

Agile-Based Application Architecture Design for Billet Management in Industrial Manufacturing

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ABSTRACT

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This study presents the planning and iterative development of an enterprise application architecture for the Billet Stacker Rail system in an aluminum manufacturing environment. The system is designed to enhance the management of billet logistics, including receiving, inspection, stacking, and transfer processes. Using the Agile methodology, particularly the Scrum framework, the development team collaborated closely with operational stakeholders to capture requirements and validate functionality through a series of Sprints. The process included modeling workflows, designing class and entity diagrams, and creating interactive user interface mockups. The system architecture was developed incrementally to support modularity, traceability, and real-time data recording. Each component from billet tracking to user management was prototyped and refined based on continuous feedback. The Agile approach facilitated rapid adjustments to changing requirements, reduced development risk, and supported a user-centered design process. The result is a robust and scalable application blueprint that aligns with the industrial environment's needs for efficiency, reliability, and transparency in billet management operations.

1. INTRODUCTION

The aluminum industry is one of the manufacturing sectors that plays a vital role in providing raw materials for various aluminum-based products. In the aluminum production process, raw material management is key to ensuring the efficiency and quality of the final product [1][2]. One important element in this process is the Billet Stacker Rail, a transportation system that enables the efficient transport and stacking of aluminum billets. Billets, which are raw aluminum bars, are the basic material in aluminum production. To ensure that aluminum production runs smoothly, there needs to be a system capable of regulating the flow of billets with precision [3][4][5]. The Billet Stacker Rail system is a solution used in many aluminum plants, such as PT Indonesia Asahan Aluminium (INALUM), to achieve this goal. Identify the industry's needs in optimizing aluminum raw material management and propose concrete steps to improve production efficiency by utilizing Billet Stacker Rail technology.

Application Architecture Planning is an important method in the development of efficient and effective information systems. In a corporate context, application architecture planning can help improve the efficiency and effectiveness of information systems used to support business processes [6][7]. The Billet Stacker Rail case study is an example of how application architecture planning can be applied in the development of information systems for companies. This process is used to build information systems that support business and government activities by considering business needs, application skills, and technical architecture [8][9][10]. Application architecture is used to determine the project requirements described and create an architectural scheme that aligns with the development strategy [11][12]. Risk management analysis, vision architecture creation, business architecture creation, data architecture creation, application architecture creation, and technology architecture creation are some of the stages that will be carried out in a project [13][14]. The use of the latest technology in this project is very important to improve the efficiency and effectiveness of the information system that has been developed. The use of methods that utilize the latest technology is one example [15].

Although previous research on enterprise application architecture and Agile methodologies has shown promising results in various domains, studies that explicitly integrate Agile-based approaches into billet management systems in the aluminium industry are still very limited. Most existing research focuses only on generic architecture frameworks or Agile implementation in conventional software projects, without considering the specific operational constraints of billet stacker rail systems. This has led to a gap in understanding how modularity, real-time data logging, and user-centered design can be systematically integrated to support billet logistics in an industrial environment. To address this gap, this research contributes by proposing an Agile-based application architecture design tailored to billet management needs. This study presents a modular blueprint in the form of class

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diagrams, entity models, and interface designs that can be used as a reference for similar industrial systems. In addition, the Scrum-based iterative development process demonstrates how system architecture can be continuously aligned with the real needs of users in a manufacturing environment. This contribution not only provides a practical basis for billet management system design but also expands the academic discourse on the adaptation of Agile methodologies in the context of industrial applications.

2. LITERATURE REVIEW

2.1 Industrial Business Needs Based Application Architecture Planning

Contemporary industrial businesses face unprecedented demands to match the technology infrastructure with evolving business requirements, which calls for sophisticated application architecture planning strategies with business needs analysis at their core. Enterprise architecture practice has understood that successful industrial application development must be envisioned, developed, and installed since strict understanding of organizational requirements, stakeholder interests, and business objectives [16][17][18]. This architect-planning guided by business is a break from the past technology-focused practice and has expertise in the imperative need of converting business imperatives into repeatable architectural plans that can respond to industrial purposes and, at the same time, provide scope for future modification [19][20][21]. Methodological foundation for needs-based application architecture planning in business is borrowed from validated and verified frameworks such as TOGAF (The Open Group Architecture Framework) that provides disciplined guidelines to conducting in-depth business requirements analysis and stakeholder engagement processes. Evidence supports that effective industrial architecture planning commences with careful analysis of business capabilities, process requirements, and strategic objectives, and their disciplined translation into appropriate technological solutions. The TOGAF ADM specifically identifies Business Architecture phase as a precursor to building consistent application architectures that have a direct applicability to ensure technological investment is done with a direct response to determined business needs compared to tracking technology installation in abstraction [22][23][24]. Besides, contemporary practices involve domain-driven design practices that enable architects to identify application boundaries naturally aligned with business domain models, enabling simpler traceability from technical implementations to business requirements. Industrial settings present their own types of challenges to business needs architecture design in that they hold difficult operating environments, safety concerns, and integration demands with mounted production systems. These challenges have been exacerbated by Industry 4.0 paradigms bringing additional demands for real-time data processing, cyber-physical system integration, and flexibility into manufacturing in manners that must be fully examined and translated into appropriate application architecture. Literature has established that industrial application architecture planning for effective industrial application entails custom-fit approaches with the capability to meet stringent performance requirements, reliability expectations, as well as compliance requirements with regulation typical of the industrial environment. Furthermore, increased applications of Industrial Internet of Things (IIoT) technologies need business requirements analysis to be extended beyond conventional enterprise borders in a way that can address ecosystem-level needs like supplier integration, customer connectivity, and regulatory reporting requirements that must be baked into the design right from the start [25][26][27].

2.2 Agile Applications for Industrial Application Development

The implementation of agile methods in industrial application development has become a primary answer to the rising levels of sophistication and dynamic forces present in today's manufacturing environments, where classical waterfall methodologies are not sufficient to meet the rising pace of technological transformation and changing business requirements. Evidence indicates that agile transformations, particularly Scrum and Kanban, have been highly promising in an industrial context by enhancing speed of delivery, stakeholder involvement, risk management, and team motivation through flexible practices that foster responsiveness, collaboration, and receptiveness to change. Industrial adoption of agile techniques requires intimate customization to address the issues of the manufacturing environment, for example, safety-critical specifications, hardware-software integration issues, and regulatory constraints hindering industrial applications from general software development projects. Recent research identifies that agile practices enable industrial businesses to achieve improved collaboration, lower release time, more deployments per day, and improved overall software quality with the same level of rigor needed for industrial automation systems [28][29][30]. Integrating DevOps practices with agile development has resulted in large synergies for industrial application development, where CI/CD pipelines accelerate the speed of software releases while maintaining quality expectations needed for industrial operations. Industrial DevOps is a paradigm that combines development and operational processes particularly tailored for production environments using automated security testing, automated deployment, and continuous monitoring features that address the unique needs of industrial cyber-physical systems. Research establishes DevOps automation in industrial settings achieves maximum effect on software quality through disciplined automation discipline, while continuous integration and deployment operations require special adaptation to accommodate hardware dependency and real-time requirements common to industrial systems. Embedded DevOps evolution applies these principles to firmware and embedded system development, handling hardware dependency, real-time requirements, and safety-criticality with adapted tooling, testing practices, pipeline automation, and security methods [31], [32][33]. Rapid prototyping methods have found growing use in solution development for industry to enable fast validation of automation solutions, control systems, and manufacturing processes in a series of iterative development cycles reducing development costs and time-to-market. Industrial rapid control prototyping (RCP) systems offer theoretical analysis and product design of networked control systems using low-cost, flexible platforms from PC-based controllers to embedded targets such that control algorithms are comprehensively tested before they are implemented on a mass scale. Rapid prototyping application extends

beyond software development and includes hardware-software co-design application where model-in-the-loop (MIL), software-in-the-loop (SIL), and hardware-in-the-loop (HIL) methods ensure end-to-end testability of real-time industrial control systems. Recent research indicates that open-source hardware and software blocks-based rapid prototyping platforms can potentially significantly reduce the cost of development without sacrificing the required levels of performance and reliability needed in industrial applications, particularly in the power electronics, process control, and industrial automation system domains [34][35][36].

3. RESEARCH METHODS

This study uses a system development approach based on the Agile methodology, specifically the Scrum framework, to plan the architecture of enterprise applications in the context of the aluminum manufacturing industry. This approach was chosen because it provides flexibility to changing requirements and enables iterative system development through intensive collaboration between developers and stakeholders [37][38]. Scrum consists of three main roles: Product Owner, Scrum Master, and Development Team. The work cycle in Scrum is divided into time units called Sprints, which typically last 1–4 weeks. Each Sprint begins with Sprint Planning, followed by Daily Scrum as a daily coordination forum, Sprint Review for evaluating results, and Sprint Retrospective for reflection and improvement of the development process [39]. The methodological stages conducted in this study include:

1. Observation of the Billet Stacker Rail business process, including recording workflows and identifying system requirements from the receipt to storage of billets.
2. Mapping operational processes in the form of flowcharts to illustrate the sequence of activities and critical points that require digital support systems.
3. Designing the data model and system through the creation of class diagrams and Entity Relationship Diagrams (ERD) as the basis for the database structure.
4. Creating a user interface prototype (mockup) to illustrate the system's appearance and main functionalities from the user's perspective.
5. Gradual validation of the prototype and system flow, conducted over several Sprints using Agile principles, involving operational users as feedback providers.

This approach is based on the principle that application architecture is not only built on technical theory but also adapted to the industrial process context where the system is applied. Application architecture planning must consider quality attributes such as reliability, modifiability, and efficiency according to domain requirements [40]. By combining an iterative and user-oriented work model, system development in this study can respond to real needs with relevant and adaptive solutions.

4. RESULTS AND DISCUSSIONS

This research produced an application architecture design for the Billet Stacker Rail system that can improve the efficiency of billet management in the aluminium industry. The development process was carried out through an iterative approach based on the Agile methodology, starting from understanding the operational process to the visual design of the application.

4.1 Operational Process Modeling

The first step was to identify and model the main business processes in billet management. This process begins with the receipt of cast billets, quality inspection, transfer to the stacker system, stacking based on specific criteria, and transferring to the storage or further production area. To document this process systematically, a flowchart was created to illustrate all stages of activity in the Billet Stacker Rail system.

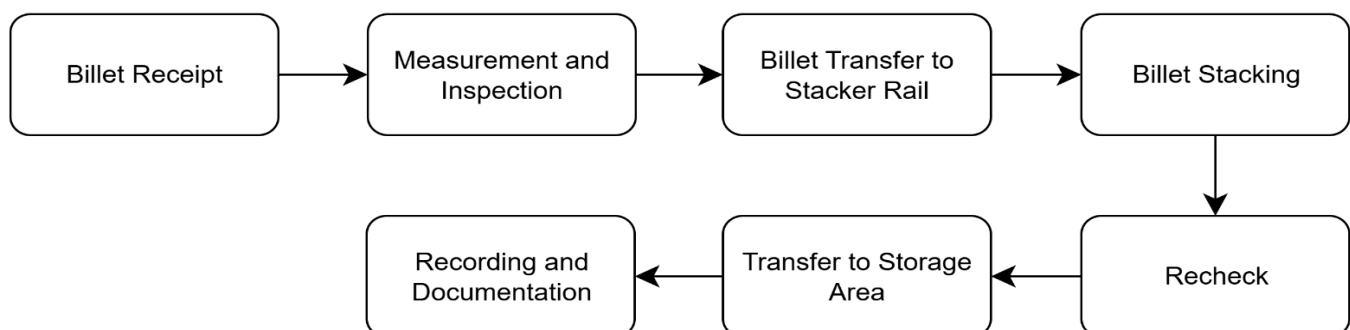


Figure 1. Flowchart of Billet Handling Process in Billet Stacker Rail

This visualization helps identify points that require application-based support systems, such as inspection recording, stacking arrangements, and real-time billet tracking.

4.2 System Structure Design

Based on the modeled operational processes, the next step is to define the data structure and main entities in the system. This is visualized in the form of a class diagram, which includes entities such as Billet, StackerRail, User, Inspection, and Activity.

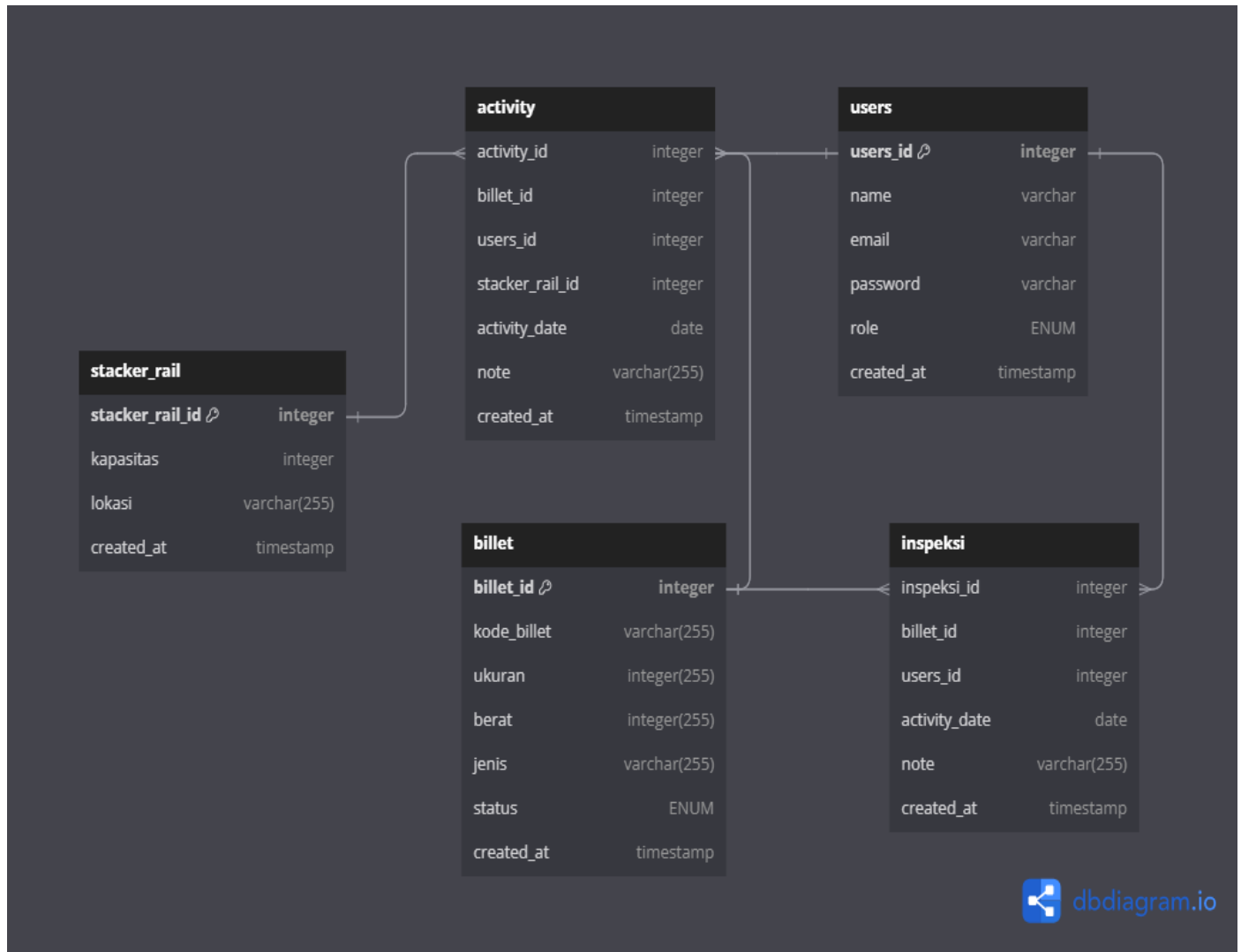


Figure 2. Class Diagram of Billet Stacker Rail Monitoring Application

Each entity has attributes and relationships that reflect the functional requirements of the system. For example, each Billet has attributes such as ID, Size, Weight, Date, and Status, and is connected to activities and inspection results. These relationships are designed to support the traceability of each billet unit.

4.3 Application Interface Design

The user interface is designed to meet the operational needs of both field users and administrators. The system display mockup was developed as an initial overview of the visual design and navigation of the application's features. The main page is the Dashboard, which displays billet statistics, current status, and a summary of system activity.

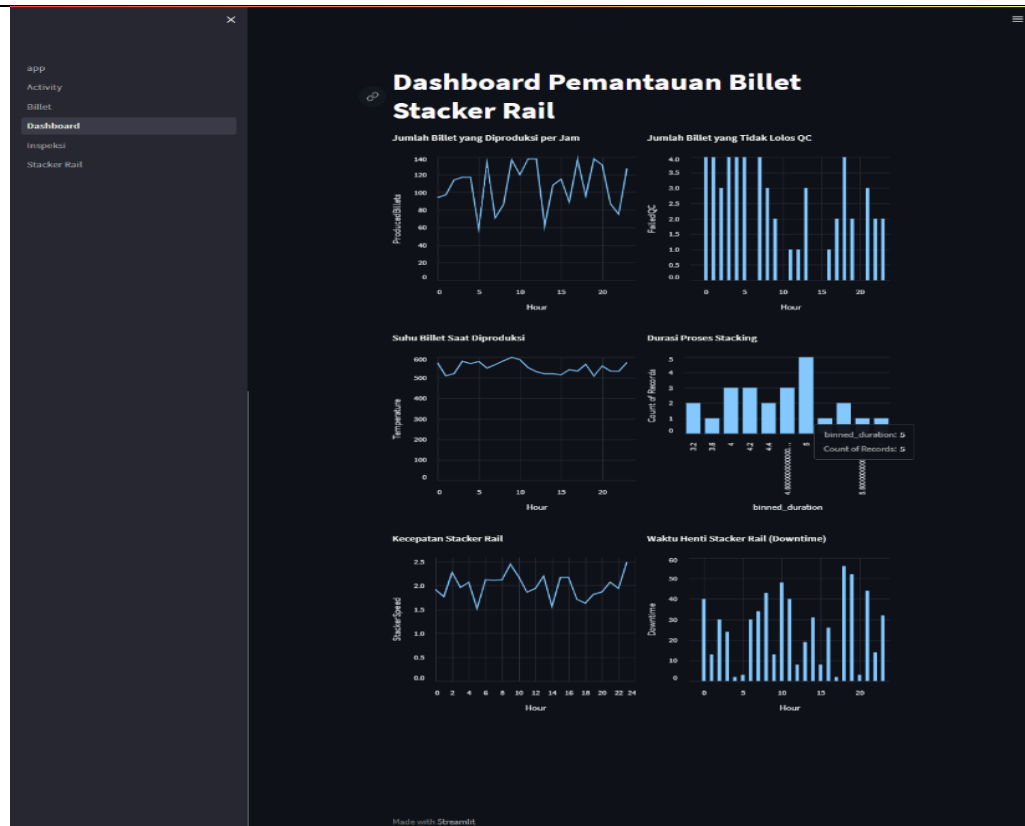


Figure 3. Mockup – Main Dashboard Display

The Billet Data page contains a list of billets along with their technical details and status.

ID	Ukuran	Berat	Jenis	Penerimaan	Status	
0	1	20	200	Aluminium	2024-01-03	diterima
1	3	220	230	Aluminium	2024-01-03	diterima
2	5	200	200	Alum	2024-01-01	diterima

Figure 4. Mockup – Billet Data Display

The Activity page displays the history of billet transfer, inspection, and stacking activities.

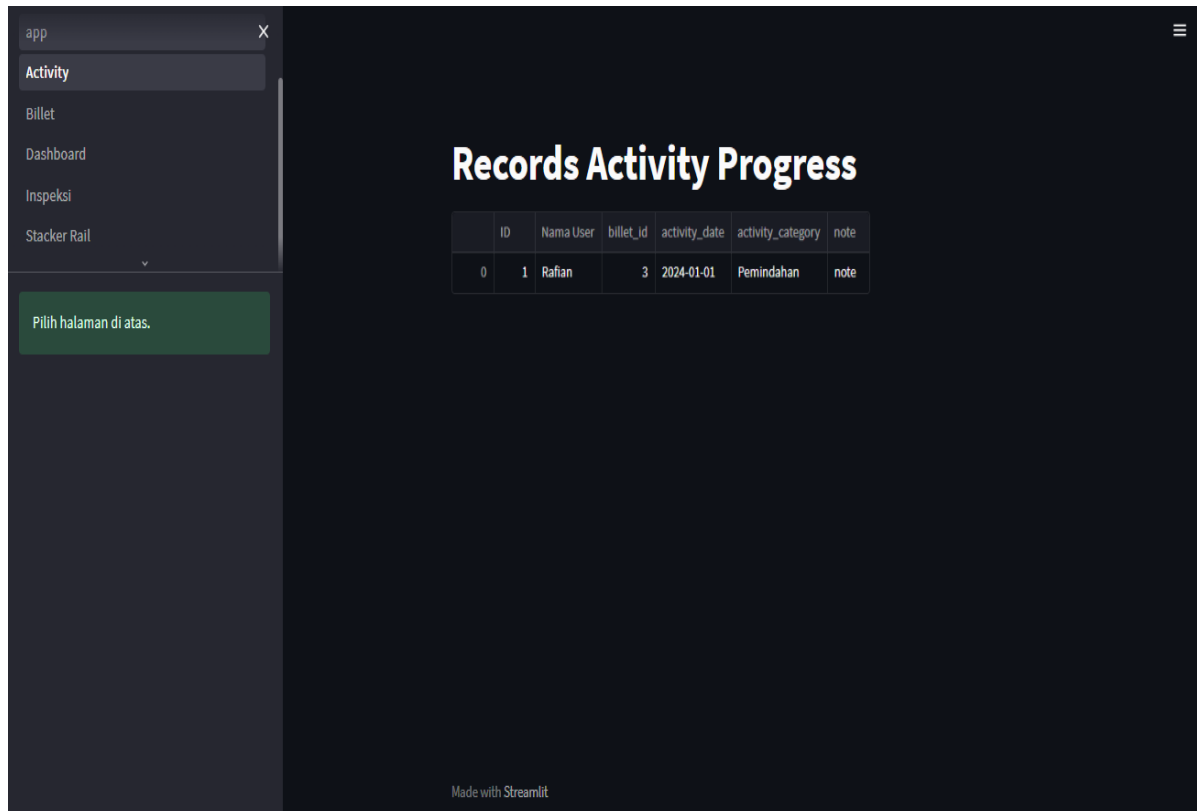


Figure 5. Mockup – Activity Log Display

The Inspection page is used to record the results of billet quality inspections.

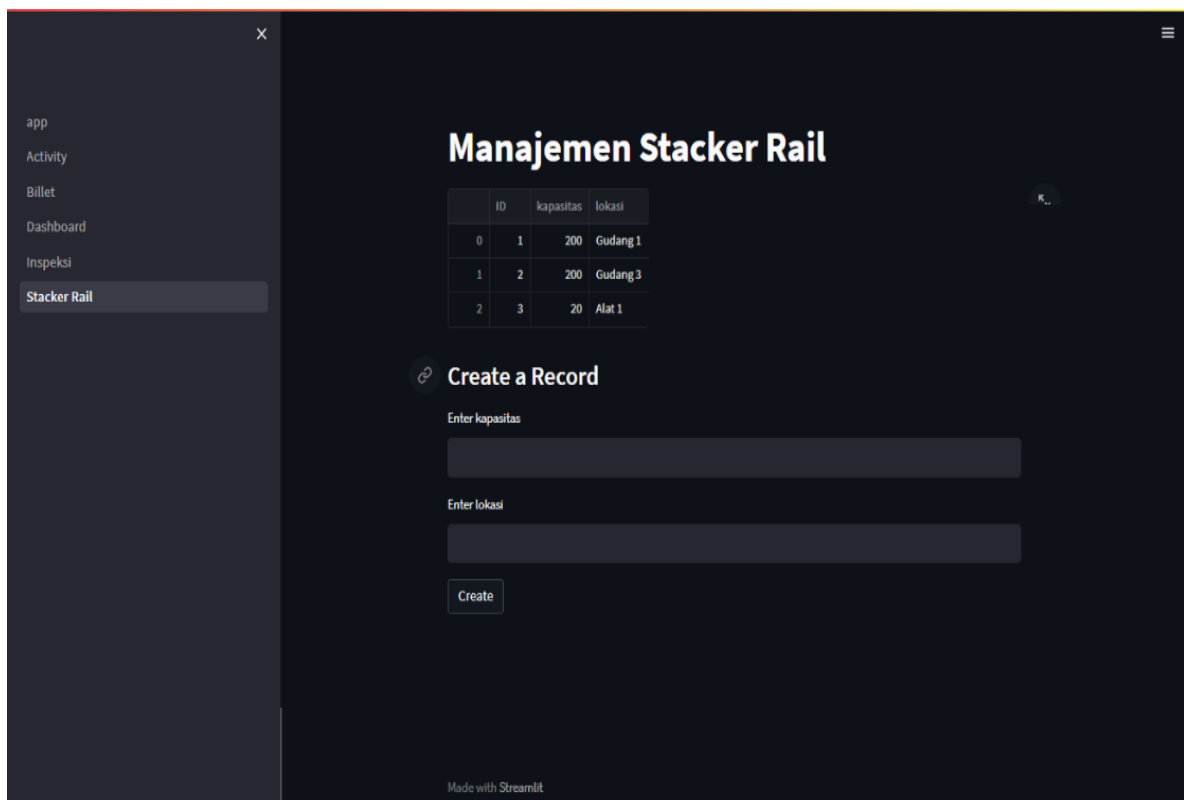


Figure 6. Mockup – Inspection Form View

The User page is used to manage user accounts, roles, and access authorizations.

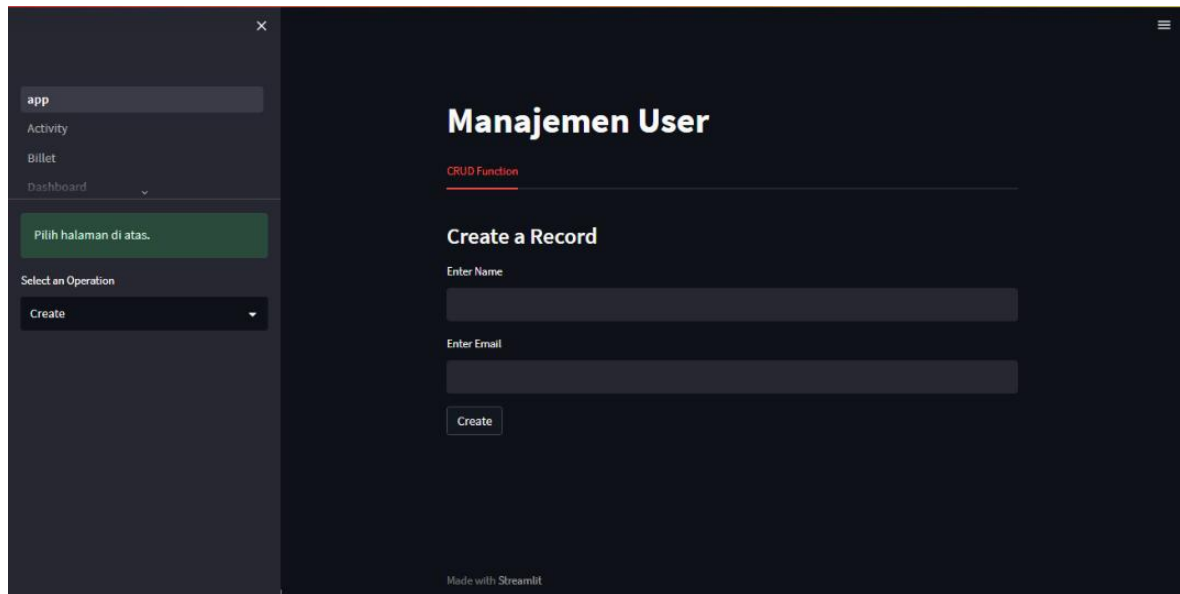


Figure 7. Mockup – User Management View

This design was created with user-centered design principles in mind, ensuring that the interface is easy to understand, lightweight to run, and supports operational tasks efficiently.

4.4 System Architecture Viewpoint

The system architecture is designed following a layered approach that ensures modularity, scalability, and maintainability. At the highest level, the architecture consists of three main layers in Figure 8:

1. **Presentation Layer** – Provides user interfaces for operators, inspectors, and administrators. This includes dashboards, billet data views, inspection forms, and user management interfaces.
2. **Application Layer** – Manages the business logic and core functionalities, including billet tracking, inspection management, stacking operations, and user access control.
3. **Data Layer** – Responsible for data storage, retrieval, and consistency. This layer hosts the database schema derived from the entity relationship diagram, ensuring traceability of billet information.

To support integration with industrial environments, the architecture is designed with modular service endpoints that allow interoperability with plant systems such as PLCs, SCADA, and IoT-based data collection. Each module is loosely coupled, enabling future extensions without major architectural changes.

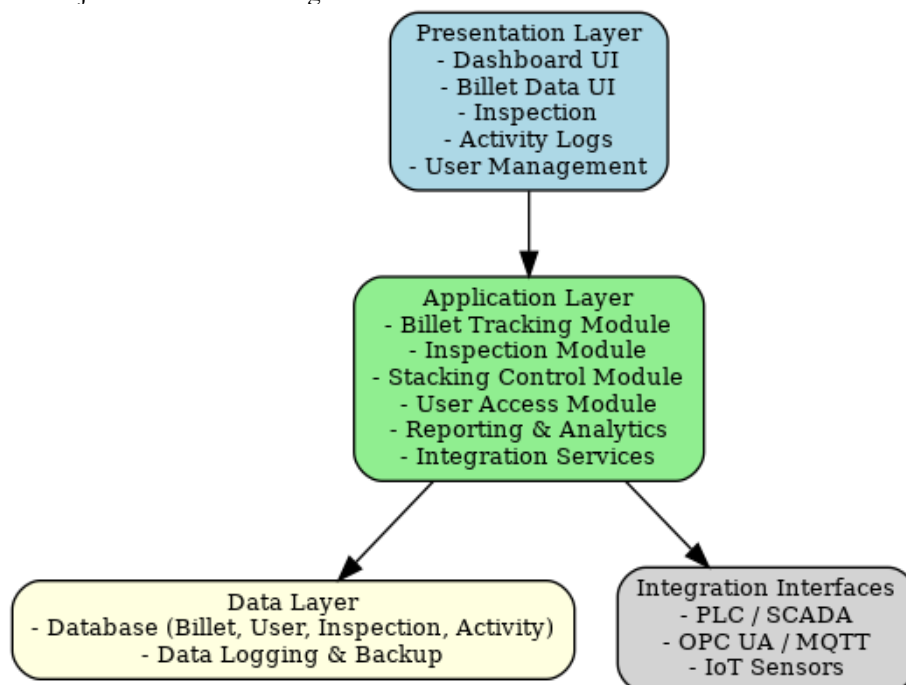


Figure 8. System Architecture Viewpoint

4.5 Reflection on Agile Implementation

The use of the Agile methodology, particularly the Scrum methodology, was very effective in iterative development of the Billet Stacker Rail application. Agile principles enabled the project team to adaptively react to changing user requirements, prioritize functionality in order of operational importance, and provide tangible results by Sprints-based iterative development cycles. During the early Sprints, feedback was centered around usability of the system specifically dashboard design, inspection input effectiveness, and legibility of billet status indicators. These were rapidly resolved in the form of interface redesign and enhanced data visualization components. The software evolved in a few weeks from conceptual model to functional prototype, tested and validated by operations personnel who frequently served as Product Owners and testers. This close coupling with users is one of the key strengths of Agile in system projects in industry, enabling domain expertise to influence system behavior and design directly.

The incremental nature of Scrum facilitated a continuous validation process. Rather than delivering a completed system at the end of the development process (as in waterfall processes), functionality was validated, enhanced, and merged in each Sprint. This methodology is especially worth its while in factory environments, where operation processes may vary a little from shift to shift or production run to production run, and where user feedback can simultaneously prevent the invasion of crippling flaws into the end system. Architecturally, Agile methods supported modular thinking each subsystem was treated as a loosely coupled element that could be inserted or removed independently. Such modularity is also consistent with future scalability and maintainability of the system; whereby future extensions can be implemented without major overhauls.

Additionally, Agile facilitated the team to perform rapid prototyping, something that was crucial in testing hypotheses on system flow and interface design. In practice, Agile allowed the use of mockups and click-through prototypes to simulate use in operation before final implementation, thus minimizing cost of development and time-to-feedback. Incremental improvements like this allowed the application to become increasingly user-expectation aligned, with potential for better adoption at the deployment phase. There were problems, though. For instance, Scrum ceremonies had to be tailored to the constraint of industrial operations, in which operation personnel were not allowed much time for meetings or reviews. To that end, daily lightweight reporting and asynchronous feedback collection were established. Moreover, not everyone in the team was conversant with Agile at initial stages, so internal coaching was necessary to develop common understanding of roles and responsibilities. In short, the Agile methodology was not only a method for software development but also a collaborative framework for plotting technology solutions against operational needs. It promoted transparency, stakeholder engagement, and fail-fast learning culture, all of which are essential while designing mission-critical applications in rapidly evolving industrial settings. Experience in this project supports findings in industrial software development research that Agile, when properly adapted, can considerably increase the quality and suitability of enterprise applications.

5. CONCLUSION

This study delves deeply into enterprise application architecture planning with a focus on the implementation and development of systems for Billet Stacker Rail. In exploring important aspects of enterprise application architecture, this research has formed a deep understanding of the needs of the Billet Stacker Rail system. The identification and determination of the scope of enterprise applications has become a strong foundation for designing an architecture that meets needs while considering crucial factors. In application architecture planning, the importance of system efficiency and performance is a key concern. Optimal design and the selection of appropriate technology can ensure optimal performance of the Billet Stacker Rail, reduce downtime, and enhance productivity. The conclusions of this research encourage further steps in application development. More in-depth testing, prototype implementation, and closer integration with the company's business needs are key considerations in the ongoing development process. By completing this study, our hope is that the findings and conclusions outlined can serve as a valuable contribution to the development of enterprise application architecture, not only within the context of this case study but also to foster thinking and innovation in broader fields.

This study is limited to the design and prototyping stage without full integration into actual plant systems such as PLCs, SCADA, OPC UA/MQTT, or real-time industrial networks. The methodology was conducted within a constrained academic setting, so detailed experimental validation involving larger participant groups, formal instruments, and quantitative performance metrics could not be carried out. As future work, further research should focus on deploying the proposed architecture in real industrial environments, evaluating system performance through measurable indicators such as response time, data consistency, and operational efficiency, as well as exploring broader integration with Industry 4.0 technologies.

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