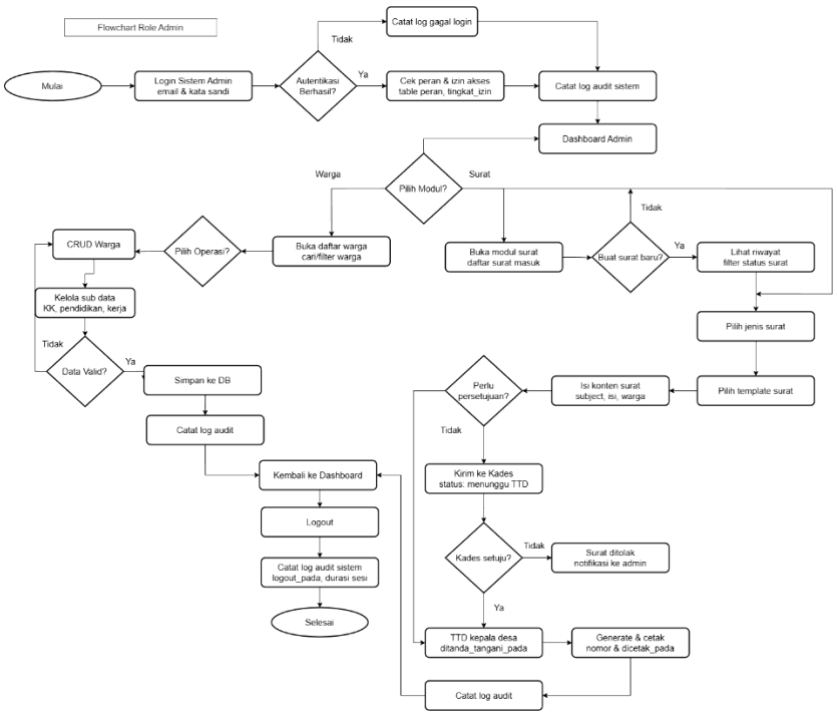

Fig. 1: Flowchart role of admin

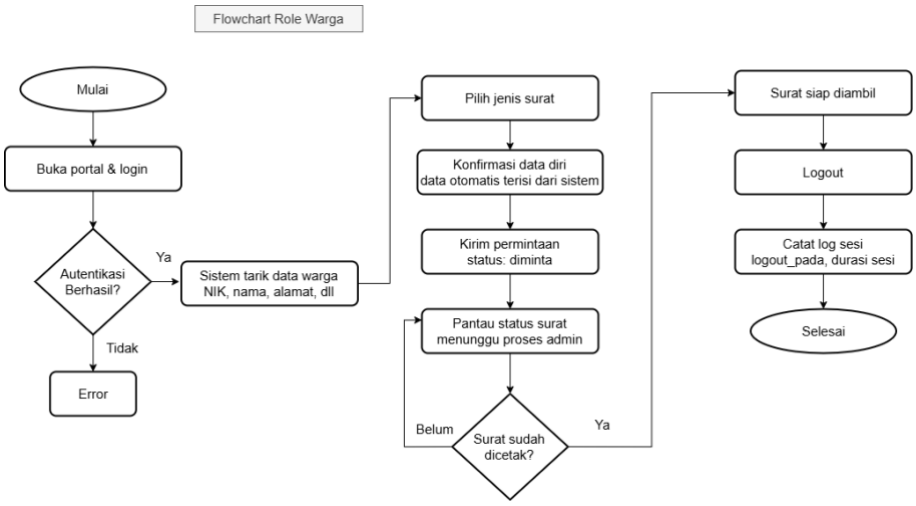

Fig. 2: Flowchart role of warga

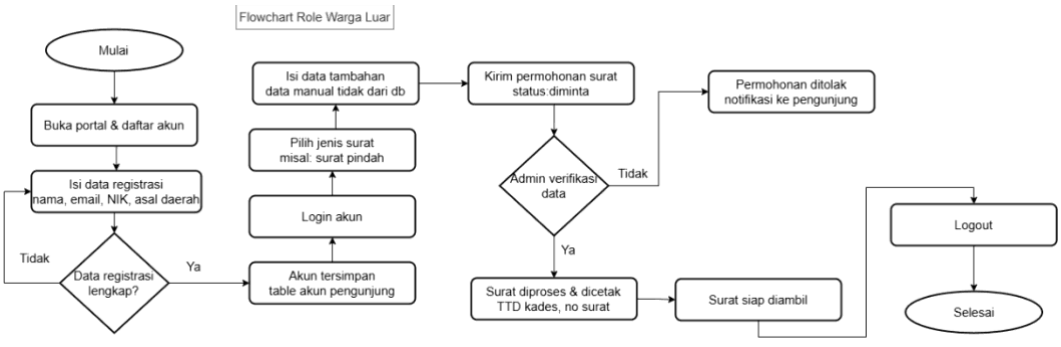

Fig. 3: Flowchart role of foreign citizens

Village administrators have a system flow for managing resident data and mail services. In the system design process, Laravel's Global Scope mechanism was used to restrict data access based on active tenants. This ensures that each village can only access data held by its respective tenant.

Registered resident data is designed with a self-service concept, allowing user data to be linked to resident data already stored in the system. This eliminates the need for repeated user data input. However, outside residents are designed to use a self-registration system through the visitor_account table, which can be verified by the Village Administration before processing the service [9], [12].

The system uses a stateful flow approach with several main statuses: draft, submitted, processed, completed, and rejected. Furthermore, the role-based access control (RBAC) concept used in the system design also supports a letter approval mechanism based on specific roles [12]. One way to monitor system activity is by recording changes in letter status in the audit log.

5. Conclusion

This study successfully designed the architectural foundation of the NUSA PRAJA village government system, with two main contributions: the implementation of the multi-tenant isolation and surrogate key concepts on the NUSAEKA platform. The multi-tenant architecture was designed using a shared database approach with column-level isolation, where the tenant_id column is used to bind data to a specific village.

By separating the National Identification Number (NIK) from the relationships between tables, the Surrogate Key concept was implemented when creating the database. While internal identities are used as the primary key for all relationships, the NIK is stored only in the citizen table in an encrypted state. In the event of a breach in the relational table, this method assesses the NIK data more accurately than conventional encryption. Furthermore, this study produced an ERD design with 14 flowcharts and main tables for three user roles.

For further research, it is recommended to proceed to the full implementation stage including the development of CRUD population data, NIK encryption with modern algorithms, implementation of multi-tenant Global Scope, and testing of data isolation on many tenants simultaneously.

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