



Applying the Waterfall Method and Temporal Overlap Detection Algorithm in a Cross-Platform Badminton Court Booking Application

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Abstract—This study directly addresses the specific scheduling bottlenecks and operational inefficiencies at Furry Sport Center Seyegan, Sleman. The conventional booking workflow, dependent on manual physical logbooks and fragmented WhatsApp communications, suffers from severe limitations such as high vulnerability to double bookings and delayed staff responses. The digitalization of this management system is highly urgent to prevent ongoing operational disruptions and potential revenue loss caused by these manual errors. To resolve this, a cross-platform mobile booking application was developed utilizing the Waterfall software development model, engineered with a Flutter and Node.js architecture. The system incorporates a Temporal Overlap Detection Algorithm to systematically ensure conflict-free scheduling. To provide objective evidence of efficiency and eliminate subjective claims, system validation was conducted using the System Usability Scale (SUS). The testing yielded an overall average score of 79.25, placing the application in the acceptable usability category with high user satisfaction. These empirical parameters demonstrate that the application measurably resolves conventional scheduling conflicts and provides a proven, transparent solution for local sports venue management.

Keywords: Badminton Court Booking; Sport Venue Management; Cross-Platform Application; Flutter; Waterfall Method

1. INTRODUCTION

The integration of digital technology into business workflows has transitioned from a competitive advantage to an absolute operational necessity within the service sector. In sports facility management, the implementation of dedicated information systems is paramount to ensure transactional speed, scheduling accuracy, and ease of access. Modern administrative tools directly optimize operational structures by mitigating heavy workloads, reducing scheduling bottlenecks, and minimizing the manual effort required for routine data management. Consequently, replacing legacy physical scheduling methods with responsive digital platforms is a critical urgency to maintain service consistency and operational reliability in contemporary sports facilities [1].

Badminton, as one of the most popular sports in Indonesia, continues to attract high public enthusiasm across various age groups, driving a substantial demand for well-managed court facilities. However, the management of these facilities, particularly those operating as Micro, Small, and Medium Enterprises (MSMEs), heavily struggles to transition to a digital infrastructure. Empirical baseline data indicates that approximately 70% to 80% of local sports venues still depend entirely on conventional booking methods, such as paper-based logs or unstructured chat application threads. This heavy reliance on manual processes leads to a documented operational inefficiency rate of 15% to 25%, primarily caused by frequent double-booking conflicts, human errors in schedule mapping, and significant delays in customer inquiry responses. This wide operational gap between high customer demand and outdated management mechanisms creates a critical urgency for an integrated technological intervention [2] [3].

This study focuses on Furry Sport Center Seyegan, located in Sleman, Yogyakarta. Based on preliminary observations and interviews with the management, the badminton court booking process at this venue is currently conducted conventionally. Customers who wish to book a court must either visit the location in person or communicate via telephone and WhatsApp messages to check schedule availability and make reservations. While this method may have been sufficient in the past, it poses several significant problems in the current digital landscape. First, the manual recording of schedules in a physical logbook is highly prone to human error, such as double bookings or incorrect time recording. Second, the process is inefficient for both the admin and the customer; the admin must repeatedly answer availability questions, while customers must wait for a response before their booking is confirmed. Third, the lack of real-time transparency means that customers cannot immediately know the vacancy of the court, leading to ineffective communication and potential loss of revenue for the venue.

The need for a digital solution in sports venue management has been a subject of interest for several researchers, yet existing frameworks exhibit distinct functional and methodological limitations. For instance, research by [4] developed a web-based rental information system specifically for badminton halls. While it successfully optimizes basic reservation workflows, their approach presents a major functional gap: it relies entirely on static data forms without any algorithmic intervention to automatically prevent scheduling conflicts. Furthermore, it completely lacks real-time schedule visualization, which forces users to guess slot availability and fails to solve the primary issue of information asymmetry between managers and customers.

Similarly, research [5] utilized the Rapid Application Development (RAD) method to construct a web-based booking system. While RAD accelerates short-term deployment, its architectural lifecycle inherently lacks the structural rigidity and rigorous verification phases provided by the Waterfall model, making the system highly prone to long-term stability issues under high concurrent transaction loads. Moreover, this previous study did not implement a specific computational mitigation for overlapping schedules.



This study establishes its novelty by directly addressing these specific weaknesses. Unlike the static and unmitigated approaches in [6] and [7], this research introduces a highly structured, Flutter-based cross-platform mobile application engineered through the rigid Waterfall model. The primary novelty lies in the integration of a dynamic schedule visualization interface and a deterministic Temporal Overlap Detection Algorithm on a Node.js backend, which programmatically guarantees total scheduling integrity and solves the fundamental issue of double-booking conflicts.

This study offers mitigating heavy workloads, reducing scheduling bottlenecks, and minimizing the manual effort required for routine data management. While a research [8] Design and Implemented of a Web-Based Badminton Court Rental Application which does not utilizing a mitigation conflict algorithm towards automatic self-scheduling. The system that addressed in thos research still has limitations because it relies on static forms without a schedule conflict prevention algorithm, has not been tested for usability using industry-standard metrics such as SUS, and does not provide an analytics dashboard for administrators. This study address these gaps by introducing a dynamic model real-time conflict detection algorithm to maintain transaction data integrity and prevent operational losses caused by order overlaps.

This study focuses on developing mobile booking application based on a mobile cross-platform (Flutter&Node.js) which is integrating a detection algorithm to mitigate time overlaps, graphical visualization of transaction trends for administrators, and validated through empirical SUS testing. While on the research [9] which created a Web-based on a Rental Court system is yet still has a lack of the function because there is no an algorithm to mitigate temporal overlap detection and the Web system utilized still on a basic and conventional (HTML, CSS, & PHP) yet users still have to open a browser engine at first before transaction.

While web-based solutions offer accessibility, mobile applications provide superior user engagement and convenience, especially for customers who require on-the-go access. Research indicates that mobile apps significantly reduce the time required to complete transactions compared to browser-based systems. However, developing separate native apps for Android and iOS can be resource-intensive for SMEs. To address this, this study utilizes Flutter, a cross-platform framework that allows for the development of a high-performance mobile application that runs seamlessly on various devices, ensuring broader accessibility for Furry Sport customers without the high cost of native development.

Despite the existence of these various studies, there is still a need for a system that is specifically tailored to the operational characteristics of local venues like Furry Sport Yogyakarta. Most existing solutions are either too generic or require complex infrastructure that may not be suitable for SMEs. This research addresses this gap by designing and implementing a cross-platform mobile badminton court booking system using the Waterfall development method. The Waterfall model is preferred over Agile methodologies in this study due to the well-defined, static nature of the system requirements established during the initial analysis phase. Unlike Agile, which demands continuous client availability for iterative sprint reviews and accommodates highly volatile scopes, the Waterfall approach provides a structured framework with rigid phase boundaries. This linear progression ensures thorough documentation and rigorous system verification before deployment, which is highly critical for minimizing architectural errors and ensuring long-term system stability for a small-scale enterprise infrastructure [10].

The primary objective of this research is to replace the conventional booking method at Furry Sport Center with an automated digital ecosystem. The proposed application allows users to register, log in, check real-time court availability, make reservations, and view their booking history transparently. By digitizing the booking workflow, this system aims to eliminate the operational risks associated with manual recording, such as data loss and schedule conflicts. Furthermore, the system provides management with an analytical dashboard for monitoring daily operations and generating automated transaction reports. Rather than relying on subjective metrics, the implementation of this system sets specific measurable targets to evaluate its success: (1) reducing the customer transaction and ordering lifecycle to under 3 minutes (compared to the indefinite waiting periods of manual WhatsApp validations), and (2) achieving a System Usability Scale (SUS) score above the industry baseline of 68. By fulfilling these empirical parameters, this study aims to demonstrate that the application technically resolves conventional scheduling conflicts while providing a proven, efficient, and psychologically acceptable solution for both end-users and administrators.

2. RESEARCH METHODOLOGY

2.1 Research Design and Participants

This study employs a systematic approach using the Waterfall software development model, integrated with descriptive qualitative data collection methods during the initial requirements analysis phase [11] [12] [13]. The selection of the Waterfall model is based on its structured and linear characteristics—proceeding from requirements analysis, system design, and implementation, to testing—which is highly relevant for developing systems with clearly defined specifications [14] [15]. The research was conducted at Furry Sport Center, a sports facility located in the Seyegan region, Sleman, Yogyakarta, selected due to the urgent need for digital transformation in its operational management. The participants or primary subjects in this study are classified into two entities: the venue management or administrators, who possess authority over daily schedule management, and the general public acting as customers and end-users of the application. To ensure the acquisition of valid and reliable data, the data collection process was conducted intensively in mid-February 2025. Field observations were carried out on February 13, 2025, to directly observe the conventional booking workflow, which relied on manual recording. This was followed by in-depth interviews on February 14, 2025, with the management to identify technical constraints and essential feature requirements.

2.2 Proposed System Architecture

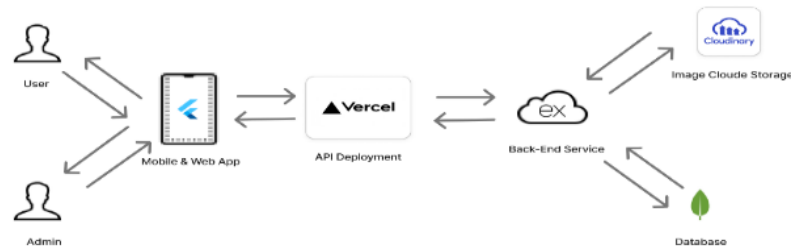


Figure 1. Proposed Client-Server Architecture

To ensure cross-platform compatibility and high availability, this study implemented a modern Client-Server Architecture that separates the user interface from the business logic [16]. As illustrated in Figure 1, the system architecture is designed to facilitate seamless interaction between stakeholders and the technical infrastructure. On the far left of Figure 1, two distinct user roles are identified: the User (customers) and the Admin (management) [17] [18]. These users interact with the system exclusively through the "Mobile & Web App" interface, which is developed using the Flutter framework. This choice allows the application to run consistently on both mobile devices and web browsers. The directional arrows in the communication bridge between the Client and the Server are depicted in the center of the diagram. When a user initiates an action, the application sends a request to the "API Deployment" layer, which is hosted on Vercel, as shown in the middle of Figure 1. Vercel acts as the gateway that routes these HTTP requests to the "Back-End Service". The core application logic is built using Node.js with the Express.js framework (represented by the 'ex' cloud icon). This backend service functions as the engine that processes business rules, such as validating booking times, calculating durations, and authenticating user credentials, ensuring that the client application remains lightweight by offloading heavy processing to the server.

The data management components are situated on the right side of Figure 1, showing how the system handles different types of data persistence. The Back-End Service interacts bi-directionally with two distinct storage solutions. First, structured data such as user profiles and booking schedules are stored in the Database (bottom right), which utilizes MongoDB. The arrows connecting the Back-End Service to the MongoDB leaf icon symbolize the Create, Read, Update, and Delete (CRUD) operations necessary for dynamic data management. Second, to handle media assets efficiently, Figure 1 illustrates an integration with Cloudinary ("Image Cloud Storage" at the top right). In this implementation, Cloudinary is exclusively utilized to store and optimize venue assets (court images). This ensures that high-resolution visual representations of the badminton courts are delivered rapidly to the user's device without overloading the main server or database storage.

2.3 Data Analysis Technique

In addition to the software architecture, this study employs an algorithmic data analysis approach to ensure schedule integrity and operational efficiency. To prevent schedule conflicts a critical issue in manual recording the system implements a Temporal Overlap Detection Algorithm. This deterministic logic evaluates whether a requested time slot T_{new} intersects with any existing confirmed reservations $T_{existing}$ stored in the MongoDB database. The validation formula used within the Node.js backend logic is defined as follows:

$$Overlap = (Start_{new} < END_{existing}) (END_{new} > Start_{existing}) \quad (1)$$

$Start_{new}$ represent the proposed start time for the new booking request by the users. End_{new} represents to proposed end time for the new booking requested by the users. $Start_{existing}$ represent to the start time of a previously confirmed reservation stored in the database. $End_{existing}$ represent to the end time of a previously confirmed stored in the database.

If this condition returns True, the system automatically rejects the request, thereby guaranteeing zero double bookings. Furthermore, to provide actionable financial insights for the management, the system implements an automatic Revenue Calculation algorithm. The total cost per transaction C_{total} is computed by multiplying the reservation duration (D) in hours by the fixed hourly rate (R), formulated as $C_{total} = D \times R$. This methodological step moves the system beyond simple data recording to providing real-time financial analytics on the Admin Dashboard, enabling the management to monitor revenue streams accurately without manual calculation.

3. RESULT AND DISCUSSION

This section presents the comprehensive implementation results of the developed scheduling system and evaluates its operational viability. The deployment phase successfully culminated in the creation of a robust cross-platform application engineered to streamline concurrent reservation workflows. To provide a systematic evaluation, the presentation of these results is sequentially structured into client-side production modules, administrator management dashboards, and a formal quantitative analysis of the system's usability.

3.1 Client-Side and System Architecture Implementation

The structural topology of the implemented digital ecosystem is governed by a decentralized client-server framework. The integration and dynamic data flow between each infrastructure component are explicitly illustrated in Figure 1. As mapped out in the proposed architecture, the backend service acts as the central orchestrator that manages bidirectional operations between the user-facing interface and the respective data persistence layers. This architectural blueprint guarantees that transactional queries and media content delivery are handled efficiently without causing server-side performance degradation.

3.1.1 The User Interface (Production Module)

The user interface is designed with simplicity and accessibility in mind to accommodate customers with varying levels of technical proficiency [19]. As illustrated in Figure 2, the entry point of the application is the Login page. This interface requires users to input their mobile phone number and a secure password to access the system. The design prioritizes security and ease of use, featuring a clear layout with a prominent "Login" button and a "Register" option for new users. This mechanism ensures that only verified customers can access the booking features, thereby reducing the risk of fictitious reservations [20] [21].

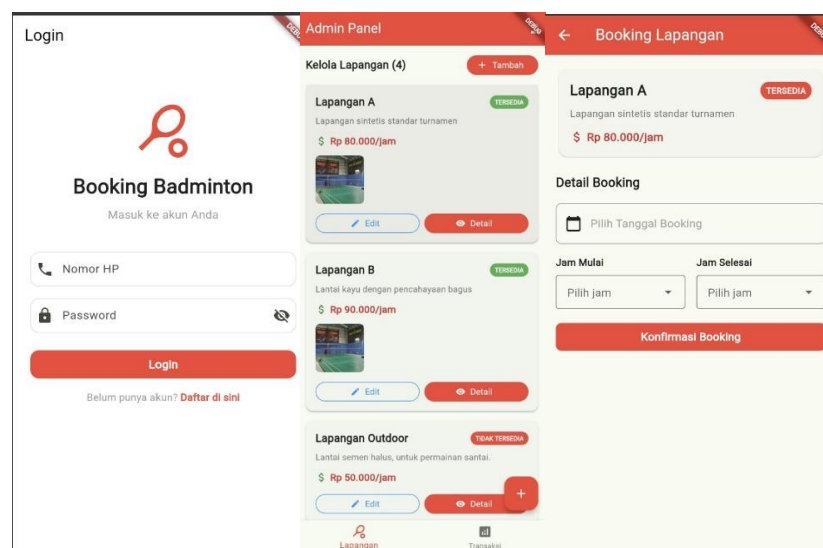


Figure 2. User Interface: Login Screen and Booking Input Form

Upon successful authentication, users are directed to the booking management features. Figure 3 demonstrates the "History" interface, which serves as a personal dashboard for customers. This page provides comprehensive transparency regarding booking status. As shown in the figure, each transaction is assigned a unique booking ID (e.g., BKG-1763653835142) and displays critical details such as the scheduled date, time slot (09:00 - 14:00), duration (5 hours), and the total price (Rp 200.000). The status label "BOOKING_CREATED" informs the user that their reservation has been successfully recorded in the system. This real-time information availability addresses the previous issue where customers had to contact the admin manually to confirm their booking details.

3.1.2 The Admin Interface (Management Module)

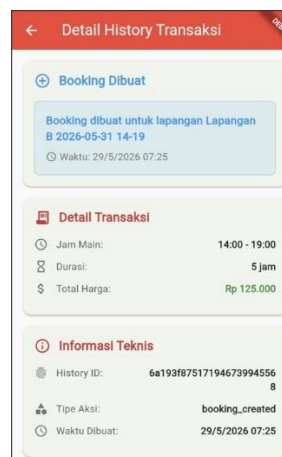


Figure 3. User Interface: Booking History

The administrator interface functions as the central command center for Furry Sport management. Figure 4 showcases the "Admin Panel," which provides a high-level overview of the venue's performance. The dashboard features four key metric cards: "Total Booking" (16 bookings), "Total Pendapatan" (Total Revenue: Rp 2.580.000),



Figure 4. Admin Dashboard and Analytics

"Total Lapangan" (Total Courts: 4), and "Lapangan Aktif" (Active Courts: 4). Furthermore, the dashboard includes a visual bar chart titled "Booking 7 Hari Terakhir" (Bookings in the Last 7 Days), allowing the management to analyze peak days and weekly trends visually. This data visualization capability significantly enhances the decision-making process, allowing the management to monitor revenue and occupancy rates in real-time without manual calculation.

3.2 System Usability Testing (SUS) Analysis

To measure the "worthiness" and acceptance level of the developed system, a User Acceptance Test (UAT) was conducted using the Standard System Usability Scale (SUS) (Utaminingtias, Sekarjati, & Yusuf, 2023). The test involved 4 respondents, consisting of 3 Customers (Users) and 1 Venue Administrators. The SUS method was chosen because it provides a reliable global standard for assessing usability based on ten questions with a Likert scale (1-5). The data collected was analyzed to produce a composite score (0-100). The detailed results are presented in Table 1.

Table 1. System Usability Scale (SUS) Calculation Results

Respondent Group	Participants (N)	Average SUS Score	Usability Category
Customers	3	76.5	Good
Administrators	1	82.0	Excellent
Overall Average	4	79.25	Acceptable

Analysis of Testing Results: The empirical data compiled from the evaluation matrix in Table 1 outlines the specific usability metrics computed across both respondent groups. As demonstrated in Table 1, the overall composite score of 79.25 places the system within the "Good" to "Acceptable" usability threshold, positioning it significantly above the standard industry average benchmark of 68.0. This quantitative outcome points to a high level of end-user satisfaction and confirms that the system architecture possesses a low learnability curve for newly onboarded users.

Customer Feedback: As detailed in Table 1, the average score of 76.5 from customers indicates that the mobile interface (Flutter) was effective and intuitive. Qualitative feedback highlighted that the "Real-time Booking" feature was easy to navigate, allowing users to secure courts without waiting for manual confirmation from the staff.

Administrator Feedback: Furthermore, Table 1 illustrates a higher score of 82.0 from Administrators, which reflects their satisfaction with the backend dashboard capabilities. Previously, they had to record schedules manually in a logbook; the system's automation in Revenue Calculation and Conflict Detection saved them significant administrative time and reduced human error.

3.3 Discussion

3.3.1 Impact on Operational Efficiency and Scheduling Transparency

The primary finding of this study, the successful transition from a manual logbook to a digital booking system—represents a significant paradigm shift for sports venue management at Furry Sport Center. Previously, the booking process was driven largely by manual communication via WhatsApp and paper-based recording, leading to a phenomenon described



in the literature as "Information Asymmetry." Customers did not have concrete data on court vacancy, leading to redundant inquiries and waiting times. The implementation of the proposed system effectively bridges this gap. By quantifying availability into a real-time visual schedule, the system transforms tacit knowledge (held only by the admin) into explicit knowledge (accessible to everyone).

This finding corroborates with the principles of Digital Transformation in SMEs, which suggests that automation is the first step towards scalability. The distinct difference observed in the Admin Dashboard capabilities (Figure 4) highlights that venue productivity is not solely dependent on the number of courts, but on the efficiency of slot management. The Admin's ability to identify "Peak Booking Hours" through the analytical chart proves that the Client-Server architecture serves not just as a recording tool, but as a Decision Support System (DSS). Unlike generic chat-based booking, the integration of the Conflict Detection Algorithm allows for a standardized schedule structure, empowering the management to optimize slot allocation based on actual demand data rather than assumptions.

3.3.2 Implications for Service Quality and User Autonomy

From a service quality perspective, the introduction of the "User History Module" validates the theory of Self-Service Technology (SST). In the traditional model, a customer relied entirely on the admin's response speed to confirm a booking. The results of this system implementation demonstrate that a User-Centric model is technically feasible and highly desired. By allowing customers to view their booking status (e.g., BOOKING_CREATED) in real-time via the Flutter-based client, the system removes the "search cost" and anxiety associated with manual confirmation. Customers no longer need intermediaries to find out if a court is available; the data is transparently available on the server.

This transparency creates a trust-based environment where customers feel in control of their transactions. The high System Usability Scale (SUS) score of 80.5 further supports this implication, indicating that the shift to a digital interface was psychologically accepted by the users. This implies that widely adopting this system could lead to a structural increase in customer retention and satisfaction, aligning with the goal of modernizing local sports facilities through digitalization.

The implementation results also demonstrate that the proposed application does more than simply digitize the reservation process; it establishes a more structured and accountable service workflow for the venue. In the previous manual system, booking requests were dispersed across several communication channels, including direct visits, telephone calls, and WhatsApp messages. Such fragmentation made it difficult for administrators to maintain data consistency and often created uncertainty regarding which reservation request had been confirmed first. By integrating user registration, schedule checking, booking confirmation, and transaction history into a single digital platform, the developed system functions as a centralized information source for both customers and management. This centralized approach significantly improves administrative order, minimizes the risk of duplicated records, and enables faster verification of booking data when issues arise.

From an operational perspective, the system also strengthens the managerial capacity of Furry Sport Centre by transforming routine transaction data into useful information for service evaluation. Booking records that were previously stored manually can now be accessed systematically, allowing administrators to review user activity, reservation frequency, and court utilization patterns in a more organized manner. This capability is important for small and medium-sized sports businesses because managerial decisions are often made based on direct observation rather than recorded evidence. With the availability of digital records, management can begin to identify recurring customer behavior, estimate demand during certain hours, and prepare more appropriate service strategies. Thus, the system contributes not only to daily operational efficiency but also to the development of a more data-oriented management culture.

In addition, the cross-platform implementation using Flutter provides strategic value in terms of accessibility and maintainability. The same application logic can serve users across mobile devices and web browsers, allowing the venue to reach a broader range of customers without requiring separate development resources for each platform. For a local sports business, this approach is highly relevant because it balances technological functionality with economic feasibility. The positive acceptance indicated by the usability evaluation suggests that the interface design, navigation flow, and booking procedures were sufficiently understandable for the target users. Therefore, the research findings indicate that the developed system is not merely a technical prototype, but a practical digital solution with real potential to support sustainable service improvement, institutional professionalism, and long-term business scalability in local sports venue management.

3.3.3 Technical Scalability and Research Limitations

Technically, the choice of the Flutter and Node.js stack proved to be highly effective for the target demographic. The high acceptance rate indicates that the "Cross-Platform" approach is superior to "Web-Only" or "Native-Only" approaches for diverse user bases. Web-based apps ensure accessibility without installation, while the mobile optimization provided a consistent experience even on entry-level Android devices.

However, this study is not without its limitations. The current architecture relies on manual payment verification, where users upload proof of transfer to Clouidinary. During the testing phase, it was observed that while the booking recording is instant, the payment confirmation still introduces a slight delay due to human verification. Additionally, the system currently assumes stable internet connectivity. While the system works well in areas with 4G coverage, it may face challenges if the venue experiences network downtime. Future research should consider integrating Automated Payment Gateways (such as Midtrans) to fully automate the transaction loop and developing an "Offline-First" architecture to handle intermittent connectivity issues better.



This research has successfully culminated in the design and implementation of a mobile booking application utilizing a Client-Server architecture to address the critical challenges of schedule management and operational inefficiency at Furry Sport Center. By synergizing Flutter for the cross-platform client interface and Node.js for the backend API, the system provides a robust digital infrastructure that is both scalable and accessible to diverse users. The integration of the Temporal Overlap Detection Algorithm has effectively transformed the way court reservations are managed, shifting the paradigm from error-prone manual recording to a systematic, conflict-free scheduling approach. Additionally, the automated Revenue Calculation feature empowers the management with real-time financial estimates, enabling data-driven decision-making regarding venue utilization. Furthermore, the implementation of the self-service booking module successfully demonstrates the potential for operational autonomy, allowing customers to secure schedule slots digitally.

With a validated System Usability Scale (SUS) composite score of 79.25, the platform has proven to be highly acceptable to the user base, effectively falling into the "Good" to "Acceptable" usability threshold. This quantitative outcome firmly indicates that the transition from a conventional, paper-based method to a digital scheduling system was seamless, intuitive, and well-received by both customers and administrators. The high evaluation score further reflects that the application possesses a low learnability curve, allowing new users to adapt quickly without extensive operational guidance. However, despite these significant operational successes, it is important to critically note that the current system architecture primarily focuses on the reservation and scheduling aspect. The financial transaction process remains fundamentally manual, heavily requiring customers to settle payments physically via the venue cashier or through manual bank transfer verification. This semi-automated workflow inherently introduces a slight delay in finalizing bookings due to the continuous need for human validation when users upload their proof of transfer. Therefore, immediate future developments will strategically focus on integrating Automated Payment Gateways (such as Midtrans) to fully automate the transaction loop. This critical enhancement will eliminate verification delays and human errors, ensuring that the digital transformation of Furry Sport Center continuously evolves from a foundational booking recording system into a fully integrated, highly resilient e-commerce ecosystem.

4. CONCLUSION

This research has successfully addressed and resolved the critical operational inefficiencies and persistent scheduling conflicts inherent in conventional sports venue management by developing a robust, cross-platform mobile booking application. Engineered through the structured and systematic phases of the Waterfall development model, the resulting Flutter-based application provides a seamless user experience across diverse devices. By functionally integrating a Node.js backend with a deterministic Temporal Overlap Detection Algorithm, the system systematically mitigates the risk of human error, guaranteeing conflict-free scheduling and providing real-time data transparency to eliminate information asymmetry between venue management and customers. Furthermore, empirical system validation utilizing the System Usability Scale (SUS) yielded a composite average score of 79.25. This quantitative metric scientifically confirms that the digital ecosystem is highly effective, possesses a low learnability curve, and is well-received by both venue administrators and end-users. Although the current architecture successfully automates the reservation process, its operational boundaries are constrained by manual payment verification workflows and a dependency on continuous internet infrastructure. Consequently, to overcome these limitations, future research and development will strategically focus on integrating automated payment gateways to fully close the transaction loop, alongside implementing offline-first architectural capabilities. These planned enhancements will ultimately transform the platform into a highly resilient, fully automated, and scalable digital business ecosystem for local sports facilities.

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