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OceanMedic: Web-Based Ambulance Ship Ordering System with Integrated Vessel Data Acquisition

Ryan Satria Wijaya[1], Aditya Gading Saputra[2]

[1]Robotic Engineering, Electrical Engineering, Politeknik Negeri Batam, Batam City, Indonesia

[2]Robotic Engineering, Electrical Engineering, Politeknik Negeri Batam, Batam City, Indonesia

[1]ryan@polibatam.ac.id, [2]adityagading2003@gmail.com

Abstract

Healthcare provision in archipelagic regions remains constrained by fragmented communication and significant dispatch delays in maritime emergency referrals. This study presents and empirically evaluates OceanMedic, a web-based coordination platform designed to unify ambulance ship booking, role-based dispatch workflows, and OpenStreetMap-based WebGIS with STM32-driven AIS-like telemetry for real-time vessel tracking. A quantitative within-subject evaluation ($N = 50$) in a controlled baseline environment compared OceanMedic against conventional phone-based coordination. OceanMedic significantly reduced mean response time from 5.48 s to 2.03 s ($p < 0.001$) and task completion time from 61.70 s to 4.38 s ($p < 0.001$). System data completeness and validity both reached 98.0% during land-based telemetry hardware testing, while maintaining sub-3-second response times for up to 10 concurrent requests. User evaluations confirmed high perceived usability ($\mu = 4.26$) and ease of interaction ($\mu = 4.22$), although adoption intention remained moderate ($\mu = 3.80$) due to anticipated sea-surface operational constraints. A literature-based architectural feature comparison against GEMAR demonstrates how OceanMedic successfully extends WebGIS-based EMS paradigms from urban road networks to maritime evacuation corridors. Overall, OceanMedic provides a foundational, scalable reference framework for future archipelagic emergency medical services.

Keywords: Emergency Medical Services; Maritime Emergency System; WebGIS; Vessel Monitoring; Dispatch System;

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1. Introduction

Healthcare provision in island and archipelagic settings is still heavily affected by scattered geography, limited physical infrastructure, and insufficient human resources, which collectively reduce the ability of health systems to deliver essential care promptly to dispersed communities[1]. Residents of remote islands frequently must endure extended travel durations, remain highly dependent on the availability of transport modes, and are particularly vulnerable to unpredictable weather and sea conditions, factors that strongly influence how emergency referrals are carried out and when patients can reach higher-level facilities[2]. Under such circumstances, emergency care can be subject to considerable delays, with reports indicating that the transfer of patients from isolated islands may require several hours, depending on whether boats or helicopters are available and on the state of the sea at the time[3].

At the same time, coordination of emergency services in many remote and island environments still depends primarily on basic, conventional means of communication and on patchy communication infrastructure, which can impede the rapid circulation of critical information during urgent situations[4]. When communication pathways are fragmented, informal, or poorly organized, the movement of key information between on-scene responders, transport operators, and receiving health facilities can be disrupted, weakening both the quality and timeliness of emergency actions[5]. Empirical work on search-and-rescue in remote areas and on disaster response consistently highlights that continuous, interconnected communication systems and a shared operational picture are fundamental for synchronising multiple teams, as well as for avoiding overlapping efforts and dangerous gaps in the overall response[6].

Current Emergency Medical Service (EMS) frameworks are largely built around road networks and land-based transport systems, making them difficult to translate directly into maritime or archipelagic contexts where sea routes form the primary evacuation corridors[7]. In parallel, maritime monitoring and surveillance systems are typically oriented toward navigation, safety, and logistics, and are seldom linked with clinical workflows or prehospital care pathways[8]. This disconnection between health service delivery systems and maritime operational platforms creates a structural gap that hinders the development of integrated solutions for emergency medical transport in island and coastal environments[9].

Recent advances in disaster management and maritime domains demonstrate that integrating multi-source geospatial data into Geographic Information Systems (GIS) and combining these with IoT-based sensing can markedly improve monitoring, route optimisation, and decision-making in complex, remote settings[10]. At the same time, digital health initiatives in remote and island areas have increasingly leveraged telemedicine, virtual care, and digital communication platforms to extend specialist support and alleviate geographic barriers to healthcare access[11]. Building on these developments, this study proposes and evaluates OceanMedic, a web-based platform that unifies ambulance ship booking, real-time vessel tracking, and GIS-driven visualization within a single integrated environment, for maritime emergency coordination, with the overarching aim of improving coordination efficiency, accelerating emergency response, and enhancing situational awareness among stakeholders involved in maritime healthcare in geographically isolated island settings.

2. Methods

2.1 System Overview

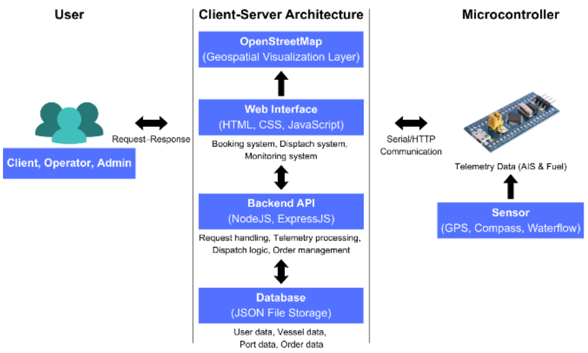

Figure 1. OceanMedic client–server architecture showing how web-based booking and dispatch workflows are integrated with STM32-based vessel telemetry through RESTful endpoints

As illustrated in Figure 1, OceanMedic is implemented as a web-based coordination platform with a client–server architecture that brings together emergency booking, dispatch coordination, and real-time vessel monitoring in a single system. The application offers a browser-based interface built with HTML, CSS, and JavaScript, allowing clients, operators, and administrators to work through role-specific workflows for submitting service requests, assigning and managing vessels, and overseeing active missions[12].

Behind the interface, a backend built with Node.js and Express exposes RESTful endpoints that handle request processing, dispatch logic, order management, and the intake of telemetry data sent from vessels. Geospatial views are provided through an OpenStreetMap-based web map, which presents vessel locations, nearby ports, and current operating status on an interactive display.

On the sensing side, an STM32-based microcontroller collects measurements from onboard sensors, including GPS, compass, and fuel-related data, and forwards them to the backend over serial or HTTP connections, where they are interpreted as AIS-like telemetry to enhance situational awareness[13]. To validate system responsiveness and data pipeline integrity prior to offshore deployment, telemetry streams were captured from physical hardware sensor setups during land-based prototype simulations rather than live vessel operations at sea[14].

All operational entities, such as users, vessels, ports, and service orders, are maintained in a JSON-based file store, giving the prototype a lightweight data layer that is simple to deploy and adequate for controlled experimental testing[15].

2.2 Database Schema

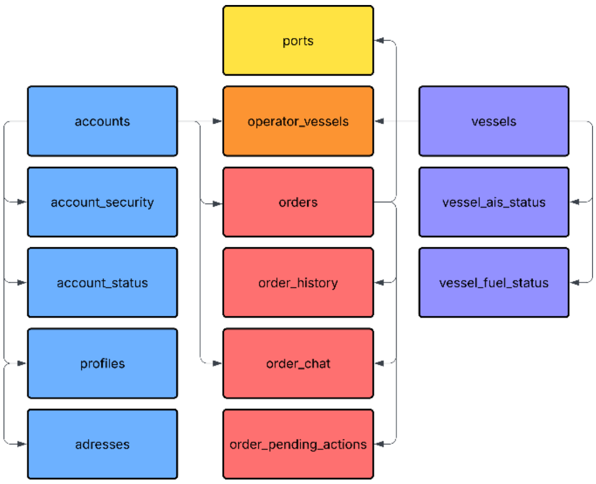

Figure 2. Logical database schema highlighting the order-centric linkage between users, vessels, and ports that encodes the end-to-end ambulance ship workflow

Figure 2 shows that the OceanMedic platform has a logical database schema that organizes data for emergency requests, vessel operations, and user interactions[16]. The schema is built around four core entities—users, orders, vessels, and ports—whose relationships mirror the workflow of ambulance ship services[17].

The user entity stores account and role information for clients, operators, and administrators, enabling role-based access to booking, dispatch, and system management[18]. The order entity is the central hub, representing each emergency request and linking it to the assigned vessel, the responsible operator, and the selected departure and destination ports. The vessel entity models ambulance ships with identifiers, operational status, and monitoring attributes, while the port entity represents embarkation and destination locations for inter-island transport[19].

Monitoring-related attributes—including AIS-like navigation fields and fuel telemetry—are attached to vessels to support real-time tracking and situational awareness. Although the current prototype stores data in JSON-based files for lightweight deployment, the logical schema is extensible and can be mapped to relational or cloud-based databases in future large-scale implementations.

2.3 Evaluation Method

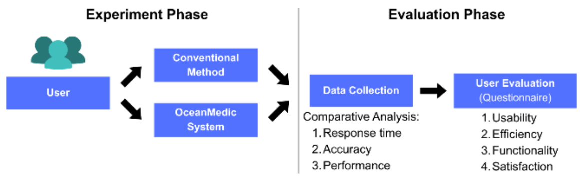

Figure 3. Overview of the performance evaluation setup used to measure response time, data accuracy, and system stability under varying concurrent request loads

The OceanMedic system is evaluated using a dual-phase evaluation framework conducted in a controlled environment where the client interface, backend server, and data store run on a single local machine to measure baseline computational performance[20]. This single-machine setup establishes a best-case baseline for system processing throughput; however, it does not simulate the real-world network latency or low-bandwidth conditions typical of remote maritime operational environments.

The first evaluation method employs a user-based simulation experiment in which selected participants perform emergency ordering tasks using both conventional methods (phone calls) and the OceanMedic system[21]. To establish a clear study design, the performance benchmark was conducted using a within-subject (paired) experimental setup involving 50 human participants. Each participant executed the emergency ordering task under both conditions—once using the phone-based manual protocol and once via the OceanMedic web platform—resulting in 50 paired execution trials per metric. Performance metrics including response time, accuracy, and system efficiency are collected and compared between the two approaches to quantify improvements[22]. After completing the simulation tasks, all 50 participants completed structured usability questionnaires covering user acceptance and system usability[23].

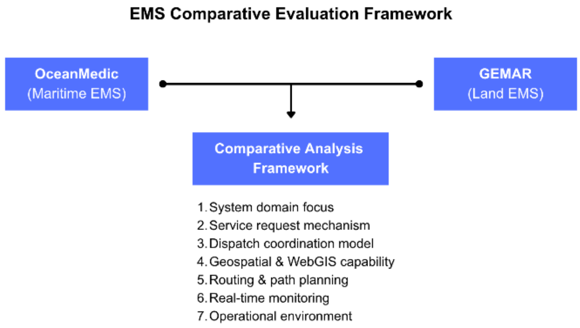

Figure 4. Comparative EMS evaluation framework positioning OceanMedic against GEMAR along seven dimensions, including domain focus, service request mechanisms, and WebGIS capabilities

The second evaluation method involves a qualitative, literature-based feature comparison in which OceanMedic is systematically analyzed alongside GEMAR (web-based GIS for Emergency Management and Ambulance Routing), a representative land-based emergency medical dispatch platform[24]. This comparison is explicitly structured as a literature-based conceptual and architectural feature mapping rather than an empirical, head-to-head performance benchmark.

GEMAR was selected as the comparison baseline because it represents a closely related research domain with documented implementation of emergency dispatch capabilities, geospatial visualization, real-time monitoring, and routing mechanisms. The comparative framework analyzes seven key dimensions: system domain focus, service request mechanism, dispatch coordination model, geospatial and WebGIS capability, routing and path planning, real-time monitoring, and operational environment[25].

3. Results and Discussions

3.1 Comparative Performance

Table 1. Comparative Performance Evaluation

Metric	Method	N	Mean	SD	Improve	*t*-statistic	*p*-value
Response Time (s)	System	50	2.03	0.41	62.9%	$t = 20.35$	$P < 0.001$
	Manual	50	5.48	1.12	-		
Task Completion Time (s)	System	50	4.38	0.96	92.9%	$t = 32.58$	$P < 0.001$
	Manual	50	61.7	12.4	-		

Table 1 compares OceanMedic's performance against conventional manual coordination across response time and task completion time. Evaluated using a within-subject paired design with 50 participants ($N = 50$, yielding 50 paired measurements per metric), OceanMedic demonstrated statistically significant efficiency gains across all workflows.

For response time, OceanMedic achieved a mean of 2.03 s ($\mathrm{SD} = 0.41$) compared to 5.48 s ($\mathrm{SD} = 1.12$) for manual phone-based coordination—representing a 62.9% latency reduction. A paired-samples t-test confirmed this improvement was statistically significant ($t(49) = 20.35, p < 0.001$). The substantial reduction in standard deviation further highlights improved operational predictability.

The advantage was even more pronounced for full task completion time (request submission to dispatch confirmation): OceanMedic averaged 4.38 s ($\mathrm{SD} = 0.96$) compared to 61.70 s ($\mathrm{SD} = 12.40$) for manual procedures, marking a 92.9% improvement ($t(49) = 32.58, p < 0.001$). This sharp reduction confirms that digitizing sequential manual steps (recording details, verifying availability, and relaying dispatch logistics) eliminates critical bottlenecks and operational variability.

3.2 System Data Accuracy

Table 2. System Data Accuracy Evaluation

Metric	N	Success	Failed	Mean
Data Completeness	50	49	1	98.0%
Data Validity	50	49	1	98.0%
Data Entry Error Rate	50	49	1	2.0%

Table 2 summarizes OceanMedic's data handling performance across 50 trial runs ($N = 50$), evaluating completeness, validity, and entry error rates. In 49 out of 50 trials, all mandatory fields were successfully recorded and validated, yielding a 98.0% success rate for both data completeness and validity, alongside a low 2.0% entry error rate.

Crucially, the telemetry data ingestion pipeline was evaluated using empirical measurements captured directly from an STM32-based hardware setup during land-based bench testing prior to maritime deployment. While these physical sensor streams (GPS, compass, and fuel indicators) confirm hardware integration and system parsing accuracy under controlled conditions, full validation under actual sea-surface operating conditions and patchy network environments remains an objective for future offshore field trials.

The low 2.0% error rate is directly attributable to UI-level constrained input design: required fields are enforced, emergency types use dropdown lists, and locations are selected interactively via maps rather than raw text. By shifting data correctness from manual human entry to structured interfaces, OceanMedic minimizes misheard details and missing fields—establishing a reliable data foundation for downstream dispatch and tracking workflows.

Ensuring high baseline data accuracy during the initial intake phase is vital to prevent compounding errors in downstream medical dispatch and vessel routing. While these controlled land-based results validate the robustness of the data parsing pipeline, incorporating edge-level data verification will further guard against transient sensor corruption in field settings. Future work will focus on testing this input validation layer against real-world packet loss and signal instability during live maritime operations.

3.3 System Performance

Table 3. System Performance Evaluation

Request	N	Avg	SD	Range	Condition
5	10	1.84	0.18	1.6-2.1	Stable
10	10	2.12	0.23	1.8-2.6	Stable
20	10	3.36	0.42	3.0-4.1	Slight Delay
30	10	5.27	0.68	5.0-6.8	Noticeable Lag

Table 3 evaluates OceanMedic's system stability and response latency under stress, testing four simulated concurrent load levels (5, 10, 20, and 30 parallel booking requests) across 10 repeated runs per level ($N = 10$). At lower concurrency levels (5 and 10 parallel requests), the platform maintains high stability with average response times of 1.84 s ($\mathrm{SD} = 0.18$) and 2.12 s ($\mathrm{SD} = 0.23$), respectively—confirming reliable, sub-3-second performance for normal operational loads.

As concurrent traffic increases to 20 requests, latency and variance begin to rise, reaching a mean of 3.36 s ($\mathrm{SD} = 0.42$, range 3.0–4.1 s), classified as "Slight Delay." At 30 concurrent requests, response times increase further to a mean of 5.27 s ($\mathrm{SD} = 0.68$, range 5.0–6.8 s), marked by "Noticeable Lag." This degradation highlights the computational throughput capacity and processing boundary of the single-machine prototype configuration under resource contention.

Crucially, because these benchmarks were conducted in a local single-machine environment, they represent a best-case baseline for server processing capacity and do not yet account for real-world network packet loss or variable bandwidth typical of maritime areas. Overall, while the current architecture easily accommodates routine daily operations (up to 10 concurrent requests), scaling to higher traffic densities or real-world deployment will require distributed node architecture, load balancing, and database optimization.

To maintain sub-second processing integrity during sudden emergency spikes across archipelagic medical networks, future infrastructure iterations must implement active queue management and horizontal scaling. Additionally, empirical testing under simulated network throttling will be necessary to establish accurate latency bounds beyond ideal single-machine conditions. These enhancements will ensure that baseline processing speeds translate effectively into resilient field operational performance.

3.4 User Evaluation

Table 4. User Acceptance Evaluation

Dimension	Indicator	Mean	SD	Scale
Ease of Interaction	The system is straightforward to operate	4.3	0.48	4–5
	The interaction flow is easy to understand	4.2	0.42	4–5
	The system is flexible during use	4.1	0.73	3–5
	New users can quickly adapt to the system	4.3	0.48	4–5
	The system is easy to learn	4.2	0.42	4-5
Operational Benefit	The system improves task performance	4.0	0.81	3-5
	The system increases work productivity	4.0	0.66	3-5
	The system enhances task effectiveness	4.0	0.81	3-5
	The system is useful in handling emergency cases	4.3	0.67	3-5
	The system helps complete tasks faster	4.2	0.42	4-5
Adoption Intention	I am willing to use this system	3.9	0.73	3-5
	I plan to use the system in future scenarios	3.8	0.63	3-5
	I would rely on this system during emergencies	3.7	0.82	3-5

Table 5. System Usability Evaluation

Dimension	Indicator	Mean	SD	Scale
Information Clarity	The system provides relevant information	4.1	0.56	3–5
	The information is well-structured and organized	4.3	0.48	4–5
	The information is sufficiently detailed	4.0	0.66	3–5
	The system delivers necessary content	4.2	0.78	3-5
Interface Design	The interface appearance is visually appealing	4.5	0.52	4-5
	The layout design is user-friendly	4.3	0.48	4-5
	The display is clear and readable	4.4	0.51	4-5
	The color scheme is appropriate	4.4	0.51	4-5
Navigation Experience	The dashboard is easy to operate	4.1	0.73	3-5
	Navigation between features is clear	4.3	0.48	4-5
	Users can easily move through the system	4.3	0.48	4-5

Following the simulation trials, all 50 participants ($N = 50$) completed structured user acceptance (Table 4) and system usability (Table 5) questionnaires evaluated on a 5-point Likert scale. Overall, usability ratings ($\mu = 4.26$) outscored acceptance scores ($\mu = 4.08$), confirming that while the interface is exceptionally intuitive, operational adoption during critical emergencies requires further field validation.

In user acceptance (Table 4), *Ease of Interaction* performed best ($\mu = 4.22$), with users highlighting operational clarity ($\mu = 4.30$) and learnability ($\mu = 4.20$). *Operational Benefit* also scored high ($\mu = 4.10$), specifically for emergency utility ($\mu = 4.30$). Conversely, *Adoption Intention* recorded the lowest mean ($\mu = 3.80$), with reliance during active emergencies scoring 3.70 (SD = 0.82). This lower rating reflects practitioner hesitation to fully transition from established phone-based workflows without proven system reliability under live operational conditions.

System usability (Table 5) received stronger consensus, led by *Interface Design* ($\mu = 4.40$; visual appeal $\mu = 4.50$), followed by *Navigation Experience* ($\mu = 4.23$) and *Information Clarity* ($\mu = 4.15$). This gap between superior usability perceptions and conservative adoption willingness indicates that user trust is constrained by anticipated sea-surface conditions—such as intermittent satellite links and packet loss. Consequently, future developments should prioritize offline caching, store-and-forward protocols, and fail-safe communication channels to build operational confidence in archipelagic healthcare networks.

3.5 Comparative Framework

Table 6. Comparative Framework Analysis

Feature	GEMAR[24]	OceanMedic
Primary domain focus	Web-based GIS for emergency management in urban settings, with two subsystems: emergency reporting and ambulance routing.	Web-based ambulance ship ordering and coordination for maritime EMS in archipelagic regions.
Booking mechanism	No explicit in-system ambulance booking; requests assumed to originate from conventional communication (e.g., phone)	Explicit web-based ambulance ship ordering, where each request is represented as a structured "order" linked to users, ports, and vessels.
Dispatch coordination	Provides decision support by selecting the nearest ambulance and generating optimal routes, but dispatch is not modelled as a full role-based coordination interface; focus is on routing and hospital selection for clinical operators.	Provides role-specific interfaces (client, operator, administrator) so that operators can assign vessels, manage missions, and oversee active orders in a coordinated workflow.
WebGIS / geospatial visualization	Web-based GIS integrating geospatial information, GPS, and optimization; visualizes emergency locations, ambulance positions, and routes on a map for urban areas (e.g., Malang city).	OpenStreetMap-based WebGIS visualizing vessel locations, nearby ports, and current mission status for maritime coordination.
Routing and path planning	Ambulance routing subsystem computes optimal routes from ambulance to emergency location and then to the nearest clinical center, using road network analysis and shortest-path algorithms stored in the database.	Current prototype models vessel movement as simplified straight-line trajectories between ports; maritime routing algorithms (A*, RRT) have been reviewed conceptually from literature but are not yet implemented in the live dispatch engine.
Real-time monitoring / telemetry	Uses geolocation/geocoding and road-network data, but does not describe integration of AIS or hardware sensor telemetry; ambulance positions are derived from GIS/GPS context, not from an AIS-like embedded hardware pipeline.	Integrates STM32-based hardware telemetry (GPS, compass heading, fuel data) verified through land-based prototype simulations rather than live sea operations.
Target environment and constraints	Urban road networks with high population density and traffic problems; main challenge is finding optimal routes and nearest hospitals in a complex city topology.	Targeted for island and coastal environments; current performance benchmarks reflect a controlled single-machine baseline prior to future offshore trials under intermittent network conditions.

Table 6 presents a qualitative, literature-based architectural feature comparison between GEMAR [24]—a representative land-based WebGIS emergency dispatch system—and OceanMedic. This comparison is explicitly structured as a literature-derived functional mapping across seven core operational dimensions rather than an empirical head-to-head performance benchmark [8]. While both platforms leverage WebGIS technologies to enhance emergency coordination, they target fundamentally distinct operational environments and address different workflow requirements.

GEMAR focuses on urban road networks, serving primarily as a decision-support system that calculates optimal shortest paths over terrestrial road topologies without providing an integrated, role-based booking pipeline. In contrast, OceanMedic adapts the WebGIS paradigm to archipelagic maritime environments by introducing an end-to-end, role-specific dispatch workflow. OceanMedic digitizes the full emergency referral lifecycle—from patient booking submission to operator dispatch—and enriches situational awareness by integrating real-time hardware telemetry (GPS, heading, and fuel parameters) collected via STM32-based microcontrollers.

Regarding path planning, GEMAR utilizes mature road-network routing algorithms, whereas the current OceanMedic prototype models vessel transit using simplified port-to-port straight-line trajectories. Complex maritime routing algorithms—such as A and Rapidly-exploring Random Trees (RRT)—were reviewed and conceptualized from literature [25] but are not yet implemented or empirically tested within OceanMedic's live dispatch engine. Overall, this literature comparison highlights that OceanMedic successfully extends WebGIS emergency coordination into the maritime domain by unifying structured booking workflows, role-based management, and embedded hardware tracking.

3.6 Limitations

Several limitations should be acknowledged when interpreting the findings of this study. First, the performance evaluation was conducted within a controlled, single-device local environment using JSON-based file storage. Consequently, the reported latency and throughput represent a best-case computational baseline and do not fully reflect distributed system behavior under intermittent satellite connectivity, high packet loss, or variable bandwidth conditions typical of remote archipelagic settings. Second, although the real-time vessel monitoring pipeline was successfully verified using physical STM32-based hardware sensors, data streams were captured during land-based prototype simulations rather than live maritime operations, meaning that hardware durability, sensor signal attenuation, and transmission reliability under severe sea-surface conditions require further offshore field validation. Third, while advanced maritime path-planning algorithms (such as A and RRT) were reviewed conceptually from literature, they are not yet integrated into the live dispatch engine; the current prototype models vessel transit using simplified straight-line trajectories between waypoints, omitting dynamic maritime constraints such as bathymetry, weather conditions, and sea currents.*

Despite these constraints, this study establishes the technical feasibility of unifying ambulance ship booking, dispatch coordination, and hardware-based tracking into an integrated WebGIS platform. The current prototype serves as a foundational architecture that can be extended through future research. Priorities for subsequent work include migrating to a scalable distributed cloud infrastructure, deploying telemetry hardware onto active vessels for live ocean-testing, and fully embedding dynamic maritime routing logic into dispatch decision-making to provide robust, real-world decision support for archipelagic emergency medical services.

4. Conclusions

This study presented and empirically evaluated OceanMedic, a web-based coordination platform that integrates ambulance ship booking, role-based dispatch workflows, and WebGIS-based vessel tracking to address communication fragmentation and dispatch delays in archipelagic emergency medical referrals. Quantitative evaluations in a controlled baseline environment demonstrated substantial performance gains over conventional phone-based protocols: mean response time was reduced by 62.9% (from 5.48 s to 2.03 s; $p < 0.001$) and full task completion time by 92.9% (from 61.70 s to 4.38 s; $p < 0.001$). Furthermore, data completeness and validity both reached 98.0% during land-based telemetry hardware testing, while system response latencies remained comfortably under 3 seconds for routine concurrent loads (up to 10 parallel requests)—confirming that the prototype reliably supports everyday operational scenarios.

Structured questionnaire responses ($N = 50$) confirmed high user satisfaction, particularly regarding interface design ($\mu = 4.40$) and ease of interaction ($\mu = 4.22$). However, lower adoption intention scores ($\mu = 3.70$) highlighted that establishing practitioner trust in mission-critical maritime tools requires demonstrating system resilience under real-world sea-surface conditions and patchy satellite networks. Additionally, a literature-based feature comparison with GEMAR underscored OceanMedic's architectural and empirical contribution: while GEMAR optimizes urban road-based EMS, OceanMedic successfully extends WebGIS emergency coordination into maritime environments by unifying structured order workflows, role-specific dispatch, and embedded hardware sensor telemetry within a single platform. Overall, OceanMedic delivers both a functional prototype and a scalable reference architecture for future digital healthcare dispatch in geographically isolated island regions.

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