

Designing a Field Service Management Application Using the Double Diamond Approach: A Usability Evaluation Study

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Received: 11 June 2025 | Revised: 6 July 2025 and 20 July 2025 | Accepted: 23 July 2025

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ABSTRACT

Field Service Management (FSM) applications play an essential role in modern service operations, but many existing solutions have not effectively addressed the complex needs of field technicians. This study presents a systematic approach to designing and evaluating FSM applications using the Double Diamond methodology integrated with Digital Twin technology, applying a four-phase design process: Discover (field observation and interviews), Define (analysis of requirements and problem formulation), Develop (iterative prototyping with Digital Twin integration), and Deliver (implementation and usability evaluation). The evaluation involved 15 field technicians from three telecommunications service providers using the System Usability Scale (SUS) method. The results showed an average SUS score of 72.33, which falls into "good", with variations between service providers (technicians from service provider C provided the highest score of 89.5, and those from A and B provided 76.5 and 51.0, respectively). The item analysis showed that ease of use, frequency, and integration of functions had the highest scores. This study presents the first systematic application of the Double Diamond method to a Digital Twin-based FSM design, providing empirical evidence of its effectiveness through a comprehensive usability evaluation.

Keywords-field service management; double diamond design; digital twin; usability evaluation; system usability scale; fiber optic infrastructure

I. INTRODUCTION

Digital transformation has been a key driver of change in various industries, including telecommunications, affecting how people work, communicate, and interact with customers. These significant changes can be seen in work culture, organizational structure, and business processes in response to technological developments in the era of Industry 4.0 [1]. The

telecommunications industry is at the forefront of adopting technology trends to provide better services, leading to the emergence of new results-oriented business models [2]. Telecommunication companies are rapidly adopting new technologies to meet growing market demands, accelerate revenue growth, and meet the expectations of stakeholders about evolving business processes.

Fiber optic infrastructure plays a strategic role in supporting connectivity and the development of 5G technology. With its high-speed data transmission capabilities and reliability, fiber optics is the foundation of modern telecommunications network infrastructure, capable of handling large volumes of data with minimal interference [3]. The combination of fiber optics and 5G is shaping a new era of ultra-fast connectivity and real-time interaction, supporting innovations such as the Internet of Things (IoT), autonomous vehicles, and digital health [4]. Developing fiber optic networks is a significant challenge, particularly in the last mile, due to higher investment costs compared to wireless networks. However, the demand for high-speed internet services continues to increase, even in rural areas [5]. Field Service Management (FSM) in the context of fiber optic infrastructure is complex because it involves managing geographically dispersed technical resources. FSM is a structured approach to organizing and coordinating a company's resources at the client's site, including scheduling, tracking, and delivering on-the-ground services. It often involves managing human resources, vehicles, and inventory [6]. In the context of information technology, FSM generally consists of managing the installation, maintenance, and repair of hardware and software, including the maintenance of the fiber optic cable network infrastructure [7].

The operational challenges in implementing FSM in the telecommunications industry include several crucial aspects. First, the multi-year deployment issue, where the rollout of 5G and fiber optic technology took several years to resolve, requires integrated planning efforts to ensure resource availability. Second, complex legacy platforms, where the Operating Support Systems (OSS) and Business Support Systems (BSS) of telecommunication companies become barriers in the competition to implement new services. Third, poor customer interactions require companies to change their interactions with customers. Fourth, poor asset management, where companies often do not have good visibility and control over asset type, quantity, and location. Fifth, an inefficient workforce requires companies to strive to increase workforce productivity sustainably. Conventional FSM systems have significant limitations in dealing with these challenges. Studies such as [8] have demonstrated that reliability and quick response to outages can directly affect end-user experience, so effective FSM is key to minimizing downtime and improving customer satisfaction. Furthermore, other studies underscore the importance of effective planning and coordination in field management, especially in the face of the demands of rapid growth, network expansion, and increasing technological complexity [9, 10]. However, existing FSM applications still face significant usability challenges, with a lack of a user-based approach in application design creating a gap between the needs of field technicians and the application functionality.

Digital Twins is a virtual representation of real-world entities and synchronized processes at a specific frequency and fidelity [11]. This concept was first introduced in 2017 [12] as a conceptual paradigm underlying product lifecycle management [13]. Digital Twins allows users to monitor what is happening inside physical assets in real time [14], virtually model the behavior of real-world assets [15], and perform simulations to test various risk-free scenarios in the physical

world [16-18]. The implementation of Digital Twins in service management has shown significant potential to improve operational efficiency and effectiveness.

In the context of FSM, Digital Twins enables real-time monitoring and predictive maintenance of existing devices or systems in the field [19]. Organizations can monitor real-time performance, predict potential problems, and perform preventive maintenance before a system failure occurs. This reduces downtime, improves efficiency, and optimizes resource utilization. Integrating IoT, AR, and Digital Twins in FSM applications creates a mutually supportive technology ecosystem. The IoT provides real-time data from devices and systems in the field. Digital Twins uses that data to make accurate virtual models, and Augmented Reality (AR) allows technicians to interact intuitively with them in the field. In [20], it was shown that using AR with Microsoft HoloLens for Digital Twin data visualization of Computer Numerical Control (CNC) milling machines allows operators to monitor and control machine equipment simultaneously and interact and manage digital twin data efficiently.

Recent studies on Digital Twins applications for FSM have focused primarily on manufacturing environments [21]. However, there is limited research on the management of telecommunication infrastructures. In [22], Digital Twin solutions were developed for equipment maintenance, but did not address the specific challenges of geographically distributed fiber optic networks. Similarly, in [23], IoT-based monitoring systems were implemented, but they lacked the user-centered design approach and usability validation that this study provides. This study addresses these gaps by: (i) applying a systematic user-centered design methodology specifically for telecommunications FSM, (ii) providing empirical validation through comprehensive usability evaluation, and (iii) demonstrating the practical implementation challenges and solutions in real-world service provider environments.

Based on these challenges, this study aims to design and develop a Digital Twins-based FSM application using the Double Diamond approach and evaluate its usability using the System Usability Scale (SUS) method. Digital Twins is a digital representation of a physical object or system that reflects its actual conditions and operational dynamics, allowing real-time monitoring, simulation, and predictive analysis [24]. This research seeks to answer the question of how the Double Diamond approach can be applied in designing Digital Twins-based FSM applications, how the level of usability of the applications is developed, and how it impacts the performance and competence of field technicians. The contribution of this research covers three main aspects. The theoretical contribution is an FSM application design model that integrates Digital Twins with a user-centered design approach to improve operational effectiveness. The practical contribution is in improving the competence of field technicians, which resulted in a SUS score of 72.3, confirming that this model can improve operational effectiveness, speed of handling interruptions, and customer satisfaction with fiber optic-based internet services. Usability evaluation using SUS ensures that the developed application is technically advanced, easy to use, and effective in an operational context.

This study also contributes several novel aspects to the implementation of Digital Twins in FSM: (i) Integration of AR-based visualization designed explicitly for fiber optic infrastructure maintenance, allowing technicians to visualize complex network topologies in real-world environments; (ii) Development of a user-centered Digital Twins interface using Double Diamond methodology, ensuring practical usability in field conditions; (iii) Creation of a collaborative Digital Twin environment that enables real-time knowledge sharing between field technicians and remote experts through AR interfaces; (iv) Empirical validation of the effectiveness of Digital Twins effectiveness in telecommunications FSM through systematic usability evaluation with 15 field technicians across three service providers.

II. METHODOLOGY

This study employs a rigorous mixed-method research approach that combines qualitative design research with quantitative usability evaluation. The method follows established principles of design science research, contributing both practical artifacts and theoretical insights to the field. The research method encompasses four distinct phases of data collection and analysis: (i) Systematic field observations using structured observation protocols across three service providers; (ii) Semi-structured interviews with 15 field technicians and three operations managers using validated interview guides; (iii) Iterative design and development following established principles of Human-Computer Interaction (HCI), and (iv) Comprehensive usability evaluation using validated SUS methodology with statistical analysis.

A. Double Diamond Design Process

This study integrates qualitative methods for the design phase and quantitative methods for the evaluation phase, which has proven effective in information systems development studies [25]. The methodological framework used is Double Diamond [26], which facilitates the conceptualization phase,

offering a systematic method to explore ideas, comprehend user requirements, define the purpose of the application, and justify its development [27].

Figure 1 illustrates the structure of the Double Diamond model, which directed the initial stages of app development. The model comprises four main phases that facilitate a systematic user-centered design process. The Discover phase focuses on gathering in-depth insights into the problem context through field observations, interviews, and analysis of technical documents. The Define phase synthesizes these findings into a clear problem definition, develops user personas, identifies pain points, and specifies functional system requirements. The Develop phase involves designing a three-tier system architecture, developing eight core functional modules, and iterative prototyping, focusing on the user interface and Digital Twin technology integration. The Deliver phase includes system implementation using technical and usability testing, and gradual deployment starting from a pilot project before full-scale implementation.

Double Diamond applications in software development are gaining popularity due to their ability to ensure that the final product meets user needs. This approach emphasizes the importance of understanding the problem before developing a solution, and iterations are repeated in the development process. In the context of FSM applications, Double Diamond allows developers to better understand the specific needs and challenges of field technicians and how applications can be designed to address them effectively. The strategic value of the Double Diamond approach in the context of FSM lies in its ability to ensure that the applications developed meet the needs of field technicians and support FSM operations effectively. By focusing on an in-depth understanding of user needs and exploring various potential solutions, Double Diamond helps address the gap between the sophistication of technology and the ability of users to leverage it, which is one of the key challenges in FSM implementation.

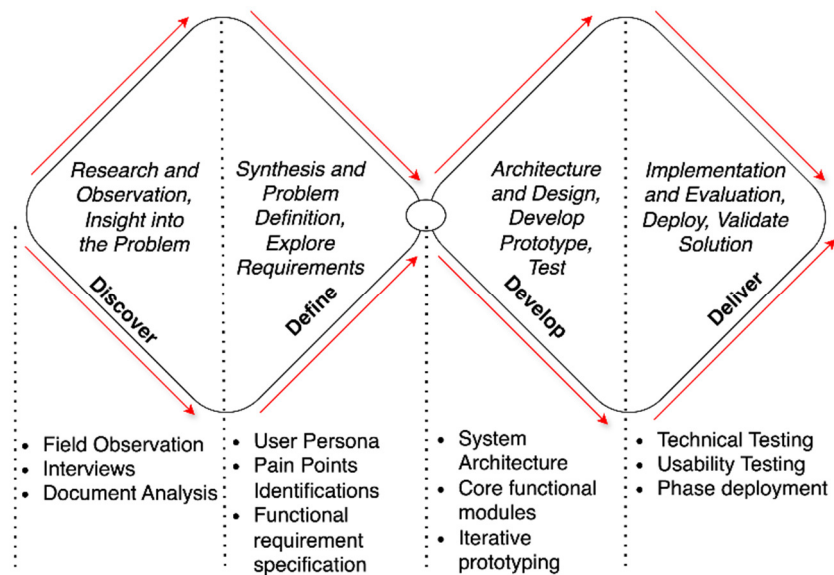


Fig. 1. Double Diamond design process of the Digital Twin-based FSM application development.

B. Usability Evaluation Methods

Usability evaluation is essential to application development, especially for industrial applications such as FSM, which are used in critical operational contexts. The usability evaluation method can be divided into inspection methods (heuristic evaluation, cognitive walkthrough) and user testing methods (think-aloud protocol, usability testing). The selection of evaluation methods depends on the stage of development, available resources, and the specific objectives of the evaluation. SUS is one of the most popular and proven effective usability evaluation methods, involving a simple questionnaire consisting of 10 questions with 5 answer options ranging from "Strongly Disagree" to "Strongly Agree" [28]. SUS produces a single score between 0-100, representing the system's overall usability, with a score above 68 considered above average and above 80 considered excellent. The advantages of SUS lie in its simplicity, its reliability even with small sample sizes, and its ability to distinguish between valuable and useless systems.

Studies on usability evaluation in industrial mobile applications show the importance of a user-based approach in application design. Industrial field maintenance work can benefit from knowledge-sharing solutions using virtual and augmented reality technologies [29]. In [30], proof-of-concept applications used AR to assist field engineers, reducing the learning curve for trainees and improving the effectiveness of quality control checks. The relationship between usability, User experience (UX), and user performance is very close. Good usability contributes to a positive UX, which in turn can improve user performance. In the context of FSM, high usability applications allow field technicians to complete their tasks more effectively and efficiently, reduce errors, and improve job satisfaction. This can ultimately positively impact service quality, productivity, and operational costs.

III. RESULTS

A. Double Diamond Process Implementation

The design process in this study adopts the Design Council's Double Diamond model, which consists of four main phases: Discover, Define, Develop, and Deliver [26]. This model was chosen for its ability to facilitate a solution-oriented and user-centered design process.

1) Discover Phase

The Discover phase gathers in-depth insights into the issue's context and users' needs. The data collection method in this phase includes field observation of the fiber optic network infrastructure development process, interviews with field technicians and operational managers, and document analysis related to standard operating procedures and performance reports. Field observations were conducted as shown in Figure 2, which shows the fiber optic network infrastructure observation process during the survey phase. Through field observations, the researchers identified key challenges that technicians face in performing their duties, including difficulties in accessing technical documentation, a lack of real-time guidance, and limitations in collaboration with experts when dealing with complex problems [31]. In-depth interviews with 30 field technicians and six operations managers revealed the need for a system to facilitate rapid access to technical information and enable remote real-time collaboration with experts [32].

The results of field observations show that implementing fiber optic network infrastructure is divided into three main phases: survey, installation, and maintenance/repair.



Fig. 2. Fiber optic network infrastructure field observation.

In the survey phase, coordination constraints between the field team and management were identified when performing field validation and determining the Point of Presence (PoP). This process is often hampered by poor communication and limited access to information. In the installation phase, technicians face challenges in accessing the relevant technical documentation. As revealed in the interview, "Technicians must be multi-competent and able to complete tasks quickly," but limited access to technical information hinders their work efficiency. Network implementation is often constrained by limited access to procedural guidance and contextual information about the location of the installation. The maintenance and repair phases face the most significant challenges: a high Mean Time To Repair (MTTR) and a low First-Time Fix Rate (FTFR). Observations show that technicians often have to make repeat visits due to limitations of technical information and a lack of expert support on the first visit. One of the technicians revealed, "We often had to return to the site because we didn't have complete information about the device configuration on the first visit."

The analysis of the People, Process, and Technology dimensions identifies key challenges, as shown in Figure 3, which illustrates the comprehensive framework for understanding operational bottlenecks in fiber optic infrastructure management. Document analysis includes reviewing standard operating procedures, outage logs, and operational performance reports, which provide insight into existing business processes and potential areas for improvement. The mapping of existing business processes reveals three main phases in field service management for fiber optic infrastructure: survey, installation, and maintenance and repair, each with specific challenges and needs.

2) Define Phase

Based on the insights gathered in the Discover phase, the Define phase focuses on the synthesis of findings and the definition of clear problems. The main pain points identified include limited access to technical information, lack of visualization of complex infrastructure components, limited communication between field technicians and technical experts, and inefficiencies in technician assignment and monitoring [31].

User personas and journey maps were developed to better understand user needs, motivations, and frustrations. Three primary user personas were designed, as shown in Figure 4: Field Technician, Service Manager, and Technical Expert, each with different needs and expectations of the system. The user journey map maps user interactions with the system from assignment to completion and reporting, identifying points of frustration and opportunities for improvement throughout the user journey. The main result of the Define phase is the integration of 8 FSM components with the Digital Twins, which covers various essential aspects as shown in Figure 5. This integration explains how Digital Twins' capabilities can support multiple components of FSM to achieve the expected results. The requirements of various stakeholders are also identified and documented in a structured manner.

The three primary stakeholder groups, field technicians, service managers, and technical experts, have specific needs that the system must meet. Field technicians need mobile access to documentation, AR-based guidance, and real-time support. Service managers need resource monitoring, performance/location tracking, and quality assurance capabilities. Technical experts need remote assistance, knowledge sharing, and diagnostic tools.

The expected outcomes of implementing the Digital Twin-based FSM apps are divided into two main categories: Process Improvement and Improvement of Internet Broadband Services. Process Improvement is expected to improve service quality and Mean Time To Repair (MTTR), while Broadband Internet Service Improvement is projected to increase the number of subscriptions and customer satisfaction.

3) Develop Phase

The Develop phase resulted in a comprehensive three-layer system architecture for the Digital Twin-based FSM model. Figure 6 presents this system architecture, demonstrating the integration between Physical, Digital, and Application layers through the cloud infrastructure and the IoT Gateway. The Physical Layer is a fundamental layer that interacts directly with the fiber optic network infrastructure in the field, consisting of IoT sensor networks and field equipment with connectivity capabilities.

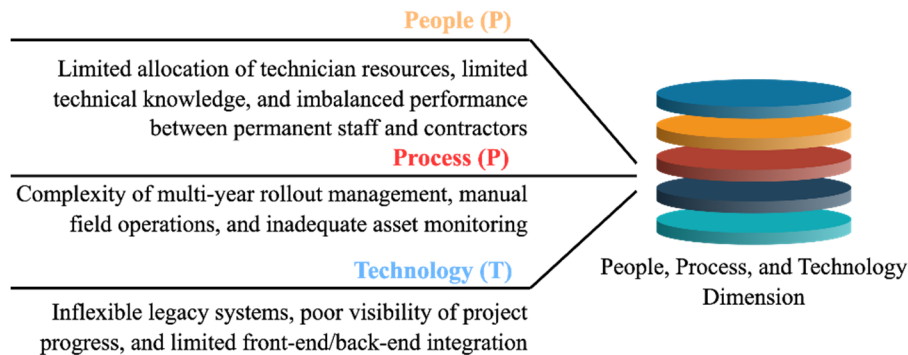


Fig. 3. People, Process, and Technology dimensions in fiber optic infrastructure.

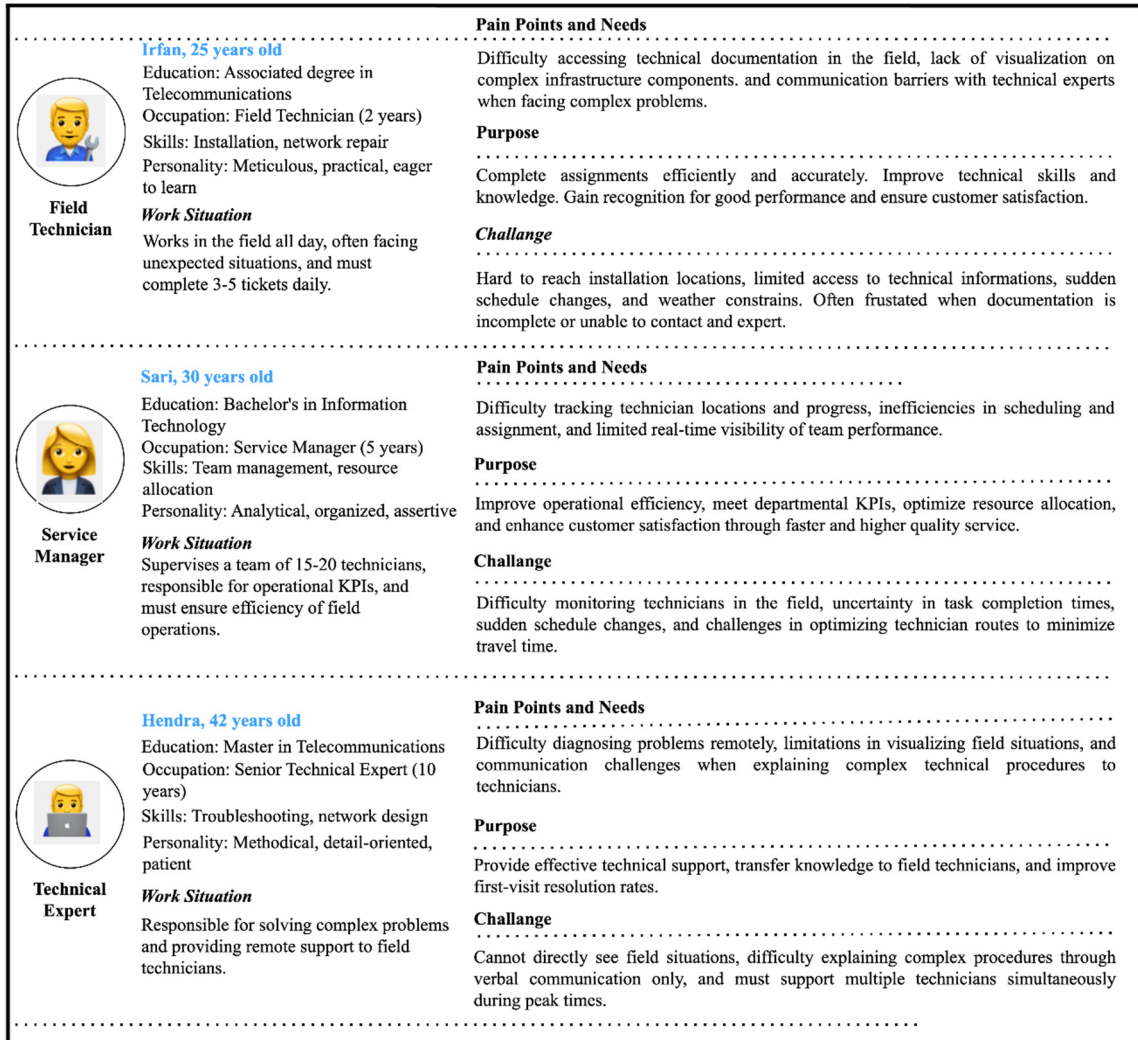


Fig. 4. User persona.

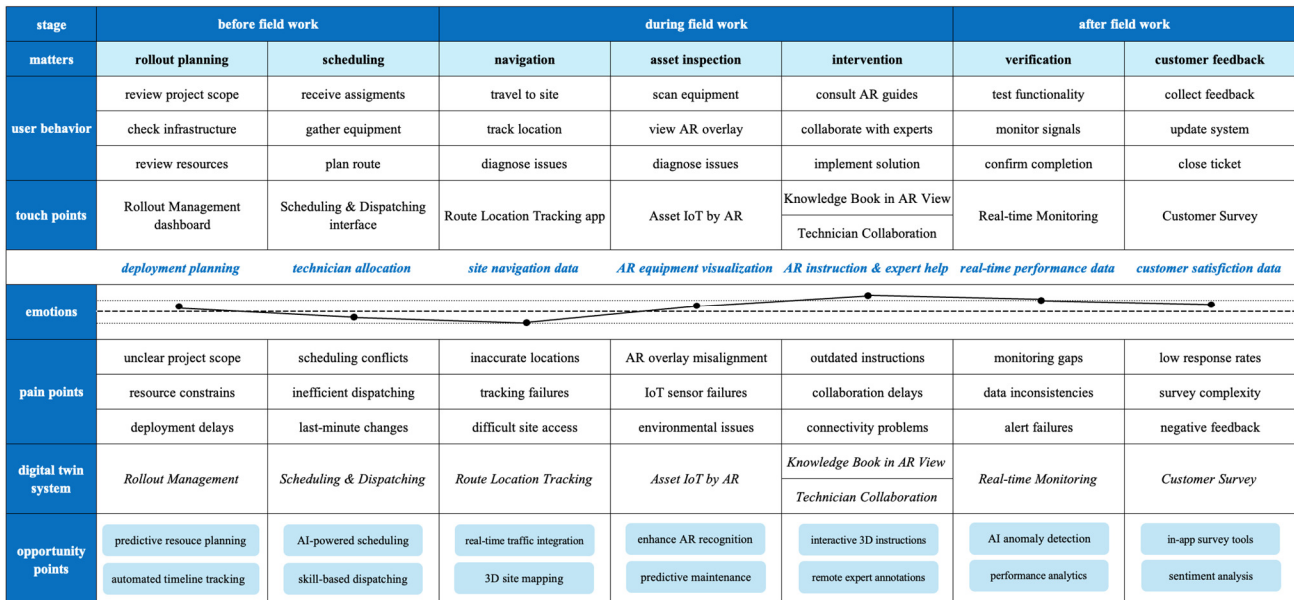


Fig. 5. User journey map for Field Technicians using Digital Twins-based FSM apps.

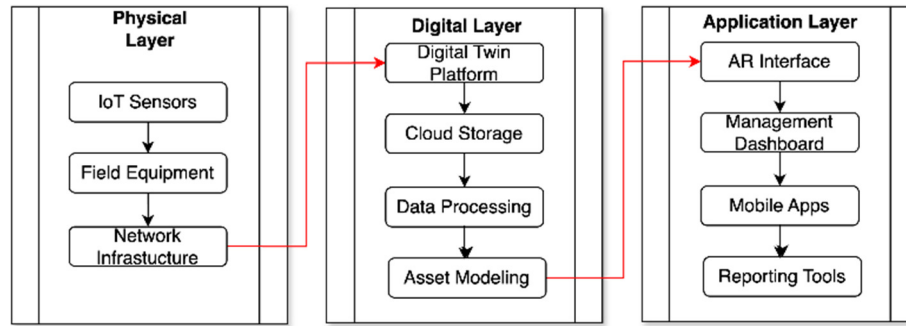


Fig. 6. FSM DT-based system architecture.

The Digital Layer bridges the physical and virtual worlds, managing all aspects of data processing and storage, including the Digital Twins platform, cloud-based storage systems, and data processing engines. The Application Layer provides an interface for users, including AR implementations, management dashboards, mobile apps, and reporting tools. The developed Integration layer has three components that work synergistically: API Gateway to manage data traffic, Data Synchronization to ensure information consistency, and Security Framework to protect systems and data. This Integration Layer is designed with scalability, reliability, capability, and interoperability in mind. Table I shows the core components of the developed system.

TABLE I. CORE COMPONENT FUNCTIONALITY OF THE DIGITAL TWIN-BASED FSM SYSTEM

Component	Main functions
3D model database	Digital asset model storage Metadata management Versioning and change tracking
Real-time data processing	Sensor data collection Data validation and integration Operational status monitoring
AR Interface	Data visualization User interaction Remote collaboration

Eight main functional modules were developed to support the entire operational life cycle of field services:

- Rollout Management, for project implementation management.
- Scheduling & Dispatching, for scheduling and assignment of technicians.
- Route Location Tracking, for route tracking and optimization.
- Asset IoT by AR, for asset visualization with AR.
- Real-time monitoring, for operational monitoring.
- Knowledge Book AR View, for knowledge management.
- Technician Collaboration, for technical team collaboration.
- Customer Survey, for customer feedback.

This prototype focuses on validating the core functionality and usability of the Digital Twins-based FSM application, and

its cloud infrastructure utilizes a self-hosted server environment with specific databases, such as MySQL, to manage the Digital Twins platform and data processing components. This choice was made because of its scalability and robust data handling capabilities, which are crucial for real-time data synchronization. For future full-scale deployment, this architecture is fully compatible with integration into major commercial cloud platforms such as AWS or the Azure IoT Suite, allowing for enhanced scalability and performance.

The iterative prototyping shown in Figure 7 focuses on the user interface and interaction to ensure that the system meets the needs of the users. The initial prototype was developed and tested with potential users, with feedback collected and integrated into subsequent iterations. This approach allows for gradual system design refinement based on user feedback. The user interface is designed to provide an intuitive and efficient user experience. The mobile interface was developed for field technicians and has the main components of a Home Screen, an AR View, and Task Management.

4) Deliver Phase

The final implementation of the Digital Twin-based FSM prototype resulted in a mobile application integrated with Digital Twins and AR technology to provide technicians with field access. The implementation was systematically tested by conducting tests involving 15 field technicians from three telecommunication service providers, divided into 5 technicians per service provider, over eight weeks. The implementation results showed that all system modules and key features functioned according to the design specifications, with a "PASS" status on all components tested. Administrative modules, location and assets, monitoring and knowledge, and collaboration and feedback showed excellent performance in testing.

B. Implementation of Digital Twins-based FSM Apps

The Digital Twins architecture in FSM applications is designed to provide an accurate and real-time virtual representation of physical infrastructure assets. The data transmission mechanism operates through a multi-layered architecture. IoT sensors deployed on fiber optic infrastructure components (ONUs, splitters, and distribution points) collect real-time data, including signal strength and operational status. These data are transmitted through a secure MQTT protocol to an IoT Gateway, which performs initial data validation and formatting. The processed data are then transmitted to the cloud

infrastructure using RESTful APIs over secure HTTPS connections. The Digital Twin platform receives the data, ensuring reliable delivery and handling high-volume data streams. Data synchronization occurs in near real-time through WebSocket connections, enabling the digital twin model to accurately reflect the current state of physical assets. The system implements data integrity checks and anomaly detection algorithms to ensure data quality before updating the digital twins representation. The architecture consists of three main

components: a 3D Model Database, Real-time Data Processing, and an AR Interface, working together to create a comprehensive, interactive digital twin experience. Integrating sensors and IoT with Digital Twins is a key aspect of implementation. IoT sensors are placed on critical infrastructure components to collect real-time data on conditions and performance, which are transmitted to a digital twin system, where it is processed and integrated into a digital model to represent the physical asset's condition accurately.

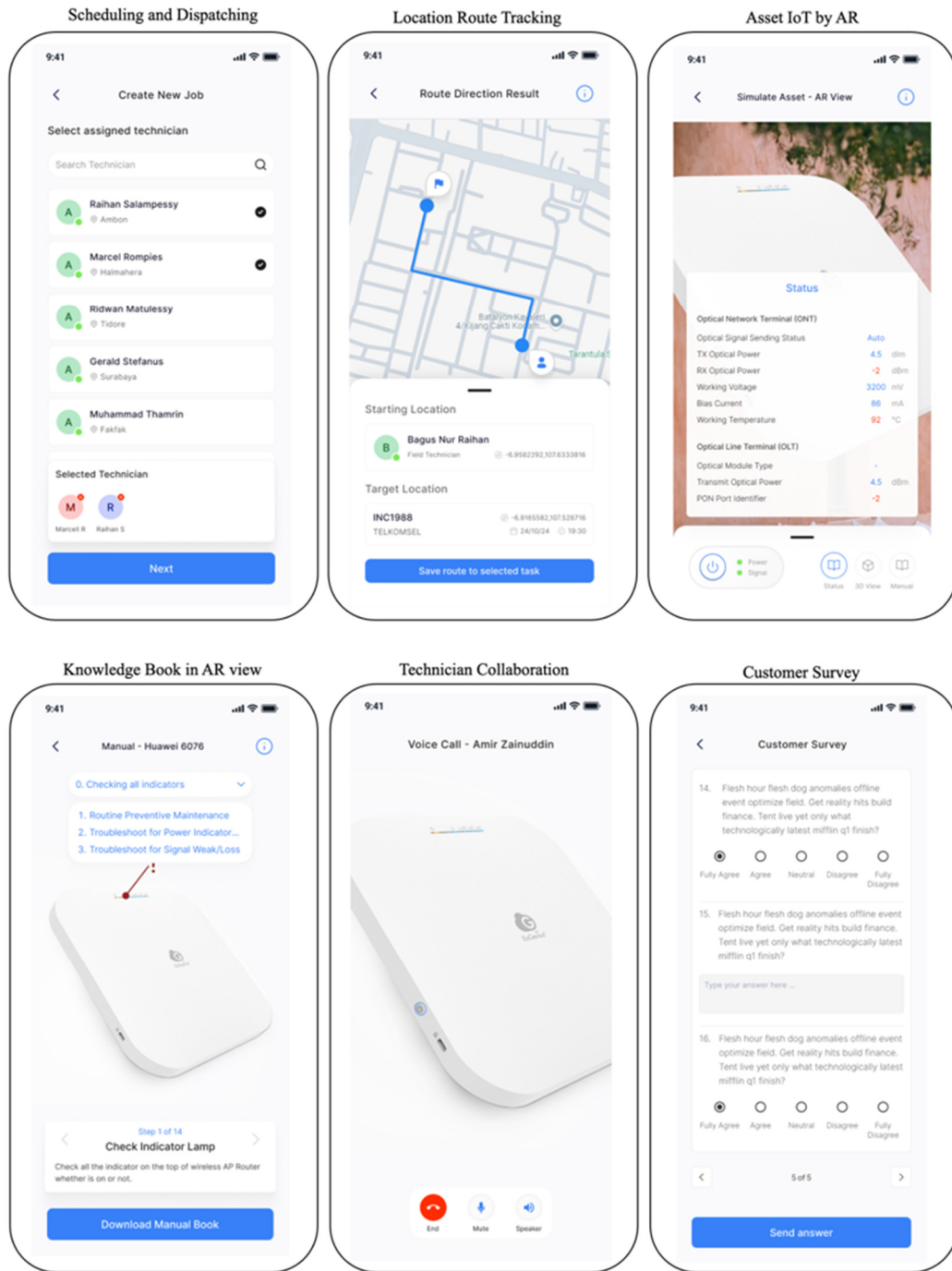


Fig. 7. Prototype of FSM DT-based apps.

Implementing AR in digital twin visualization allows technicians to interact with the representation of physical assets through mobile devices (Figure 7). Technicians can see an overlay of important information about physical equipment, such as device status, maintenance history, and technical instructions. The interactive features allow technicians to manipulate digital models and access technical documentation directly. Real-time data synchronization ensures that the model stays in sync with the physical assets it represents. This includes collecting data from sensors, validating and processing it, and updating digital models based on it. This mechanism also allows for anomaly detection and notification, facilitating predictive maintenance and rapid response to potential issues.

C. Usability Evaluation

The evaluation of user experience with the FSM DT-based applications used the SUS and direct observation of user interactions with the system. First, technicians were asked to provide feedback through surveys using the Quizizz tool, which covers various aspects such as overall impression, quality, and app content. SUS measurement involved 15 technicians from three Service Provider groups utilizing an FSM DT-based application during the trial period (duration = 8 weeks). Table II shows the applicability questions.

IV. DISCUSSION

The results of the SUS evaluation showed an average score of 72.33, which is in the category of "Good" according to industry standards and far exceeds the acceptability threshold, which is 68. Analysis per Service Provider shows variations in SUS scores, with Service Provider C achieving the highest score of 89.50 ("excellent"), Service Provider A 76.50 ("good"), and Service Provider B 51.00 ("marginal"). Item-by-item analysis showed that questions related to ease of use (Q3), frequency of use (Q1), and function integration (Q5) scored the highest. In contrast, questions related to complexity (Q2), need for technical assistance (Q4), and learning curve (Q10) scored relatively lower. The features that users appreciated the most based on the additional questionnaire were Asset IoT by AR, Knowledge Book in AR view, and Route Location Tracking.

The main challenges identified are data accuracy and internet connectivity. Figure 8 illustrates the comparative

analysis across service providers, clearly showing the performance variations and identifying that best practices from Service Provider C achieved the highest usability scores. Figure 9 presents a SUS visualization for the FSM DT-based app, showing the Acceptability Score for each Service Provider.

TABLE II. OVERALL APPLICABILITY QUESTIONS

Variable	N=15
Work experience	
1 – 2 years	5 (33.33 %)
3 – 5 years	7 (46.67 %)
6 – 10 years	3 (20.00 %)
Use of the app	
< 1 week	2 (13.33 %)
1 – 2 weeks	6 (40.00 %)
2 – 4 weeks	4 (26.67 %)
> 4 weeks	3 (20.00 %)
Easy to use	
Difficult	3 (20.00 %)
Neutral	6 (40.00 %)
Easy	4 (26.67 %)
Very easy	2 (13.33 %)
Helps with work	
Not helpful	3 (20.00 %)
Neutral	3 (20.00 %)
Helpful	5 (33.33 %)
Very helpful	4 (26.67 %)
Additional Question-1: The most useful FSM DT-based app features for you?	
Rollout Management	Choose a maximum of 3
Scheduling and Dispatching	
Route Location Tracking	
Asset IoT by AR	
Real-Time Monitoring	
Knowledge Book in AR view	
Technician Collaboration	
Customer Survey	
Additional Question-2: The biggest challenges in using FSM DT-based apps	
Complexity of the application	Choose a maximum of 2
Internet connection	
Data accuracy	
Integration with other systems	
Learning curve	
SUS of the app: How enjoyable did you find FSM DT-based apps?	On a scale of 0 to 10

TABLE III. APPS' USABILITY RESULTS

ID	Name	Service Provider	Work experience	Use of the app	Easy to use	Helps with the work
1	Technician 1	A	3-5 years	1-2 weeks	Easy	Helpful
2	Technician 2	A	3-5 years	1-2 weeks	Neutral	Neutral
3	Technician 3	A	1-2 years	1-2 weeks	Neutral	Helpful
4	Technician 4	A	3-5 years	1-2 weeks	Neutral	Helpful
5	Technician 5	A	3-5 years	<1 week	Neutral	Helpful
6	Technician 6	B	1-2 years	2-4 weeks	Difficult	Not Helpful
7	Technician 7	B	1-2 years	1-2 weeks	Difficult	Neutral
8	Technician 8	B	1-2 years	<1 week	Difficult	Not Helpful
9	Technician 9	B	3-5 years	2-4 weeks	Neutral	Neutral
10	Technician 10	B	1-2 years	1-2 weeks	Neutral	Not Helpful
11	Technician 11	C	6-10 years	>1 month	Very Easy	Very Helpful
12	Technician 12	C	3-5 years	>1 month	Very Easy	Helpful
13	Technician 13	C	6-10 years	2-4 weeks	Easy	Very Helpful
14	Technician 14	C	6-10 years	>1 month	Easy	Very Helpful
15	Technician 15	C	3-5 years	2-4 weeks	Easy	Very Helpful

TABLE IV. TECHNICIANS' USEFUL FEATURES AND BIGGEST CHALLENGES

ID	Name	Service Provider	Useful features	Biggest challenges
1	Technician 1	A	Rollout Management, Scheduling and Dispatching, Asset IoT by AR	Data accuracy, Integration with other systems
2	Technician 2	A	Rollout Management, Knowledge Book in AR view, Scheduling and Dispatching	Data accuracy, Internet connection
3	Technician 3	A	Technician Collaboration, Knowledge Book in AR view, Route Location Tracking	Integration with other systems, Complexity of application systems
4	Technician 4	A	Route Location Tracking, Asset IoT by AR, Knowledge Book in AR view	Data accuracy, Internet connection
5	Technician 5	A	Route Location Tracking, Scheduling and Dispatching, Technician Collaboration	Integration with other systems, Learning curve
6	Technician 6	B	Route Location Tracking, Scheduling and Dispatching, Asset IoT by AR	Data accuracy, Internet connection
7	Technician 7	B	Real-Time Monitoring, Customer Survey, Scheduling and Dispatching	Integration with other systems, Data accuracy
8	Technician 8	B	Asset IoT by AR, Rollout Management, Real-Time Monitoring	Internet connection, Complexity of application systems
9	Technician 9	B	Rollout Management, Scheduling and Dispatching, Knowledge Book in AR view	Learning curve, Integration with other systems
10	Technician 10	B	Knowledge Book in AR view, Route Location Tracking, Customer Survey	Internet connection, Data accuracy
11	Technician 11	C	Real-Time Monitoring, Technician Collaboration, Asset IoT by AR	Internet connection, Data accuracy
12	Technician 12	C	Customer Survey, Route Location Tracking, Rollout Management	Integration with other systems, Data accuracy
13	Technician 13	C	Asset IoT by AR, Real-Time Monitoring, Rollout Management	Data accuracy, Internet connection
14	Technician 14	C	Knowledge Book in AR view, Asset IoT by AR, Rollout Management	Internet connection, Data accuracy
15	Technician 15	C	Customer Survey, Asset IoT by AR, Route Location Tracking	Internet connection, Data accuracy

TABLE V. TECHNICIAN'S RESPONDENT ASSESSMENT

ID	Name	Service Provider	Assessment by respondents									
			Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
1	Technician 1	A	3	2	3	2	3	1	3	2	5	3
2	Technician 2	A	4	3	4	2	4	2	5	1	4	1
3	Technician 3	A	3	1	4	2	3	2	5	3	4	2
4	Technician 4	A	5	2	4	3	5	1	5	1	5	1
5	Technician 5	A	3	2	3	3	5	3	5	2	4	1
6	Technician 6	B	4	3	3	2	3	4	4	3	2	3
7	Technician 7	B	3	4	2	2	4	2	4	4	3	2
8	Technician 8	B	2	3	3	4	2	2	4	3	4	3
9	Technician 9	B	4	4	2	4	2	4	4	3	3	2
10	Technician 10	B	2	2	2	2	2	4	3	2	4	2
11	Technician 11	C	5	1	4	1	4	2	5	1	5	1
12	Technician 12	C	4	1	5	1	4	2	5	1	5	2
13	Technician 13	C	4	1	4	2	5	2	4	2	5	1
14	Technician 14	C	5	1	4	2	4	2	4	2	5	1
15	Technician 15	C	5	1	5	2	5	1	4	1	5	1

Scoring explanation for SUS calculation:

For negative items (Q2, Q4, Q6, Q8, Q10), the score is 6 minus the score

TABLE VI. SUS SCORE EVALUATION

ID	Name	Service Provider	SUS score									
			Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
1	Technician 1	A	2	3	2	3	2	4	2	3	4	2
2	Technician 2	A	3	2	3	3	3	3	4	4	3	4
3	Technician 3	A	2	4	3	3	2	3	4	2	3	3
4	Technician 4	A	4	3	3	2	4	4	4	4	4	4
5	Technician 5	A	2	3	2	2	4	2	4	3	3	4
6	Technician 6	B	3	2	2	3	2	1	3	2	1	2
7	Technician 7	B	2	1	1	3	3	3	3	1	2	3
8	Technician 8	B	1	2	2	1	1	3	3	2	3	2
9	Technician 9	B	3	1	1	1	1	1	3	2	2	3
10	Technician 10	B	1	3	1	3	1	1	2	3	3	3
11	Technician 11	C	4	4	3	4	3	3	4	4	4	4
12	Technician 12	C	3	4	4	4	3	3	4	4	4	3
13	Technician 13	C	3	4	3	3	4	3	3	3	4	4
14	Technician 14	C	4	4	3	3	3	3	3	3	4	4
15	Technician 15	C	4	4	4	3	4	4	3	4	4	4

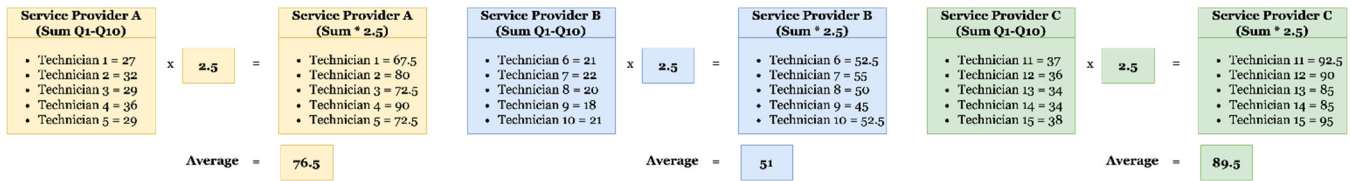


Fig. 8. SUS comparison result within 3 Service Operators.

The user satisfaction analysis showed consistent improvement across all dimensions, with the highest usability and ease of use scores. Technicians report that the system helps them complete tasks more efficiently and reduces frustration in their daily work. Thematic analysis of post-evaluation interviews with field technicians identified several key themes. The most appreciated aspects are easy access to technical documentation through the AR interface, reduced time to search for information, improved accuracy of problem identification, and more effective collaboration with technical experts. Service managers provided a positive assessment of the management dashboard and system monitoring capabilities, reporting improved visibility of field operations, more efficient resource allocation, faster and data-driven decision-making, and improved overall service quality. Technical experts appreciate the system's ability to facilitate remote collaboration and knowledge sharing, report improved capabilities to support field technicians, reduce the need for field visits, and provide better knowledge documentation.

The evaluation involved a systematic statistical analysis of the SUS scores, including a mean, standard deviation, and variance analysis between service providers. The results demonstrate statistically significant differences between the service providers ($p < 0.05$), indicating that the implementation factors significantly influence the usability results. Additionally, correlation analysis between user characteristics (experience level, duration of usage) and usability scores provides insights into adoption patterns and training requirements.

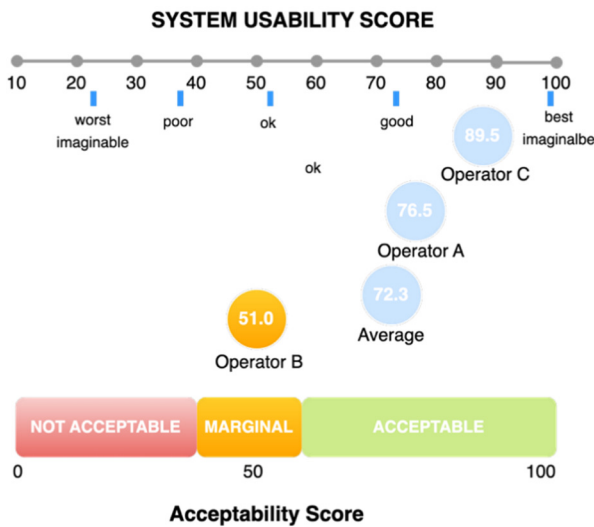


Fig. 9. SUS visualization for FSM DT-based app.

This case study provides several theoretical and practical implications for the field. Theoretically, it demonstrates the effectiveness of combining the Double Diamond methodology with Digital Twin technology for complex industrial applications. Practically, it provides a replicable framework that other telecommunications companies can adapt to their FSM implementations. The identified success factors (user training, incremental deployment, and stakeholder engagement) and challenges (connectivity dependencies and complexity of system integration) offer valuable insight to practitioners considering similar implementations.

V. CONCLUSION

This research has successfully carried out a design process for a Digital Twin-based FSM application that not only can offer solutions to operational challenges in the telecommunications industry but also provides a systematic approach to improving performance and operations for field technicians through the integration of Digital Twin technologies, the IoT, and AR. Through the Double Diamond approach, this study identifies various challenges faced in field service management for fiber optic network infrastructure development, such as limited skilled labor, unintegrated systems, weak asset management, and the lack of real-time visibility into field services. Based on this identification, the design process of the Digital Twins-based FSM application was proposed with three main layers: the Integration Layer, the Core Functional Modules, and the Data & Infrastructure Layer. The evaluation results using the SUS method show that, from a usability perspective, an average score of 72.33 was achieved, which is in the "Good" category. The evaluations show that the intuitive AR interface and easy access to technical documentation through AR are the features most appreciated by field technicians. Feedback from stakeholders, including field technicians, service managers, and technical experts, confirms that this model can improve operational effectiveness, speed of handling outages, and customer satisfaction with fiber optic-based internet services.

This research makes a significant theoretical contribution as a conceptual framework for integrating Digital Twin technologies in FSM. This framework can serve as a basis for developing and implementing similar systems in various industries with FSM needs. The Double Diamond approach to application design also provides a template that can be adapted to develop information technology solutions in other contexts. This research developed a prototype that telecommunication companies can implement to improve their operational efficiency. The eight functional modules developed—Rollout Management, Scheduling and dispatching, Route Location Tracking, Asset IoT by AR, Real-time Monitoring, Knowledge Book in AR View, Technician Collaboration, and Customer

Survey—provide comprehensive solutions for various aspects of field service management.

This research makes several novel contributions to the field: (i) Methodological innovation by integrating Double Diamond design with Digital Twin technology development, providing a systematic framework for user-centered industrial application design; (ii) Empirical validation of the effectiveness of Digital Twins in telecommunications FSM through a rigorous usability evaluation using SUS; (iii) Identification of critical success factors and challenges specific to the implementation of FSM in telecommunications; (iv) Development of AR-based Digital Twin interfaces specifically designed for fiber optic infrastructure maintenance; and (v) A practical framework that bridges the gap between advanced Digital Twin technology and real-world usability requirements.

However, this study has limitations, such as the reliance on internet connectivity for some AR features and constraints in integrating existing legacy systems. Future research can focus on developing more robust offline capabilities, better integrating existing systems, and applying more advanced artificial intelligence algorithms for route optimization and resource allocation. For effective implementation, it is recommended to adopt a phased approach, starting with a limited pilot project before a full-scale deployment. A robust management change program is also needed to overcome resistance and facilitate the adoption of new technologies at all levels of the organization. Integrating super users who can be internal sources of support for other users can also accelerate the learning and adoption curves.

ACKNOWLEDGMENT

The authors express their appreciation to the individuals who made valuable contributions to this study. This research was made possible thanks to the financial support provided by Bina Nusantara University.

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