An Integrated Information System Model for Optimizing Bulk Water Distribution

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ABSTRACT

Many companies in the bulk water distribution sector still rely on manual recording systems, which often lead to scheduling conflicts, delivery inaccuracies, and inefficient payroll management. Recent studies highlight the need for integrated information systems to optimize logistics and operational efficiency in similar industries. This study aims to design and implement an integrated information system model to optimize the distribution of bulk water from suppliers to drinking water depots. The research adopts a qualitative approach, combining literature review, field observation, and in-depth interviews. System design follows the Waterfall model, with UML modeling and Black Box Testing for validation. The developed system successfully automates scheduling, generates delivery orders, recapitulates shipment data, and manages driver payroll. Empirical testing showed scheduling time was reduced from 45–60 minutes to 10–15 minutes (~75% faster), payroll reporting from 2–3 hours to under 30 minutes (~80% faster), and data recap from up to 2 hours to instant (~100% faster). All functions were validated through testing, showing no logical errors. The integrated information system model significantly improves the efficiency, accuracy, and effectiveness of bulk water distribution. Future research may incorporate mobile technology and GPS tracking for enhanced real-time monitoring.

1. Introduction

The rapid advancement of information technology has transformed operational paradigms across various industries, including logistics and distribution, positioning information systems (IS) as crucial strategic assets that not only boost organizational efficiency and support informed decision-making but also foster a competitive advantage. Yet, small and medium-sized enterprises (SMEs) often lack the financial resources, technical expertise, and digital literacy needed to fully leverage these technologies. These constraints frequently result in scheduling conflicts, payroll inaccuracies, and inefficient reporting, making digital transformation an urgent necessity for SMEs that dominate economies in developing countries and directly influence supply chain reliability [1]. These operational inefficiencies underscore the pressing need for these enterprises to undergo a digital transformation to remain competitive and effective [2], [3].

Recent developments in integrated information systems (IIS), cloud computing, and Internet of Things (IoT) technologies have created new opportunities to optimize logistics and ensure transparency in distribution networks. IIS offers the ability to unify multiple functions—such as scheduling, monitoring, delivery orders, and reporting—into a centralized platform, thereby reducing fragmentation and minimizing redundancy[4]. For example, Zhao et al.[5] demonstrated that the integration of Building Information Modeling (BIM) with Geographic Information Systems (GIS) can significantly enhance water distribution planning by linking spatial data with infrastructure models[5]. Likewise, Wang introduced a cloud-based logistics management system that

supports real-time monitoring and scalability for water transport operations [6]. Together, these studies suggest that the informatization of distribution processes can lead to measurable improvements in both operational efficiency and service quality.

However, despite these opportunities, SMEs encounter specific adoption barriers. Limited financial resources, lack of technical expertise, and organizational resistance often hinder the implementation of advanced ICT platforms [7]. Moreover, most existing research has focused on large-scale utilities and urban water infrastructure rather than on SMEs that operate bulk water distribution services at regional or local levels [8]. This creates a gap in the literature, as SMEs are equally significant actors in ensuring water accessibility, especially in semi-urban and rural areas. The absence of tailored models for SMEs underscores the importance of developing cost-effective and adaptable systems that account for both technological and managerial constraints.

In parallel, the literature on logistics information systems emphasizes the benefits of database integration, automated scheduling, and real-time monitoring for improving data accuracy and decision-making [9]. For instance, Ezenwa et al. [1] reported that ICT adoption in transport logistics improved transparency and reduced error rates in data handling. Similarly, Rajabzadeh and Fatorachian highlighted how IoT adoption enhanced agricultural logistics by providing real-time tracking and predictive insights [10]. While these findings are promising, their application to water distribution logistics remains underexplored.

Beyond technical integration, managerial and organizational factors also determine the success of IIS implementation. Issues such as pricing strategies, driver payroll systems, and security protocols must be carefully addressed to ensure both operational sustainability and user acceptance [11]. Previous research confirms that without organizational readiness, even technically sound systems may fail to achieve their intended outcomes [12]. Therefore, a holistic approach that incorporates operational, technological, and managerial perspectives is essential for the success of any proposed model.

This research responds to the identified gaps by proposing an integrated information system model for optimizing bulk water distribution, specifically designed for SMEs. The system focuses on automating scheduling, delivery order management, payroll calculations, and distribution reporting. The model was developed using the Waterfall software development methodology, combining structured analysis with iterative validation. Unified Modeling Language (UML) diagrams were employed during the design stage, while the implementation used Laravel and MySQL to build a web-based application. System testing applied Black Box Testing to evaluate functionality and ensure user requirements were met.

The main contribution of this study is twofold. First, it provides an evidence-based model that demonstrates how integrated information systems can be applied in the specific context of SME-based water distribution. Second, it highlights the combined influence of operational, technological, and managerial factors on system performance. In doing so, this research aligns with broader trends in digital logistics and sustainable water management [13].

2. Methodology

This research employed a qualitative approach to gain a deep, comprehensive understanding of the operational, technological, and managerial complexities within bulk water distribution. This method was chosen specifically because it allows us to uncover the contextual issues—the real-world workflows, challenges, and user requirements—that are essential for designing an effective integrated information system. Data collection was conducted through literature review, field observations, and in-depth interviews with stakeholders at CV. Achdan Water Cibeusi. Field observations were carried out during 4 weeks of operational activities, focusing on scheduling, delivery, payroll, and reporting workflows. In-depth interviews were conducted with 4 key informants: 1 owner, 1 administrative staff, and 2 drivers. Each interview lasted 45–60 minutes, providing insights into operational challenges, user expectations, and system requirements. System design followed the Waterfall model, involving requirement analysis, system design, implementation, testing, and evaluation. UML diagrams (use case, class, and sequence diagrams) were employed to represent system architecture. Validation was performed using Black Box Testing, covering scheduling, delivery order generation, data recapitulation, and payroll functions.

The core object of this study is the development of a proposed integrated information system model itself, which aims to optimize the entire distribution process. The model focuses on automating critical administrative and operational tasks, including generating delivery orders, managing driver payroll, streamlining scheduling, and producing insightful distribution reports, all of which are currently pain points for the industry. The conceptual model illustrated in Figure 1 represents the framework of the integrated information system designed to optimize bulk water distribution.
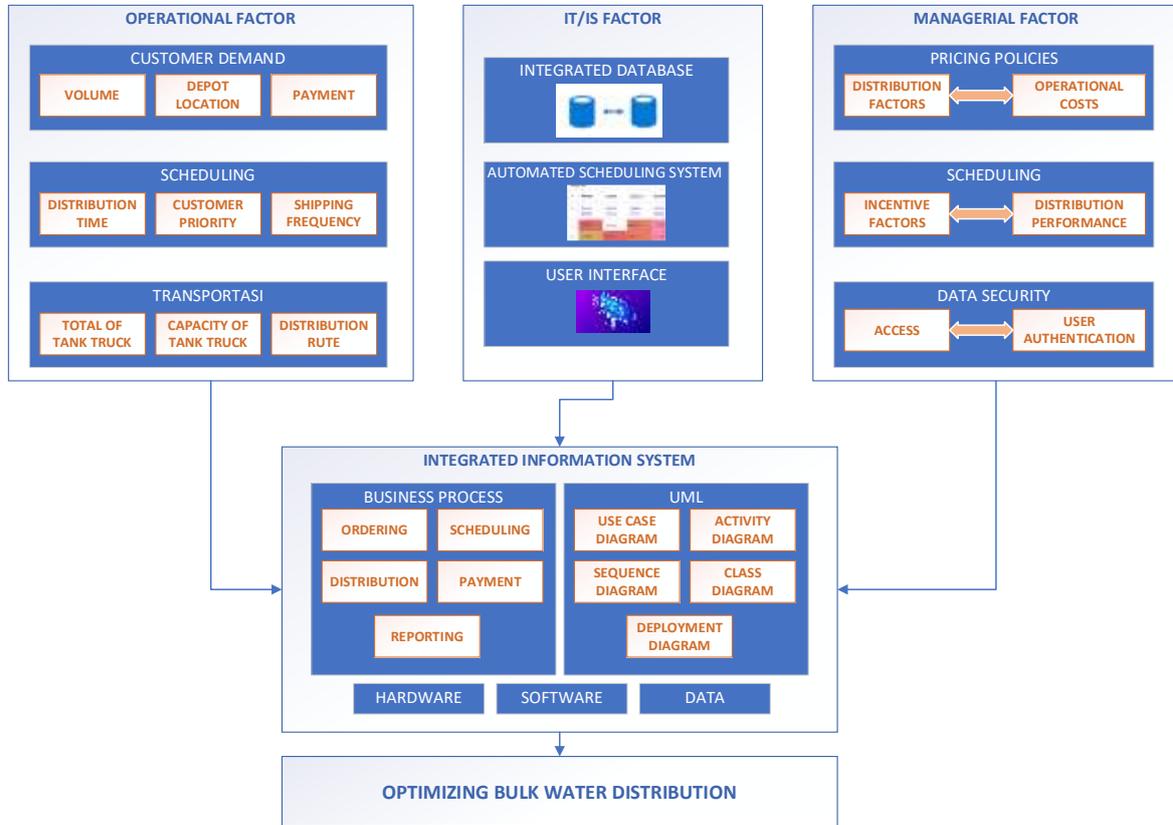

Figure 1. Model of IIS to Optimizing Bulk Water Distribution

Building upon this foundation, the conceptual model of our research is structured around three main pillars that interact synergistically to build the integrated information system model: operational factors, technological factors, and managerial factors. This structured approach ensures that the model is not merely a technical solution but a holistic system that addresses the human element and business realities.

a. **Operational factors** emphasize transportation optimization[14], scheduling systems[15], and understanding customer demand patterns [2]. These These components reflect the everyday challenges faced by enterprises, including managing fluctuating order volumes, prioritizing customers, and coordinating limited transportation resources. By mapping these operational elements, the system addresses the practical realities that often cause inefficiencies in bulk water distribution.

b. **The information system's technological** factor serves as the backbone of process integration, with critical roles played by the central database[3], automated scheduling algorithms[7], [10], GPS-based monitoring technology[10], an intuitive user interface[4], and the integration of critical modules[6]. Together, these features ensure seamless coordination across processes, reduce redundancy, and enable real-time decision support. The adoption of these information system elements allows companies to minimize errors, accelerate administrative tasks, and improve service reliability.

c. **Managerial factors** include pricing policies[11], human resources incentive systems[9], and data security[12]. By incorporating these managerial considerations, the model acknowledges that technology alone is insufficient; sustainable success requires appropriate policies, accountability mechanisms, and secure access protocols.

At the core of the model lies the integrated information system, which connects business processes such as ordering, scheduling, distribution, payment, and reporting. The system is designed using UML-based diagrams (use case, activity, sequence, class, and deployment) to ensure clarity, modularity, and maintainability[16]. Hardware, software, and data resources are aligned to support this architecture, enabling the organization to achieve optimized bulk water distribution.

Ultimately, the model demonstrates how the interplay of operational needs, technological solutions, and managerial strategies can be harmonized into a single integrated system. Its goal is not only to streamline routine administrative tasks but also to enhance the overall performance of the distribution process, reduce costs, and provide reliable service to customers.

3. Results and Discussion

The integrated information system was developed and implemented at CV. Achdan Water Cibeusi as a case study. The system architecture followed the three-pillar conceptual model—operational, technological, and managerial—and was validated through UML-based design artifacts, database modeling, and deployment structures.

3.1 System Implementation Result

3.1.1 Operational Level

At the operational level, the system automated administrative tasks such as delivery order generation, scheduling, and driver payroll management. The use case and activity diagrams demonstrated how users (administrators and owners) interact with the system to manage driver data, customer records, delivery schedules, and payroll reports.

A. **Use Case Diagram**

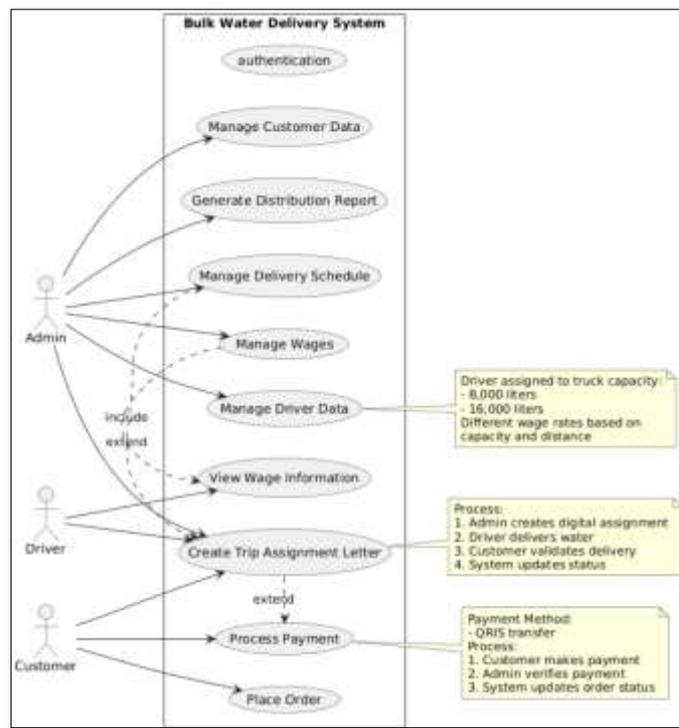The following figure 2 is a use case diagram.

Figure 2 Use Case Diagram of Bulk Water Delivery System

This use case diagram provides a comprehensive framework for the Bulk Water Delivery System, outlining the roles and interactions of its key users. The model elegantly integrates core logistical functions into a single, automated process, where Schedule and Delivery Management serves as the central hub, automatically including the creation of a Trip Assignment Letter to streamline operations. The system's design also thoughtfully addresses the human side of logistics, separating the administrative task of Managing Wages

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for the admin from the driver's ability to View Wage Information, ensuring a clear and independent flow of communication. On a practical level, the model accounts for critical business factors like varying truck capacities and distance-based wage rates, reflecting the nuanced realities of the industry. The entire operational cycle—from an admin creating a digital assignment to the driver's delivery and the customer's final validation—is seamlessly supported, with the system even facilitating modern payment methods like QRIS transfers and updating order status in real-time.

B. **Activity Diagram**

Building upon the high-level overview from the use case diagram, we now transition to a more granular analysis of the system's operational workflow. The activity diagram serves as a powerful tool for this, allowing us to meticulously break down a key function, into its component steps and decision points. This visual representation provides a clear, dynamic roadmap of how responsibilities are distributed between the system and its human actors, revealing the intricate coordination that drives efficiency. In essence, by moving from a static view of what the system does to a dynamic portrayal of how tasks are performed, we gain the crucial insights needed to ensure a seamless and effective implementation. The following is an activity diagram for managing a delivery schedule.
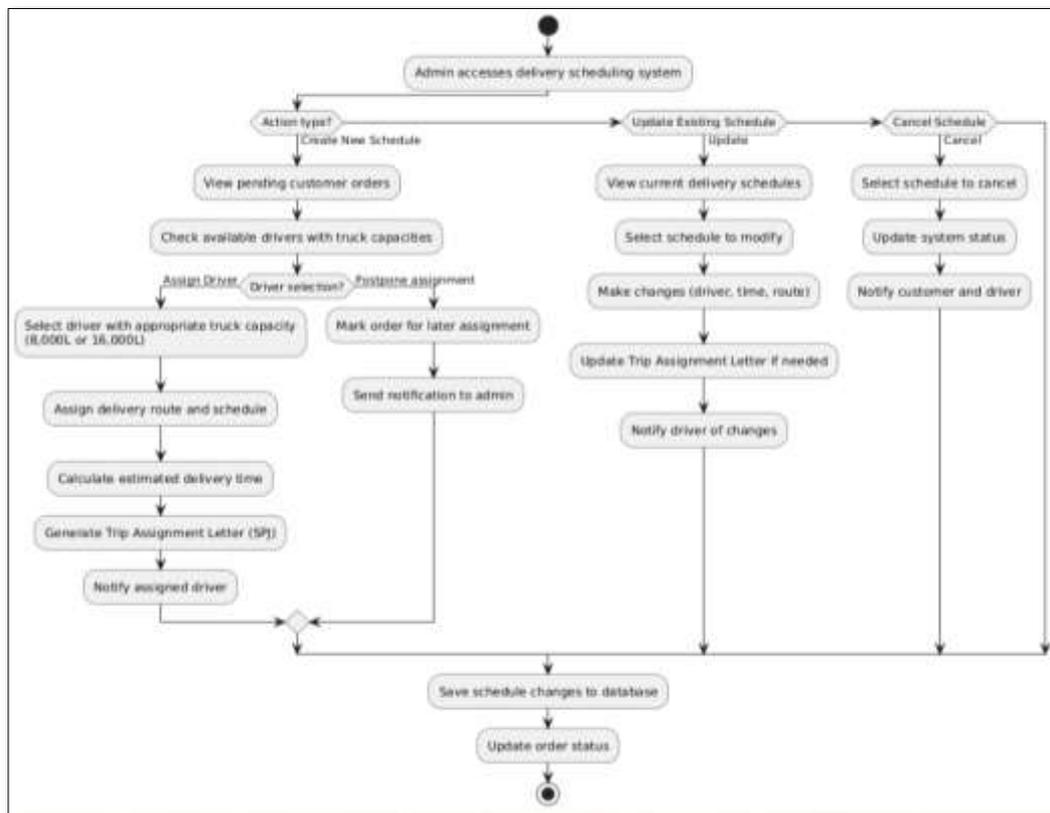

Figure 3 Manage Delivery Schedule Activity Diagram

Based on the designed activity diagram, this delivery scheduling system operates through a structured collaborative mechanism involving four related parties (Admin, System, Driver, and Customer) by utilizing digital document-based verification. The process begins with order administration and resource allocation, creation of trip assignment letters with unique QR codes as the primary validation tool, automated notifications to all parties, delivery execution based on physical documents, and concludes with receipt confirmation through QR code scanning by the customer. This completes an accurate and auditable operational cycle, forming a reliable logistics system through a hybrid approach combining manual procedures and document digitization.

3.1.2 Technological Level

At the technological level, the system integrated database structures (as shown in the ERD) with a web-based application deployed via a client-server architecture (deployment diagram). This ensured data consistency, reduced redundancy, and improved access to real-time information. The sequence diagrams

confirmed that system modules—such as order entry, scheduling, and reporting—interacted seamlessly, reflecting a coherent flow of data between actors and processes.

A. **Sequence Diagram**

This study presents a sequence diagram detailing the 'Manage Delivery Schedule' activity, one of ten core processes within the integrated system.
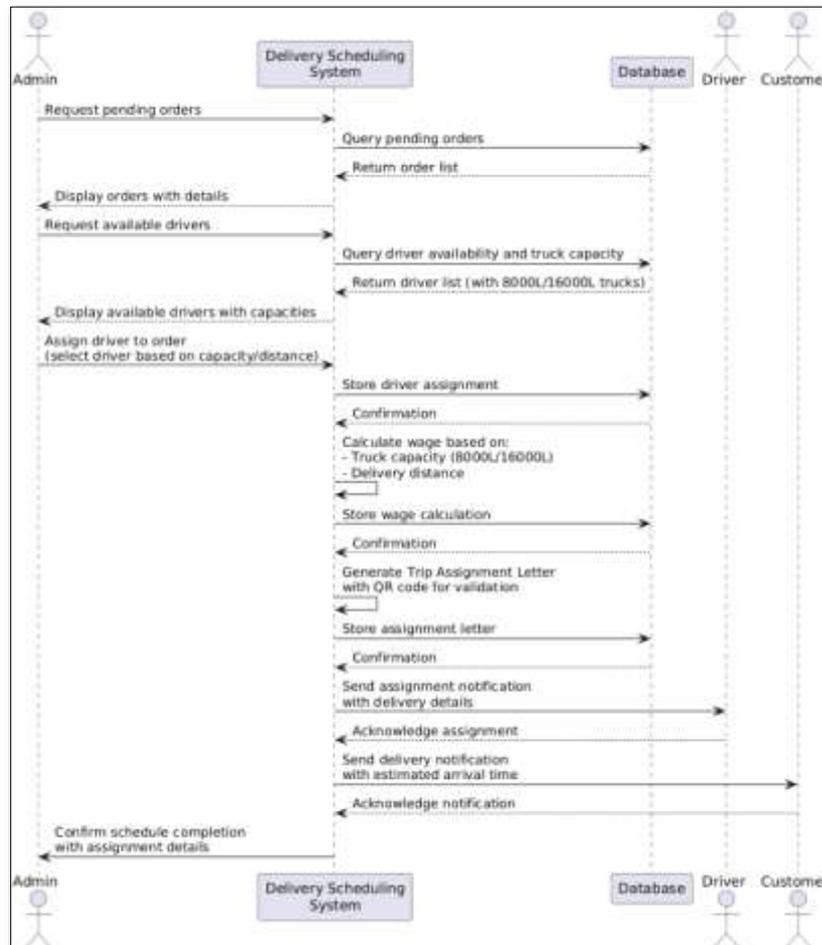

Figure 4 Manage Delivery Schedule Sequence Diagram

This streamlined process for managing delivery schedules integrates administrative oversight with automated efficiency. The Administrator initiates the workflow by reviewing pending orders and available drivers, considering truck capacities (8000L/16000L) to ensure optimal assignments. The System supports this by providing real-time data on driver availability and generating intelligent scheduling suggestions. Upon assignment, the system automatically calculates fair wages based on truck capacity and distance, produces a digital Trip Assignment Letter with a QR code, and notifies both the Driver and Customer. The Driver acknowledges the task and executes the delivery, while the Customer uses the QR code for seamless validation. This end-to-end coordination enhances transparency, reduces manual effort, and ensures efficient, accountable bulk water distribution.

B. **User Interface**

As a representative component of the system's ten user interfaces, the 'Manage Delivery Schedule' module is presented in Figure 5 to exemplify the application's design and functionality.
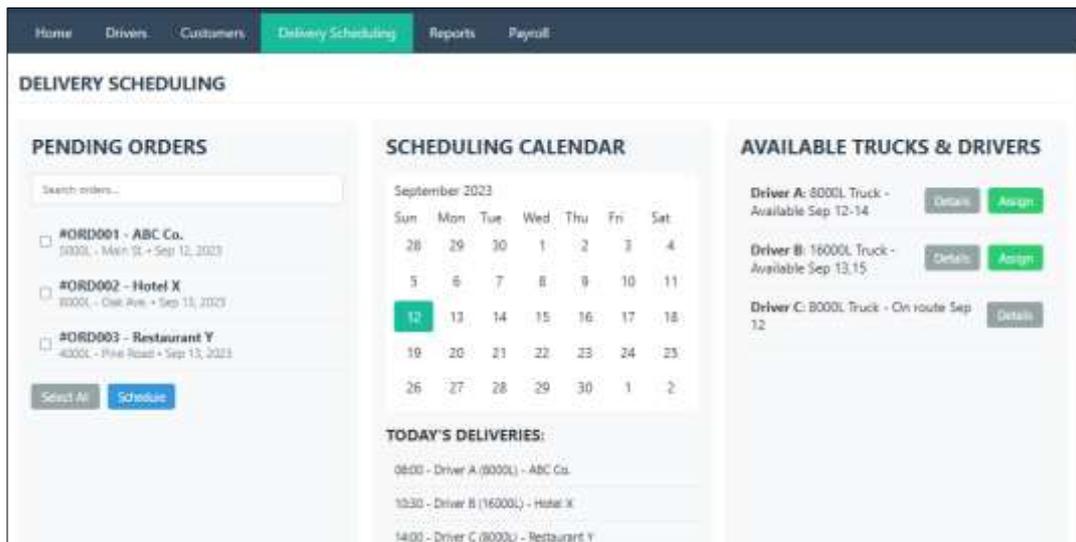
Figure 5 Manage Delivery Schedule User Interface

The 'Manage Delivery Schedule' interface presents an intuitive, user-friendly dashboard that enables administrators to efficiently coordinate bulk water distribution through a centralized visual platform featuring real-time order management, dynamic driver assignment based on truck capacity (8000L/16000L), and intelligent route optimization, while incorporating automated wage calculations, QR code generation for delivery validation, and instant notification systems that collectively transform complex logistical operations into a streamlined, transparent, and data-driven process accessible to users of all technical backgrounds.

C. **Deployment Diagram**
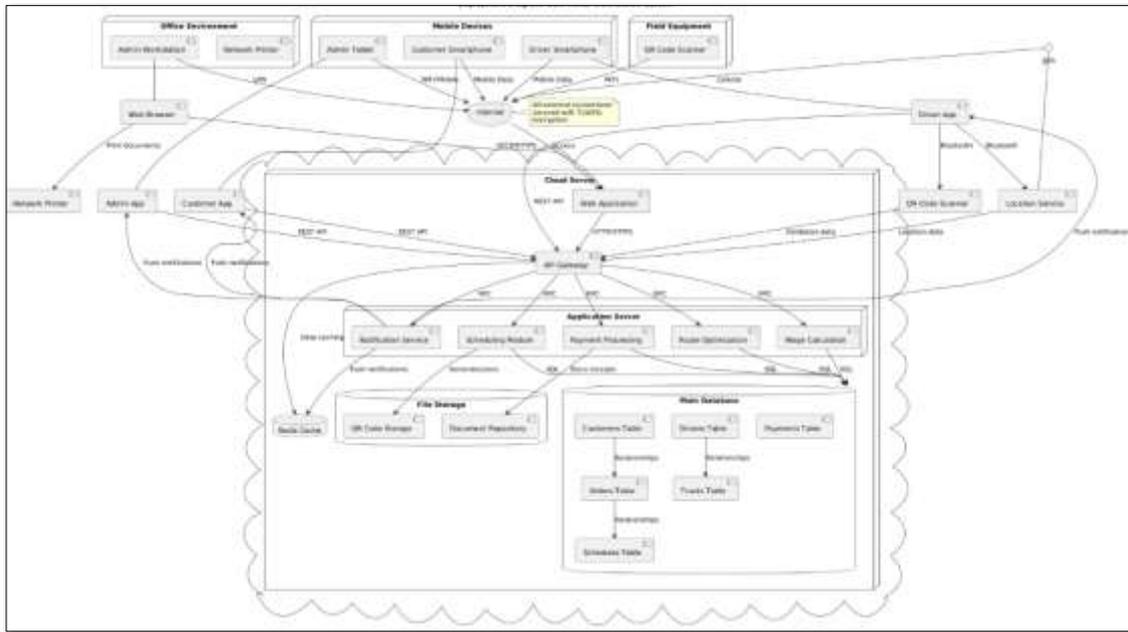
Presented below is a Deployment Diagram.

Figure 6 Deployment Diagram

The deployment diagram for the integrated bulk water distribution optimization system represents a sophisticated architectural framework that seamlessly connects various technological components, mobile devices, office environments, and field equipment through secure internet connectivity. This infrastructure hosts specialized modules for intelligent scheduling, dynamic route optimization, and automated wage

calculations based on truck capacity (8000L/16000L) and distance metrics. QR code validation mechanisms ensure complete operational transparency, while integrated database systems with caching support enable instant data synchronization across all stakeholders. Drivers utilize mobile applications for delivery management, administrators monitor operations through web interfaces, and customers validate deliveries digitally, creating a fully automated ecosystem that optimizes resource allocation and enhances distribution efficiency. The system maintains end-to-end security through modern encryption protocols, ultimately transforming traditional water distribution into a data-driven, responsive, and accountable operational model that is both accessible and practical for small and medium-sized water distribution businesses.

3.2 Functional Testing

Black Box Testing confirmed modules performed as intended.

Table 1 Functional Testing Result

Module	Test Case	Extended Outcome	Result	Status
Login	Valid credentials	Dashboard displayed	Success	Valid
Scheduling	Add schedule	Saved successfully	Success	Valid
SPJ	Generate order	Downloadable PDF	Success	Valid
Payroll	Calculate salary	Accurate report	Success	Valid
Reporting	Monthly recap	Exportable Excel	Success	Valid

3.3 Efficiency Gains

Manual scheduling (45–60 min) was reduced to 10–15 min; payroll reporting (2–3 hrs) to <30 min; data recaps became instant.

Table 2 Manual versus system Operation

Process	Manual	System	Improvement
Scheduling	45–60 min	10–15 min	~75% faster
Payroll	2–3 hrs	<30 min	~80% faster
Recap	1–2 hrs	Instant	~100% faster

The integrated information system implemented at CV. Achdan Water Cibeusi demonstrated substantial efficiency improvements, with scheduling, payroll, and reporting times reduced by 75%, 80%, and nearly 100%, respectively. These results confirm the potential of digitization to overcome inefficiencies common in bulk water distribution SMEs.

Compared with previous studies, our findings present both alignment and divergence. Zhao et al. [5] showed that integrating BIM and GIS could optimize urban-scale water distribution planning, while Wang [6] introduced a cloud-based logistics system emphasizing scalability and real-time monitoring. In contrast, our system focuses on SMEs operating at regional levels, demonstrating that significant efficiency gains can be achieved without the need for high-cost infrastructure. Similarly, Ezenwa et al. [1] reported improvements in transport logistics transparency through ICT adoption, which resonates with our results on enhanced reporting accuracy. Rajabzadeh and Fatorachian [10] highlighted IoT's role in agricultural logistics, whereas our study emphasizes a modular web-based approach that is more financially feasible for SMEs.

Thus, rather than merely describing improvements, this discussion underscores how our results complement existing literature by filling the gap between high-scale utility studies and the operational realities

of small enterprises. The evidence indicates that integrated systems tailored for SMEs can achieve measurable efficiency comparable to more advanced solutions, but with substantially lower resource requirements.

While the implemented system proved effective in improving operational efficiency, scalability and cost considerations remain critical for SMEs. Financial constraints often limit the ability of small enterprises to adopt advanced ICT platforms such as IoT-based monitoring or large-scale cloud infrastructures [7] . Recent studies further confirm that ICT adoption in SMEs is strongly correlated with improved logistics performance [17] and that adoption patterns vary significantly depending on firm size, sector, and contextual readiness [18].

Our model demonstrates that a web-based solution developed with open-source tools (Laravel, MySQL) can provide substantial benefits at relatively low cost, making it more accessible for SMEs with limited budgets. However, scaling the system to handle larger networks of depots or regional operations would likely require additional investment in server capacity, cybersecurity, and mobile integration. This highlights the trade-off between affordability and scalability, and suggests that phased adoption strategies may be the most viable pathway for SMEs seeking digital transformation.

4. Conclusion

This study designed and implemented an integrated information system model to optimize bulk water distribution for SMEs. The system automated scheduling, payroll, and reporting, demonstrating significant improvements in efficiency, accuracy, and transparency at CV. Achdan Water Cibeusi.

The research contributes by presenting a practical, resource-conscious model tailored for SMEs, extending prior studies that largely focused on large-scale infrastructures. Limitations include the absence of real-time GPS and IoT integration, and future work should expand the model to support predictive analytics and wider scalability.

In conclusion, aligning operational, technological, and managerial factors through an integrated information system provides a viable pathway to more efficient and sustainable bulk water distribution management.

Declarations

Author contribution. The first author was responsible for conducting the literature review, developing the model, providing methodological guidance, and writing the manuscript. The second author was responsible for data collection and software development. All authors have reviewed and approved the final version of the manuscript.
Conflict of interest. The authors declare no conflict of interest related to this research or the publication of this paper.
Additional information. No additional information is available for this paper.

Data and Software Availability Statements

The datasets generated and analyzed during this study, as well as the software modules developed for the integrated information system, are available from the corresponding author upon reasonable request. Due to organizational confidentiality at CV. Achdan Water Cibeusi, the raw operational data used for testing cannot be made publicly available. However, anonymized datasets, UML design diagrams, and source code components implemented with the Laravel framework and MySQL database are archived and may be shared for academic and non-commercial research purposes.

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