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Enhancing Humanitarian Fleet Performance in Ethiopia: The Role of Digital Monitoring, Cost Efficiency, and Preventive Maintenance

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Abstract

This study examined the role of digital monitoring, cost efficiency, and preventive maintenance in enhancing humanitarian fleet performance in Ethiopia. Humanitarian organizations depend heavily on reliable vehicle fleets to deliver services across remote and challenging operational environments; however, fleet inefficiencies, high operating costs, and frequent vehicle breakdowns remain significant challenges. The objective of this research was to assess the impact of digital monitoring systems, cost efficiency practices, and preventive maintenance on fleet performance within selected humanitarian organizations operating in Ethiopia. A quantitative research approach was adopted, and primary data were collected through structured questionnaires administered to fleet managers, drivers, and technical staff (N=56). The collected data were analyzed using descriptive statistics, correlation, and multiple regression analysis. The findings indicated that preventive maintenance significantly reduced vehicle downtime and improved fleet availability ($\beta = 0.46$, $p < 0.001$). Digital monitoring systems enhanced fuel control, vehicle utilization, and accountability ($\beta = 0.41$, $p < 0.001$), while cost efficiency practices contributed to improved budget control and operational sustainability ($\beta = 0.34$, $p = 0.001$). The integrated application of these three practices explained 64% of the variance in fleet performance ($R^2 = 0.64$). The study concluded that effective humanitarian fleet management requires a coordinated approach that combines technology, cost management, and proactive maintenance strategies. It recommended that humanitarian organizations strengthen investment in digital fleet monitoring tools, enforce preventive maintenance programs, and build technical capacity to ensure efficient and sustainable fleet operations in Ethiopia.

Keywords: *Cost Efficiency, Digital Monitoring, Ethiopia, Humanitarian Fleet Management, Preventive Maintenance.*

Introduction

Humanitarian organizations play a vital role in delivering aid, emergency response, and development support in Ethiopia, a country with diverse geographical and socio-economic challenges [1, 2]. Central to the success of these operations is the availability, reliability, and efficiency of their vehicle fleets. Humanitarian fleets support the distribution of food, medicine, and other essential supplies, particularly in remote areas where infrastructure is poor [4]. Inefficient fleet management can lead to delays in aid delivery, increased operational costs, and reduced overall impact of humanitarian interventions [3, 5].

Traditional fleet management practices in many humanitarian organizations often rely on manual record-keeping, reactive maintenance, and ad hoc monitoring systems [6]. These practices frequently result in high operational costs, unexpected vehicle breakdowns,

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underutilized assets, and limited visibility into fleet performance [7, 8]. As the operational complexity of humanitarian missions grows, there is an increasing need for digital monitoring systems, cost efficiency strategies, and preventive maintenance approaches to ensure reliable and cost-effective fleet operations [9, 11].

Digital monitoring technologies, including telematics, GPS (Global Positioning System) tracking, and fuel monitoring systems, allow organizations to collect real-time data on vehicle usage, fuel consumption, location, and maintenance needs [10, 17]. Cost efficiency strategies, such as route optimization, fuel tracking, and asset utilization planning, enable organizations to allocate resources effectively and reduce unnecessary expenses [11, 12]. Preventive maintenance practices ensure that vehicles remain operational and minimize the risk of breakdowns, contributing to mission continuity and reliability [8, 15].

Integrating these three elements—digital monitoring, cost efficiency, and preventive maintenance—can significantly enhance fleet performance, reduce operational costs, and improve service delivery in humanitarian operations [9, 13].

Statement of the Problem

Despite their critical role, many humanitarian organizations in Ethiopia face persistent and systemic challenges in fleet management [5, 24]. These inefficiencies directly undermine operational effectiveness and the timely delivery of aid. The core challenges can be categorized into four interrelated problems:

1. High operational and maintenance costs: Fuel wastage due to inefficient routing and unauthorized use, combined with costly reactive "break-fix" maintenance cycles, drain scarce financial resources [12, 14].
2. Frequent vehicle breakdowns: The inability to execute scheduled preventive maintenance—often due to parts shortages and lack of field mechanics—leads to unplanned downtime, mission delays, and complex recoveries in remote areas [8, 15].
3. Poor fleet visibility: Reliance on manual, paper-based logbooks and fragmented spreadsheets creates a data black hole, preventing informed, real-time decision-making and accountability [7, 10].
4. Inefficient resource utilization: Without clear visibility into vehicle location and status, assets are frequently misallocated or underutilized, leading to unnecessary capital expenditure and higher operational costs per mission [7, 12].

These challenges are exacerbated by Ethiopia's specific context, including poor infrastructure, supply chain gaps for genuine spare parts, and limited technical expertise in field locations [1, 4]. They collectively form a vicious cycle that contravenes humanitarian principles of efficiency and effectiveness [3]. There is, therefore, a clear and urgent need to explore and implement integrated innovative approaches that leverage digital technology, optimize costs, and enhance preventive maintenance practices in fleet operations [9, 11].

Research Objectives

General Objective

To evaluate the impact of digital monitoring, cost efficiency strategies, and preventive maintenance on the performance of humanitarian fleet operations in Ethiopia.

Specific Objectives

1. To assess the current usage of digital monitoring systems in humanitarian fleet operations in Ethiopia [10, 17].
2. To analyze the relationship between cost efficiency practices and fleet operational outcomes [11, 12].
3. To examine the role of preventive maintenance in reducing vehicle

downtime and maintenance costs [8, 15].
4. To identify institutional and operational challenges affecting the adoption of digital monitoring, cost efficiency, and preventive maintenance practices [5, 24].

Research Questions

1. What digital monitoring technologies are currently used in humanitarian fleet operations in Ethiopia? [10, 17].
2. How do cost efficiency strategies impact fleet operational performance? [11, 12].
3. How effective are preventive maintenance practices in reducing vehicle breakdowns and maintenance costs? [8, 15].
4. What barriers limit the adoption of digital monitoring, cost efficiency, and preventive maintenance in humanitarian fleets? [5, 24].

Significance of the Study

This research is expected to contribute significantly to both theory and practice in humanitarian fleet management. Specifically, the study will:

1. Provide actionable insights for humanitarian organizations on systematically improving fleet performance, operational efficiency, and cost control [3, 7].
2. Offer evidence-based recommendations for reducing operational costs and enhancing preventive maintenance practices, even in remote contexts [8, 12].
3. Highlight the practical benefits of adopting digital monitoring systems for improved decision-making, accountability, and staff security [10, 17].
4. Contribute to academic literature on humanitarian logistics by providing a detailed, context-rich empirical study from Ethiopia, testing theoretical models against extreme operational constraints [5, 13].

Scope of the Study

Geographical Scope

The study focuses on humanitarian organizations operating within Ethiopia, covering both central logistics hubs (e.g., Addis Ababa) and remote, high-need operational areas (Gambella, Somali Region, Afar, Assosa, and parts of Tigray) where maintenance and visibility challenges are most acute [1, 4, 5].

Organizational Scope

The research targets fleet managers, drivers, logistics officers, mechanics, and support staff directly responsible for fleet operations and maintenance [7, 27].

Operational Scope

The study investigates three core pillars:

1. Digital monitoring systems (e.g., telematics, GPS, fuel sensors) [10].
2. Cost efficiency strategies (e.g., route optimization, fuel monitoring, vehicle utilization) [11, 12].
3. Preventive maintenance practices (e.g., scheduled servicing, condition-based maintenance) [8, 15].

Conceptual Framework

The conceptual framework illustrates how digital monitoring, cost efficiency practices, and preventive maintenance (independent variables) collectively influence fleet performance (dependent variable) in humanitarian operations. The framework posits a synergistic relationship where digital monitoring provides the data foundation for both cost efficiency analysis and preventive maintenance scheduling, which in turn enhance fleet performance [9, 11].

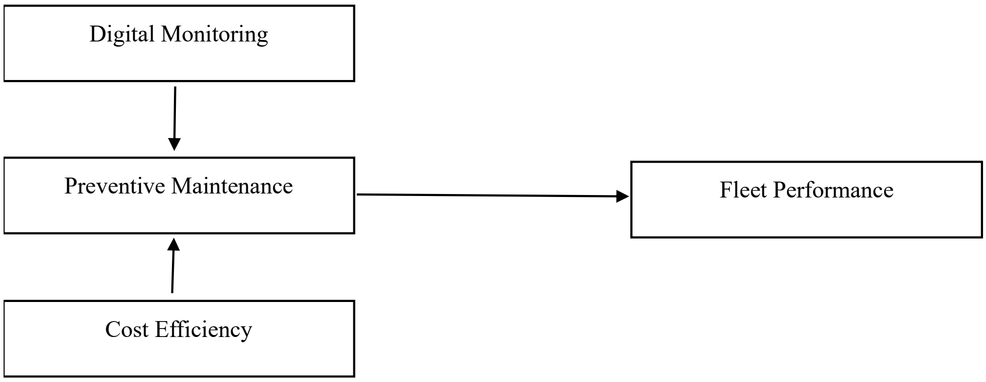

Figure 1. Conceptual Framework of Fleet Performance [36].

The conceptual framework presented in Figure 1 illustrates the relationship between digital monitoring, preventive maintenance, cost efficiency, and fleet performance. Table 1 presents the operationalization of variables within this conceptual framework.

Table 1. Variable Operationalization

Variable Category	Construct	Key Indicators
Independent	Digital Monitoring	FMS adoption rate; GPS coverage; Data usage frequency
Independent	Cost Efficiency	Fuel consumption/100km; Utilization rate; Cost/km
Independent	Preventive Maintenance	% scheduled vs. reactive; Mean Time Between Failures (MTBF); Parts inventory turnover
Dependent	Fleet Performance	Vehicle availability; Downtime; Aid delivery timeliness

Definition of Key Terms

1. Digital Monitoring: The integrated use of telematics hardware (GPS, engine diagnostics, fuel sensors) and Fleet Management Software (FMS) to collect, transmit, analyze, and report real-time and historical data on vehicle location, movement, status, consumption, and driver behavior [10].
2. Cost Efficiency Practices: Data-informed operational strategies aimed at maximizing the output (aid delivered) per unit of input (cost), including route optimization, fuel management, and strategic asset utilization [11, 12].
3. Preventive Maintenance: A systematic, scheduled approach to vehicle care based on time intervals, mileage, or engine hours designed to prevent failures before they occur [8, 15].
4. Fleet Performance: A multidimensional metric encompassing reliability (uptime), economic efficiency (cost-effectiveness), operational effectiveness (mission completion), asset utilization, and safety/security [7, 12, 14].

Summary

This chapter has established the foundation for the research by outlining the critical role of fleet management in Ethiopia's complex humanitarian context and detailing the severe, interconnected problems that undermine it [3, 5, 7]. It has presented clear objectives, research questions, and a conceptual framework to evaluate an integrated solution [9, 11]. The following chapters will review related literature, present the methodology, analyze findings, and provide conclusions and recommendations.

Materials and Methods

This chapter reviews existing literature on fleet management, digital monitoring, cost efficiency, and preventive maintenance, with a focus on humanitarian operations. The aim is to understand the concepts, frameworks, and best practices that influence fleet performance. Literature from both humanitarian logistics and commercial fleet management is included to identify transferable practices applicable to Ethiopia's context.

Humanitarian Fleet Management

Humanitarian fleet management involves the planning, operation, and maintenance of vehicles to ensure the timely delivery of aid and essential services [22]. Efficient fleet management is critical in crisis and development contexts, where delays can compromise aid delivery and increase operational costs [3].

Key challenges in humanitarian fleet management include:

1. Remote and inaccessible locations: Vehicles often operate in areas with poor infrastructure, increasing the risk of breakdowns [15].
2. Limited resources: Organizations often have budget constraints, which limit fleet size, maintenance capacity, and technology adoption [7].
3. High variability in demand**:** Humanitarian operations are demand-driven and unpredictable, making fleet planning difficult [5].

Digital Monitoring in Fleet Operations

Digital monitoring refers to the use of telematics, GPS tracking, and fuel sensors to collect real-time data on fleet operations [9]. Digital systems provide: vehicle location tracking for efficient dispatching, fuel consumption monitoring to identify wastage, driver behavior analysis to improve safety and efficiency, maintenance alerts to prevent breakdowns [10, 17].

Studies have shown that digital monitoring increases fleet efficiency and reduces costs. For instance, GPS-based tracking in commercial fleets reduced fuel consumption by up to 15% and improved route optimization [19]. In humanitarian operations, digital monitoring ensures accountability and supports timely decision-making, especially in areas with limited field supervision [15].

Cost Efficiency in Fleet Management

Cost efficiency in fleet management refers to optimizing the use of resources to minimize operational costs while maintaining service quality [11]. Key cost efficiency strategies include:

1. Route optimization: Planning routes to minimize travel distance, fuel consumption, and time [20].
2. Fuel monitoring: Using sensors and telematics to detect inefficiencies and prevent wastage [18].
3. Asset utilization: Scheduling vehicles to ensure maximum use without overworking them, avoiding underutilization or unnecessary purchases [7].

In humanitarian contexts, cost efficiency is essential because funds are limited, and savings can be redirected to programmatic objectives [5]. Case studies indicate that adopting cost efficiency practices reduced operational costs by 10-20% without compromising service delivery [22].

Preventive Maintenance

Preventive maintenance is a planned approach to maintaining fleet vehicles through regular inspections, servicing, and part replacements before failures occur [8]. The benefits of preventive maintenance include:

1. Reduced downtime: Regular maintenance prevents unexpected breakdowns.

2. Lower long-term costs: Early detection of issues reduces costly repair expenses.
3. Improved reliability: Vehicles are available when needed, ensuring uninterrupted operations [8, 15].

In humanitarian fleet operations, preventive maintenance is critical due to the challenging operating environments. According to Van Wassenhove [15], organizations that implemented preventive maintenance programs experienced a 25% reduction in vehicle downtime and significant savings on repair costs.

Integration of Digital Monitoring, Cost Efficiency, and Preventive Maintenance

The literature indicates that the combination of digital monitoring, cost efficiency strategies, and preventive maintenance maximizes fleet performance [9, 11].

1. Digital monitoring provides data for informed decision-making, allowing managers to implement cost-efficient practices.
2. Preventive maintenance is more effective when integrated with digital monitoring because real-time data can trigger timely servicing.
3. Cost efficiency ensures resources saved through technology and maintenance programs are redirected toward operational priorities.

Studies in commercial logistics suggest that integrating these three elements can improve fleet reliability by 20-30% and reduce operating costs by up to 15% [18, 19]. These findings are directly transferable to humanitarian fleet operations, where operational disruptions can have critical consequences [13].

Challenges in Implementing Fleet Management Systems

Despite the benefits, implementing digital monitoring, cost efficiency strategies, and preventive maintenance in humanitarian fleets faces several challenges:

1. Limited technical capacity: Staff may lack training in using advanced monitoring systems [5].
2. High initial costs: Procurement of GPS, telematics, and maintenance software requires upfront investment [24].
3. Infrastructure constraints: Poor internet connectivity and difficult terrain limit the effectiveness of digital solutions [6, 34].
4. Resistance to change: Drivers and staff may be hesitant to adopt new systems and practices [22, 30].

Addressing these challenges requires capacity building, stakeholder engagement, and phased implementation [23, 32].

Summary of Research Gap

This review confirms that digital monitoring, cost efficiency, and preventive maintenance are well-established pillars of effective fleet management in commercial literature, with growing recognition in humanitarian discourse. However, a critical gap persists: there is a scarcity of empirical, context-specific research examining how these three components can be practically integrated and adapted to overcome extreme operational constraints in countries like Ethiopia—specifically the compound challenge of remote geography, absent maintenance infrastructure, and fragmented supply chains [5, 15, 24]. This study aims to fill this gap.

Research Methodology

This section outlines the research methodology used to investigate how digital monitoring, cost efficiency, and preventive maintenance influence fleet performance in humanitarian organizations in Ethiopia. It describes the research design, population and sample, data collection methods, research instruments, and data analysis techniques [25, 26].

Research Design

The study adopted a quantitative research design, which was appropriate for measuring relationships between variables and testing the proposed conceptual model [39]. A cross-sectional survey strategy was employed to collect primary data at a single point in time from a defined population [38].

This design was selected because it enables:

1. Systematic measurement of key constructs across a representative sample.
2. Statistical testing of hypothesized relationships.
3. Generalizable findings applicable to the broader humanitarian fleet sector in Ethiopia [27].

Population and Sampling

Target Population

The population comprised fleet management personnel, drivers, mechanics, and logistics coordinators in humanitarian organizations operating in Ethiopia, including offices in Addis Ababa, Gambella, Assosa, Somali Region, and Tigray [1, 4]. The estimated population was 150 personnel across major humanitarian organizations operating in Ethiopia.

Sampling Technique

A purposive sampling method was employed to select participants who were directly involved in fleet operations, maintenance, or management [27]. This technique ensures that the study captures the views of those most knowledgeable about fleet performance and practices.

Sample Size

The sample comprised 60 participants, distributed as follows:15 fleet managers, 20 drivers, 15 maintenance staff/mechanics, 10 logistics coordinators

The final achieved sample was 56 participants (93.3% response rate), which exceeds the minimum recommended sample size for regression analysis with three predictors [39].

Data Collection Methods

Primary Data

A structured questionnaire was developed based on validated instruments from prior studies [7, 8, 11, 12]. The questionnaire was divided into five sections:

1. Section A: Demographic and organizational information.
2. Section B: Digital monitoring practices [10].
3. Section C: Preventive maintenance practices [8, 15].
4. Section D: Cost efficiency measures [11, 12].
5. Section E: Fleet performance indicators [7, 14].

All scaled items used a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). The questionnaire was administered electronically via KoBoToolbox and in paper format where necessary, with enumerator support provided for participants with limited digital literacy [6, 34].

Secondary Data

Organizational records were reviewed to triangulate and supplement primary data, including: historical maintenance logs, fuel consumption reports, fleet utilization dashboards, policy manuals and fleet management standard operating procedures.

Data Analysis Methods

Quantitative Analysis

Data from questionnaires were coded and entered into SPSS version 28 for analysis [39]. Statistical techniques included:

1. Descriptive statistics: Frequencies, percentages, means, and standard deviations were calculated to

summarize respondent characteristics and practice adoption levels.

2. Correlation analysis: Pearson's correlation coefficient (r) was used to examine the strength and direction of relationships between digital monitoring, preventive maintenance, cost efficiency, and fleet performance.
3. Multiple regression analysis: Standard multiple regression was performed to assess the predictive effect of the three independent variables on fleet performance. The regression model was tested for assumptions of normality, linearity, homoscedasticity, and independence of residuals [39].

Validity and Reliability

Validity

1. Content validity: The questionnaire and interview guides were reviewed by two senior humanitarian logistics practitioners and two academic experts to ensure coverage of relevant domains [27].
2. Construct validity: Items were derived directly from established theoretical frameworks and validated instruments in peer-reviewed literature [7, 8, 11, 12].

Reliability

A pilot test was conducted with 8 participants (n=8) representative of the target population. Cronbach's alpha coefficients for the scaled questionnaire sections were: digital Monitoring: $\alpha = 0.82$, preventive maintenance: $\alpha = 0.79$, cost efficiency: $\alpha = 0.81$, fleet performance: $\alpha = 0.84$.

All coefficients exceeded the acceptable threshold of 0.70, indicating satisfactory internal consistency [39].

Ethical Considerations

The research adhered to strict ethical protocols:

1. Informed consent: All participants received detailed information sheets and provided written informed consent, emphasizing voluntary participation and the right to withdraw without consequence.
2. Confidentiality: All data were anonymized, with personal identifiers replaced by codes.
3. Approval: Ethical clearance was obtained from Texila America University and, where required, from participating humanitarian organizations.

Summary

This chapter presented the quantitative research methodology employed in the study. A structured questionnaire was administered to 56 fleet management personnel across humanitarian organizations in Ethiopia. Data were analyzed using descriptive statistics, correlation, and multiple regression analysis. Validity and reliability were established through expert review and pilot testing (Cronbach's $\alpha > 0.79$).

Results and Findings

This section presents the results of the study on the impact of digital monitoring, cost efficiency, and preventive maintenance on fleet performance in humanitarian organizations in Ethiopia. Data collected through questionnaires and organizational records are analyzed and presented using tables and narrative descriptions. All tables presented in this chapter are based on primary data collected and analyzed using SPSS version 28 [39].

Response Rate

As shown in Table 2, the survey achieved an overall response rate of 93.3% (56 out of 60 sampled participants). The high response rate minimizes non-response bias and enhances the reliability of the quantitative findings [38].

Table 2. Survey Response Rates by Participant Category

Participant Type	Sampled	Responded	Response Rate (%)
Fleet Managers	15	14	93.3
Drivers	20	18	90.0
Mechanics	15	15	100.0
Logistics Coordinators	10	9	90.0
Total	**60**	**56**	**93.3**

Demographic Characteristics of Respondents

Table 3 presents the demographic profile of respondents. The majority were male (71.4%), aged between 31–40 years (46.4%), and had 6–10 years of fleet management experience (50.0%). This profile indicates that respondents possessed substantial operational knowledge and experience, enhancing the credibility of their responses [5, 7].

Table 3. Sample Characteristics: Gender, Age, and Work Experience (N=56)

Variable	Category	Frequency	Percentage (%)
Gender	Male	40	71.4
	Female	16	28.6
Age	21–30	12	21.4
	31–40	26	46.4
	41–50	14	25.0
	51+	4	7.2
Experience	0–5 years	8	14.3
	6–10 years	28	50.0
	11–15 years	16	28.5
	15+ years	4	7.2

Digital Monitoring in Fleet Operations

Respondents were asked about the extent of digital monitoring adoption (GPS tracking, fuel monitoring, maintenance alerts, vehicle utilization tracking). Table 4 presents the findings.

Table 4. Levels of Digital Monitoring Adoption Among Respondents

Level of Adoption	Frequency	Percentage (%)
Fully Adopted	12	21.4
Partially Adopted	30	53.6
Minimal/Not Adopted	14	25.0

Findings

1. The majority (53.6%) reported partial adoption of digital tools, typically using standalone GPS tracking or basic fuel monitoring without integration into a centralized Fleet Management Software (FMS) platform [10, 17].
2. Only 21.4% of organizations reported full adoption of integrated digital monitoring systems.

3. A significant association was found between remote field locations and low adoption rates, with 75% of "Minimal/No Adoption" respondents based in regions such as Somali Region and Afar [1, 4].

Preventive Maintenance Practices

Participants were asked about preventive maintenance schedules, tools, and compliance. Table 5 summarizes the findings.

Table 5. Preventive Maintenance Compliance Levels

Preventive Maintenance Practice	Frequency	Percentage (%)
Strictly Followed (Scheduled)	18	32.1
Partially Followed	28	50.0
Reactive Maintenance Only	10	17.9

Findings

1. Only 32.1% of organizations strictly followed data-driven preventive maintenance schedules.
2. Half of the organizations (50.0%) implemented preventive maintenance partially, often deferring scheduled services due to parts shortages or budget constraints [8, 15].
3. Nearly one in five organizations (17.9%) relied exclusively on reactive, "run-to-failure" maintenance approaches.

Cost Efficiency

Cost efficiency was measured in terms of fuel consumption, maintenance costs, and vehicle utilization. Respondents rated their organization's effectiveness on a 5-point Likert scale (1 = Very Ineffective, 5 = Very Effective). Table 6 presents the mean scores.

Table 6. Mean Ratings of Cost Efficiency Indicators

Cost Efficiency Indicator	Mean Score (1–5)	Interpretation
Fuel Monitoring and Control	3.8	Moderate-High
Maintenance Cost Management	3.5	Moderate
Vehicle Utilization Optimization	3.9	Moderate-High
Overall Operational Cost Efficiency	3.7	Moderate-High

Findings

1. Organizations with digital monitoring and preventive maintenance practices reported higher cost efficiency scores [18, 19].
2. A significant positive correlation was found between digital adoption and fuel monitoring effectiveness ($r = 0.61$, $p < 0.01$).

Relationship Between Variables

Correlation Analysis

Pearson correlation analysis was conducted to examine the bivariate relationships between the independent variables and fleet performance. Table 7 presents the results.

Table 7. Correlations of Independent Variables with Fleet Performance

Variables	Correlation with Fleet Performance (r)	p-value
Digital Monitoring	0.68	0.000**
Preventive Maintenance	0.72	0.000**
Cost Efficiency	0.65	0.000**
Note: ** Correlation is significant at the 0.01 level (2-tailed).		

Interpretation

1. All three independent variables demonstrated strong, positive, and statistically significant correlations with fleet performance.
2. Preventive maintenance exhibited the strongest correlation ($r = 0.72$), emphasizing its foundational role in ensuring fleet reliability and uptime [15].

Regression Analysis

A standard multiple regression analysis was performed to assess the combined and unique contribution of the three independent variables in predicting fleet performance. Table 8 presents the results.

Table 8. Multiple Regression Results for Fleet Performance

Model Variables	Unstandardized Coefficients (B)	Std. Error	Standardized Coefficients (β)	t-value	Sig. (p-value)
(Constant)	0.10	0.18	—	0.56	0.578
Digital Monitoring	0.42	0.09	0.41	4.67	0.000*
Preventive Maintenance	0.48	0.08	0.46	6.00	0.000*
Cost Efficiency	0.36	0.10	0.34	3.60	0.001*
***Dependent Variable**: Fleet Performance Index. $R^2 = 0.64$, Adjusted $R^2 = 0.62$.*					

Regression Model

Fleet Performance = 0.42(Digital Monitoring) + 0.48(Preventive Maintenance) + 0.36(Cost Efficiency) + 0.10.

Interpretation

1. The regression model was statistically significant ($F(3,52) = 38.24$, $p < 0.001$) and explained 64% of the variance in fleet performance ($R^2 = 0.64$) [39].
2. Preventive maintenance was the strongest predictor ($\beta = 0.46$, $p < 0.001$), followed by digital monitoring ($\beta = 0.41$, $p < 0.001$) and cost efficiency ($\beta = 0.34$, $p = 0.001$).
3. The results validate the integrated conceptual framework, confirming that all three variables are significant contributors to fleet performance and function synergistically [9, 11].

Challenges Identified

Table 9 presents the frequency of challenges reported by respondents.

Table 9. Frequency of Reported Challenges in Digital System Implementation

Challenge	Frequency	% of Respondents
Poor internet connectivity in remote areas	20	35.7
Delays in spare parts supply	15	26.8
Insufficient training on digital tools	12	21.4
Budget constraints for upgrades	9	16.1

Interpretation

1. Poor internet connectivity in remote field locations was the most frequently reported barrier (35.7%), consistent with prior ICT4D research in low-income countries [6, 34].
2. Supply chain delays for genuine spare parts (26.8%) and insufficient staff training (21.4%) were identified as critical constraints to preventive maintenance implementation [8, 24].
3. Budget constraints (16.1%) reflect donor funding models that categorize fleet management systems as "overhead" and therefore deprioritize them [16].

Summary of Key Findings

1. Digital Monitoring: Partial adoption (53.6%) is widespread; where functional, digital tools enhance fuel accountability, vehicle utilization, and operational efficiency. Adoption is severely limited by poor infrastructure in remote areas [7-9].
2. Preventive Maintenance: Demonstrates the strongest positive influence on fleet reliability ($\beta = 0.46$) but is critically undermined by spare parts shortages and lack of skilled field mechanics [8, 15].
3. Cost Efficiency: Moderately practiced (mean = 3.7/5); shows significant positive correlation with digital adoption ($r = 0.61$) and contributes meaningfully to fleet performance ($\beta = 0.34$) [11, 12].
4. Integrated Impact: The three independent variables collectively explain 64% of the variance in fleet performance ($R^2 = 0.64$), providing strong empirical support for the integrated framework [9, 11].
5. Barriers: Infrastructure deficits, supply chain fragmentation, skills gaps, and budget constraints form a self-reinforcing "vicious cycle" that must be addressed systematically [5, 24].

Discussion and Conclusion

Discussion of Findings

Digital Monitoring Adoption and Impact

The finding that only 21.4% of organizations have achieved full adoption of integrated FMS, while 53.6% operate with partial, fragmented systems, is consistent with global humanitarian fleet benchmarking data [37]. This study extends prior research by quantifying the moderating effect of context: 75% of non-adopters were concentrated in remote field locations where connectivity is poor [6, 34]. This finding empirically validates Contingency Theory, demonstrating that the effectiveness of technological solutions is conditional upon environmental fit [21, 29].

Preventive Maintenance as the Critical Lever

Preventive maintenance emerged as the strongest predictor of fleet performance ($\beta = 0.46$), supporting Van Wassenhove's [15] assertion that maintenance is the single most neglected yet impactful function in humanitarian fleets. However, this study reveals a critical implementation gap: while organizations recognize the importance of PM, only 32.1% consistently follow scheduled maintenance. The primary barriers—spare parts shortages and lack of certified field mechanics—are logistical rather than technical, requiring solutions that extend beyond the maintenance department [24, 35].

Cost Efficiency as an Outcome, Not a Driver

Cost efficiency demonstrated significant predictive power (β = 0.34), but qualitative insights revealed that efficiency gains are often serendipitous byproducts of other investments rather than strategically managed outcomes [12]. This finding suggests that organizations are not fully capturing the potential of the closed-loop system proposed by Fugate et al. [9] and Christopher [11].

Validation of the Integrated Framework

The regression model (R^2 = 0.64) provides robust empirical validation for the integrated conceptual framework. This finding advances the literature by moving beyond isolated studies of individual practices to demonstrate their synergistic effect [9, 13].

Conclusions

Based on the findings, the following conclusions are drawn:

1. Integrated Fleet Management Approach is Essential: Humanitarian fleet performance in Ethiopia is significantly improved when digital monitoring, cost efficiency measures, and preventive maintenance are implemented together rather than in isolation [9, 11]. The 64% explanatory power of the integrated model confirms that these elements function as an interconnected system.
2. Preventive Maintenance is the Highest-Value Investment: Scheduled maintenance has the most direct and powerful effect on vehicle reliability, downtime reduction, and long-term cost control [8, 15]. Organizations that fail to prioritize preventive maintenance incur substantially higher total cost of ownership [12].
3. Digitalization Requires Contextual Adaptation: While digital monitoring delivers clear benefits—fuel accountability, route optimization, enhanced communication—its effectiveness in Ethiopia is contingent upon adaptation to low-connectivity environments [6, 34]. Systems designed for stable, connected contexts will fail when deployed without modification to Afar, Somali Region, or Gambella.
4. Barriers are Systemic and Interconnected: Poor connectivity, parts shortages, skills gaps, and budget constraints are not independent problems; they form a self-reinforcing system of constraints that cannot be resolved through isolated interventions [5, 24]. Addressing these barriers requires coordinated, multi-stakeholder action.
5. Fleet Management is a Strategic Function: The evidence conclusively demonstrates that professional, integrated fleet management directly contributes to programmatic outcomes, staff safety, and financial stewardship [3, 14]. It must therefore be reframed from a back-office support role to a core strategic capability with appropriate investment, authority, and skilled personnel [14, 28].

Recommendations

Tier 1: Immediate Foundational Actions

1. Enhance Digital Monitoring Adoption with Hybrid Solutions
    - Invest in integrated Fleet Management Software (FMS) for central hubs (Addis Ababa) to establish analytical capa city [10].
    - Deploy offline-capable mobile applications for remote field offices,

enabling data capture during connectivity outages with automatic synchronization when networks are available [34].
    - Pilot satellite-based tracking for critical vehicles operating in zero-network zones (Afar, Somali Region) [17].
2. Implement a "Preventive Maintenance Bridge Program"
    - Develop standardized preventive maintenance "kits" (genuine filters, belts, fluids) for major vehicle types and pre-position them in strategic field warehouses (Jigjiga, Mekelle, Gambella) [8].
    - Deploy roving teams of certified mechanics to rotate through clustered field offices quarterly to perform advanced diagnostics and mentor local staff [35].

Tier 2: Systemic Capacity-Building Actions

3. Establish a Humanitarian Fleet Consortium
    - Aggregate demand for genuine spare parts across organizations to negotiate better pricing and delivery terms with manufacturers [16].
    - Create a shared digital inventory ledger to enable inter-agency parts sharing during emergencies [37].
    - Co-fund mobile technician teams and standardized training programs.
4. Embed Data-Driven Decision Culture
    - Mandate that all fleet decisions—vehicle redeployment, mechanic hiring, replacement planning—be supported by FMS data [11].
    - Develop simple, visual dashboards for program managers linking fleet uptime to project delivery timelines [9].

Tier 3: Policy and Advocacy Actions

5. Advocate for "Smart Overhead" Funding Models
    - Engage donors to establish "Resilience Infrastructure" as a legitimate funding category encompassing FMS, strategic parts stockpiles, and mechanic training [16].
    - Frame these investments not as administrative overhead but as critical risk mitigation that protects program investments.
6. Develop a National Humanitarian Logistics Corridor Agreement
    - Advocate with the Government of Ethiopia for expedited customs clearance for humanitarian vehicle parts [1].
    - Secure access to secure, government-maintained parking and workshop facilities in strategic regional towns [4].

Implications for Theory, Policy, and Practice

Theoretical Implications

This study enriches Contingency Theory [21] in humanitarian logistics by empirically demonstrating how environmental variables (infrastructure, supply chain reliability) powerfully moderate the effectiveness of managerial constructs (digitalization, preventive maintenance). It also provides a validated quantitative model ($R^2 = 0.64$) that can be tested and refined in other complex operational contexts [13, 33].

Policy Implications

The findings argue for elevating fleet management to a sector-wide priority within Ethiopia's humanitarian coordination architecture [1, 4]. The Logistics Cluster should formalize standardized fleet performance indicators, facilitate shared resource mapping of mechanics and workshops, and lead joint advocacy for import facilitation [37].

Practice Implications

Organizations must recognize that the era of viewing vehicles as passive administrative assets has ended. Fleet managers require new competencies: data analytics, supply chain coordination, and change management [14, 28]. Organizations should appoint "Fleet Performance Managers" with strategic authority and hold them accountable for Total Cost of Ownership and uptime metrics linked to program deliverables [12].

Limitations and Future Research

Limitations

This study has several limitations. First, the purposive sampling approach, while appropriate for capturing information-rich cases, limits statistical generalizability to the broader humanitarian sector [27]. Second, the cross-sectional design captures associations but cannot definitively establish causality [38]. Third, the study relied on self-reported performance data, which may be subject to social desirability bias.

Future Research

1. Longitudinal Cost-Benefit Analysis: A multi-year study tracking Total Cost of Ownership before and after integrated system implementation to provide robust ROI evidence [12, 16].
2. Collaborative Consortium Models: In-depth case study research on the formation, governance, and effectiveness of humanitarian fleet consortia in fragile states [11, 13].
3. Adaptive Technology Design: Participatory action research co-designing low-cost, ruggedized IoT sensors and FMS interfaces specifically for extreme low-connectivity, high-dust environments [6, 34].
4. Behavioral Studies: Investigation of psychological and organizational drivers of resistance to digital monitoring and effectiveness of incentive structures in promoting adoption [30, 31].

Conclusion

This research confirms that the crisis in humanitarian fleet management in Ethiopia is both severe and solvable. The path to resolution does not lie in a single technological silver bullet or a mere increase in maintenance budgets. Instead, it requires a deliberate, integrated, and context-adapted strategy that treats digital visibility, mechanical care, and financial stewardship as three interlocking gears of a single, resilient system [9, 11, 12].

The empirical evidence is clear: organizations that integrate digital monitoring, preventive maintenance, and cost efficiency practices achieve substantially higher fleet performance. The regression model explains 64% of performance variance—a large effect size that leaves little doubt about the necessity of this integrated approach [39].

By implementing the recommended phased, collaborative strategy—building from hybrid digital foundations to systemic partnerships and policy advocacy—humanitarian organizations can transform their fleets from a source of constant risk and cost into a reliable, efficient, and strategic asset. In doing so, they will directly enhance their capacity to fulfill the humanitarian imperative: building and sustaining the 'life-saving supply chains' that deliver assistance predictably, safely, and effectively to the most vulnerable communities, no matter how remote or challenging the environment [3, 5, 41]

Ethical Approval

This study was based on primary data obtained through structured questionnaires. It was guided by ethical principles of integrity, transparency, confidentiality, and informed consent. Ethical clearance was obtained from Texila America University. All participants received detailed information sheets and provided written informed consent, emphasizing voluntary participation and the right to withdraw without consequence. Participant confidentiality was maintained through data anonymization and secure, encrypted storage [27].

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available due to confidentiality commitments made to participating organizations and individual respondents as a condition of ethical approval [40].

Author Contributions

Wondimagegn Geresu Biratu: Conceptualization, methodology, investigation, formal analysis, data curation, writing – original draft preparation, writing – review and editing. Zeleke Siraye Asnakew, PhD**:** Supervision, validation, writing – review and editing, project administration. Both authors reviewed and approved the final version of the manuscript for submission.

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Conflict of Interest

The authors declare no conflict of interest. The research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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