Aerial Logistics in Hard-to-Reach Environments: Systematic Review of the Use of Class 1 UAVs in Health Supply Distribution in Military Operations and Other Context

Rodrigo Bomfim[a], Pablo Gustavo Cogo Pochmann[b] and Eduardo Borba Neves[c]
Officers' Improvement School (Escola de Aperfeiçoamento de Oficiais – EsAO), Duque de Caxias Avenue, 2071, Rio de Janeiro-RJ, Brazil

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Abstract: This study examines the potential integration of Class 1 Unmanned Aerial Vehicles (UAVs) into the COMBATER simulation software, emphasizing their role in healthcare logistics within challenging environments such as jungles and remote areas. A systematic literature review was conducted following PRISMA guidelines, supported by the TREND quality assessment checklist. The analysis identified critical operational parameters for UAV performance, including flight endurance, range, maximum speed, operational altitude, and cargo capacity. These parameters were categorized by UAV class—Mini (<15 kg) and Small (>15 kg)—to align with military doctrine and operational needs. The findings indicate that Mini drones are ideal for unit-level operations, transporting lightweight items like medications and medical supplies, while small drones are suited for brigade-level missions requiring the delivery of heavier and more complex materials, such as blood products and human organs. Limitations include the heterogeneity of studies, the lack of detailed meteorological data, and inconsistent reporting standards. To address these challenges, the study highlights the importance of constructive simulation in testing UAV applications and refining their integration into military operations. By incorporating UAV-specific data into COMBATER, this research contributes to realistic scenario modelling, supporting military decision-making and advancing logistical efficiency. The proposed framework provides a foundation for the strategic use of UAVs in military healthcare logistics, offering insights into the development of military doctrine and the optimization of operations in complex environments.

1 INTRODUCTION

The use of Unmanned Aerial Vehicles (UAVs), or drones, in simulated scenarios offers promising potential for assessing their logistical effectiveness in challenging environments, such as jungle or remote areas. In this context, Almeida et al. (2023) highlight that the COMBATER software, widely employed by the Brazilian Army, is a robust tool for modelling complex operations and testing courses of action in controlled environments. This functionality significantly enhances decision-making processes and tactical training. Although drone delivery not yet implemented, the system could be adapted in the future to analyse how drones might optimize the distribution of medical supplies in hard-to-reach areas, potentially improving outcomes for casualties and the recovery of wounded personnel.

The integration of real-world data, such as range, payload capacity, and operational conditions, into the COMBATER algorithm will enable the creation of more realistic scenarios to assess the feasibility of using drones for transporting health supplies. Given the critical importance of health supplies in sustaining operations and ensuring timely medical care, assessing their delivery via UAVs is a key focus of

[a] https://orcid.org/0009-0003-1437-3078
[b] https://orcid.org/0000-0003-3944-7953
[c] https://orcid.org/0000-0003-4507-6562

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this study. This approach would not only enhance military training but also support strategic decision-making, strengthening the Army's ability to address the challenges of contemporary operations in remote environments.

This study proposes exploring the possibility of incorporating the delivery of medical supplies by drones into the COMBATER algorithm, using real-world data to parameterize the efficiency of this logistical solution. Constructive simulation serves as a cost-effective and controlled method to evaluate the integration of UAVs in logistical processes, minimizing risks and informing live simulation strategies. Additionally, it aims to identify the most suitable echelons to receive this technology in constructive simulation before its deployment in live simulation, ensuring that its adoption is grounded in robust operational and technical evidence. This initiative could also contribute to the evolution of military doctrine by providing a data-driven foundation for integrating UAVs into logistical frameworks, enhancing operational efficiency and readiness.

2 METHODS

2.1 Eligibility Criteria

This study employed a systematic literature review, structured in alignment with the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Page et al., 2021). The temporal scope included publications on military doctrine from 1997 to the present and scientific works published between 2014 and 2024. Four languages were considered for inclusion: English, Portuguese, French, and Spanish. Regarding the types of publications, the search focused on book chapters, monographs, doctrinal manuals, scientific articles, and technical standards.

2.2 Search Strategy

The primary objective of this review was to identify and analyse studies focusing on the utilization of drones, commonly referred to as RPA (Remotely Piloted Aircraft) and UAV (Unmanned Aerial Vehicles), for medical supply operations in jungle, forest, or remote environments. The review explored topics related to logistics, medical operations, and the integration of technology in complex and challenging settings.

In this study, the research focused on drones classified as Class 1 (weighing up to 150 kg) according to NATO standards (NATO, 2019). Class 1 drones are divided into three categories based on their weight, maximum altitude, and range:

- **Micro:** drones weigh less than 2 kg, can reach an altitude of up to 200 feet AGL (Above Ground Level), and have a range of up to 5 km.
- **Mini:** drones weigh between 2 kg and 15 kg, can fly up to 3,000 feet AGL, and have a range of up to 25 km.
- **Small:** drones weigh between 15 kg and 150 kg, can reach an altitude of up to 5,000 feet AGL, and have a range of up to 50 km.

To structure the keywords used across various databases for the research on drone applications in medical supply logistics within forested environments and military operations, we adopted the PICO strategy (Population, Intervention, Comparison, and Outcome). The PICO framework aids in categorizing keywords into essential components for systematic reviews, streamlining the identification of studies that address specific aspects of the topic (Nishikawa-Pacher, 2022).

To define and guide the search strategy in the selected databases, this study adapted the PICO framework to its specific research context.

- **Problem (P):** Focused on challenging environments such as jungles and remote areas where traditional logistics face accessibility issues (keywords: "jungle," "forest," "remote area").
- **Intervention (I):** Examined the use of drones (RPA/UAV) for transporting medical supplies in hard-to-reach regions (keywords: "drone," "RPA," "UAV").
- **Comparison (C):** No direct comparison with traditional methods; the focus is on the implicit advantages of drones in these settings.
- **Outcome (O):** Aimed to improve logistics for medical supplies (Class VIII), reducing response times and risks (keywords: "medical," "medicine," "supply," "distribution," and "logistic.").

Building upon the defined PICO components, the search string was developed according to the established criteria, resulting in a set of Boolean terms tailored to the capabilities of each digital database:

- **Scopus, Web of Science, and PubMed:** The search string used was ((“drone” OR "rpa" OR "uav") AND ("medical" OR "medicine") AND ("supply" OR "distribution" OR "logistic") AND ("jungle" OR "forest" OR "remote AND area")), utilizing the advanced search feature.
- **Science Direct:** Due to limitations in Boolean operators within the database, the string ("drone" OR

"uav" OR "rpa") AND ("medical" OR "medicine") AND ("supply" OR "distribution") AND ("jungle" OR "forest") was applied in the advanced search option.

- **Defense Technical Information Center (DTIC) and The Army University:** In these databases, the string ("uav" AND "forest" AND "medical" AND "drone" AND "logistic") was employed, as the lack of an advanced search option constrained the number of applicable keywords.
- **BDEx:** As a Brazilian Army database, keyword translation and the inclusion of the term SARP (*Sistemas de Aeronaves Remotamente Pilotadas*) were necessary, reflecting its official nomenclature (Brasil, 2020).Due to limitations in search capabilities, the string ("drone" AND "SARP" AND "*logística*") was used to locate relevant studies aligning with the specific objectives of this research.

2.3 Study Selection

During the identification phase, a total of 755 duplicate records were excluded from the initial set of 1,597 references. The remaining references underwent a multi-stage screening process to ensure alignment with the research objectives.

In the first screening, titles, keywords, and abstracts were reviewed. References that were misaligned with the study's goals, such as those focusing on artificial intelligence (AI), Internet of Things (IoT), computer vision, robotics, or blockchain in healthcare systems, were eliminated. Incomplete references, such as indices, news, or abstracts without full text, and those with search keywords appearing in titles or abstracts but unrelated to the research objectives, were also excluded. Additionally, records using the acronym RPA to refer to Robotic Process Automation rather than Remotely Piloted Aircraft were removed.

The second screening addressed accessibility and language. Studies not found or written in languages other than English, French, Spanish, or Portuguese were excluded.

In the third screening, the full texts of the remaining studies were evaluated using a multi-criteria analysis. Articles classified with very strong adherence included at least four central concepts (keywords) and were fully aligned with the research objectives. Articles with strong adherence contained at least three central concepts and demonstrated coherence with the study's aims, while those with medium adherence covered at least two central concepts and aligned with the research focus. No articles were classified with weak adherence, and articles with no adherence were excluded if they lacked focus on the study's scope and objectives, even if they discussed drones.

2.4 Data Collection Process

The data collection process involved conducting searches across seven pre-defined databases using four proposed keyword combinations. These databases were selected because they are well-known and provided a higher number of studies aligned with the objectives of the systematic review. After each search, the retrieved data were imported and stored in the EndNote software for organization and subsequent analysis.

2.5 Quality Assessment of Studies

The quality of the methodologies employed in the studies included in the review was assessed based on the guidelines of the Transparent Reporting of Evaluations with Nonrandomized Designs (TREND), as described by Des Jarlais et al. (2004). This tool was chosen due to its relevance in ensuring transparency in the evaluation of studies with nonrandomized designs, such as quasi-experimental and observational studies, which are often utilized in contexts where randomized clinical trials are unfeasible or unethical (Vallvé, C, 2005). The TREND statement provides a structured checklist to evaluate aspects such as detailed descriptions of interventions, theoretical foundations, treatment allocation, consideration of confounding variables, and the overall methodological robustness (Des Jarlais et al., 2004).

The use of the TREND guidelines is also justified by the need to ensure that the results of the studies are accurate and consistent, making it easier to compare findings across studies in meta-analyses and systematic reviews. The evaluation looked at important aspects, such as how clearly the sample selection was explained, how treatments were assigned, how potential factors that could affect the results were considered, whether the results could be applied to other situations, and how strong the overall study design was. By following these steps, the studies were carefully analyzed for their reliability and accuracy. The results of this evaluation are shown in Table 1.

Table 1: Assessment of Study Quality Using the TREND Guideline.

Section/Topic	Study	Study	Study	Study	Study	Study	Study	Study	Study	Study	Study	Study	Study
	Awad et at., 2021 (Stanton, 2020)	Awad et at., 2021 (Vodafone, 2019)	Awad et at., 2021 (Hii et al., 2019)	Awad et at., 2021 (Ackerman and Koziol, 2019)	Awad et at., 2021 (Cheskes et al., 2020)	Awad et at., 2021 (Suas News, 2014)	Ayamga et at., 2021 (Sanfridsson et al., 2019)	Banik et al., 2023 (Adwibowo, 2021)	Banik et al., 2023 (Nur et al., 2020)	Braun et al., 2019 (DHL, 2018)	Braun et al., 2019 (Howell et al., 2015)	Euchi, 2021 (Amukele et al., 2017a)	Euchi, 2021 (Claesson et al., 2017)
	Reported?	Reported?	Reported?	Reported?	Reported?	Reported?	Reported?	Reported?	Reported?	Reported?	Reported?	Reported?	Reported?
Title and Abstract	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES	YES	YES
Background	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES	YES	YES
Participants	NO	NO	NO	YES	YES	NO	YES	NO	NO	NO	NO	YES	YES
Interventions	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Objectives	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES	YES	YES
Outcomes	NO	NO	YES	YES	YES	NO	YES	YES	YES	NO	YES	YES	YES
Sample Size	NO	NO	NO	NO	YES	NO	NO	NO	YES	NO	NO	YES	YES
Assignment Method	NO	NO	YES	YES	YES	YES	YES	YES	YES	NO	YES	YES	YES
Blinding (masking)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Unit of Analysis	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Statistical Methods	NO	NO	YES	NO	YES	NO	YES	YES	YES	NO	NO	YES	YES
Participant flow	NO	NO	YES	NO	YES	NO	YES	NA	NA	NO	NO	YES	YES
Recruitment	NO	NO	NA	NA	YES	NO	YES	NO	NO	NO	NO	NO	YES
Baseline Data	NO	NO	NA	NA	NA	NA	YES	NA	NA	NO	NO	YES	NO
Baseline equivalence	NO	NO	NA	NA	NA	NA	YES	NA	NA	NO	NO	NO	NO
Numbers analyzed	NO	NO	YES	YES	YES	NO	YES	NA	NA	NO	NO	YES	YES
Outcomes and estimation	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Ancillary analyses	NO	NO	NO	NO	NO	NO	YES	NO	YES	NO	NO	NO	NO
Adverse events	NO	NO	YES	NO	YES	NO	NO	NO	NO	NO	NO	YES	YES
Interpretation	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Generalizability	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Overall Evidence	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

Section/Topic	Study	Study	Study	Study	Study	Study	Study	Study	Study	Study	Study	Study	Study
	Fakhruldd in et al., 2019	Fakhruldd in et al., 2019 (Claesson et al., 2016)	Flemons et al., 2022	Grote et al., 2024	Mohd Daud et al., 2022 (Yakushiji et al., 2020)	Naor et al., 2024	Poljak, 2020 (Mesar et al., 2018)	Poljak, 2020 (Scalea et al., 2018)	Sanz-Martos, 2022 (Jain et al., 2018)	Scott, J and Scott, C, 2018	Shao et al., 2022	Sharma, S. and Sharma, H, 2024 (The Times of India, 2023)	Stierlin et al., 2024 (Amukele et al., 2017b)
	Reported?	Reported?	Reported?	Reported?	Reported?	Reported?	Reported?	Reported?	Reported?	Reported?	Reported?	Reported?	Reported?
Title and Abstract	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES
Background	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Participants	YES	NO	YES	YES	YES	YES	YES	YES	YES	NO	YES	NO	YES
Interventions	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Objectives	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES
Outcomes	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES
Sample Size	YES	YES	YES	YES	YES	YES	YES	YES	NA	NO	NO	NO	YES
Assignment Method	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES
Blinding (masking)	NO	NO	NO	NO	NO	NO	NO	NO	YES	NO	NO	NO	NO
Unit of Analysis	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Statistical Methods	YES	YES	NO	YES	NO	YES	NO	YES	YES	NO	YES	NO	YES
Participant flow	YES	NO	YES	YES	YES	YES	YES	YES	YES	NO	YES	NO	YES
Recruitment	NO	NO	YES	NO	NO	NO	NO	NO	YES	NO	NO	NO	NO
Baseline Data	YES	NA	NO	NO	NA	NA	NO	YES	YES	NO	NO	NO	YES
Baseline equivalence	NO	NA	NO	NO	NA	NA	NO	NO	YES	NO	NO	NO	YES
Numbers analyzed	YES	NA	NO	YES	YES	YES	NO	YES	YES	NO	NO	NO	YES
Outcomes and estimation	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Ancillary analyses	NO	NO	NO	NO	NO	NO	YES	NO	YES	NO	YES	NO	YES
Adverse events	NO	NO	YES	NO	YES	NO	YES	NO	YES	NO	NO	NO	NO
Interpretation	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES	YES	YES	YES
Generalizability	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES	YES	YES	YES
Overall Evidence	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES	YES	YES	YES

3 RESULTS

3.1 Study Selection and Characteristics

The Fig. 1 presents the PRISMA flow diagram used to illustrate the systematic selection process for this review on medical supply operations using Class 1 UAVs in healthcare and military contexts. The process includes four phases: Identification, Screening, Eligibility, and Inclusion. Studies were identified through databases and manual searches, followed by removing duplicates and excluding those misaligned with research objectives or limited to indexes. In the eligibility phase, studies were rigorously assessed, excluding those with superficial approaches or irrelevant technologies. Ultimately, 97 studies were included, ensuring a comprehensive synthesis aligned with the review's objectives.

Following the systematic review using the PRISMA method, a detailed analysis was conducted on studies specifically addressing the characteristics of drones used in medical supply operations in jungle, forest, or remote environments. This process resulted in the identification of 26 studies, 6 of which directly mentioned the characteristics of the drones. Additionally, the snowballing method was applied to explore references and citations of the included studies, leading to the identification of 20 additional articles categorized as the "Corpus Static." This corpus represents a fixed dataset derived from reference analysis, comprising studies that specifically addressed Class 1 UAV characteristics within their scope of research (Wohlin, 2014).

3.2 Risk of Bias in Studies

Table 1 presents the risk of bias analysis for the 26 studies evaluated using the TREND method. The 5 studies marked in red exhibited low methodological quality and a high risk of bias.

Some items from the TREND checklist are marked as "not applicable (NA)" in certain studies because these criteria may not align with the design or scope of the evaluated research. For instance, most studies do not directly involve human participants but focus on logistical interventions or operational analyses, which eliminates the need for descriptions of demographic characteristics or blinding strategies. Similarly, studies that examine technologies or technical processes without traditional comparative variables may not require advanced statistical methods or causality analyses, thus justifying their exclusion in specific evaluations.

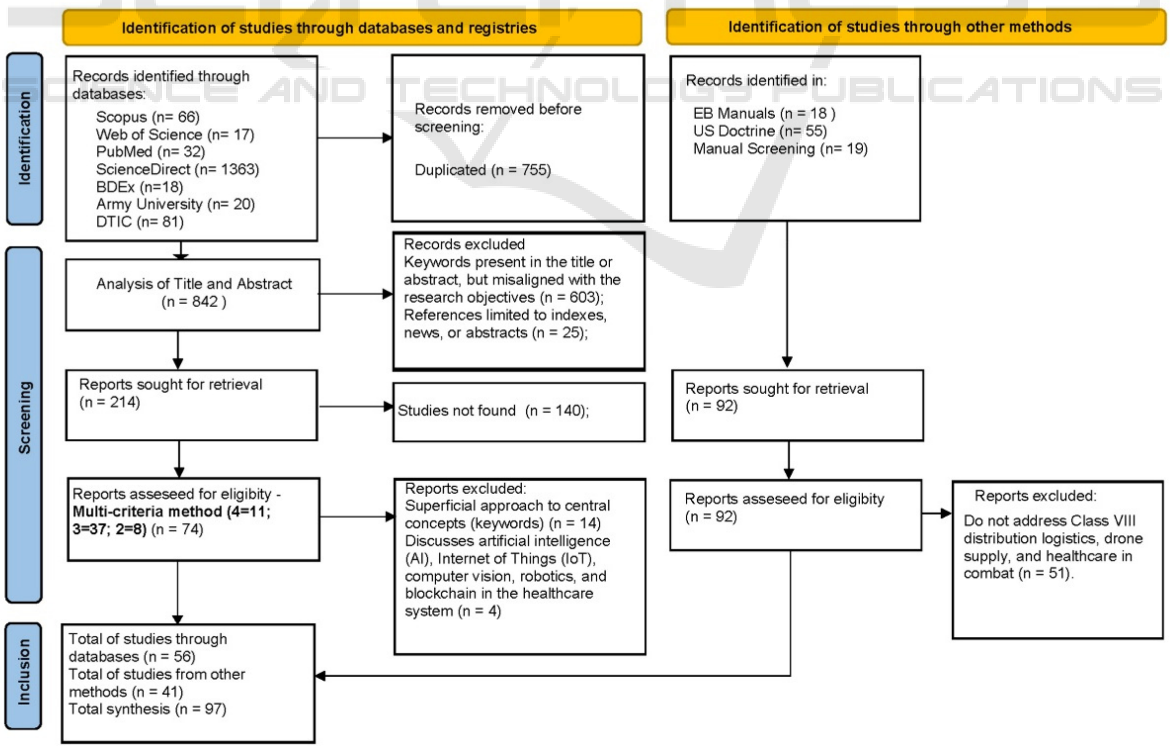

Figure 1: PRISMA flow diagram illustrating the selection process.

3.3 Results of Individual Studies

The Table 2 provides an overview of studies analysing the application of drones in health logistics, highlighting their capabilities and operational contexts. It categorizes drones based on their developers, models, configurations, and classification according to NATO UAS guidelines (NATO, 2019), detailing the operational environments (urban, rural, remote, or controlled) and delivery methods, such as ground landing, winch systems, or parachutes. Additionally, it specifies the types of medical materials transported, ranging from insulin and vaccines to emergency medical equipment and refrigerated medical cargo.

The technical performance indicators and load capacities of drones used in health logistics are presented in Table 3, which complements the analysis provided in Table 2. It details information such as flight endurance, operational range (per single battery charge), maximum speed, altitude capabilities, and load capacity for each model.

Table 2: General Characteristics of Studies on the Use of Drones in Health Logistics.

Study (Corpus Static)	Drone Information (Developers, Model, Configuration)	Country (Operation Environmental)	Category (Nato UAS Classification)	Delivery method	Type of Material Transported
Awad et at., 2021 (Hii et al., 2019)	DJI, Mavic Air, Multi-rotor-quadcopter	United Kingdom (Urban)	Mini (<15 kg)	Ground landing	Medications (Insulin)
Awad et at., 2021 (Stanton, 2020)	Volansi, VOLY C10, Multi-rotor - quadcopter	USA (Not provided)	Not provided	Ground landing	Vaccines
Awad et at., 2021 (Vodafone, 2019)	NUI Galway, Wingcopter 178 Heavy Lift, Hybrid	Irlanda (Rural and Remote Areas)	Not provided	Ground landing	Medications (for diabetes)
Awad et at., 2021 (Ackerman and Koziol, 2019)	Zipline, Not provided, Fixed Wing	Rwanda (Mountainous, Rural and Remote Areas)	Small (>15 kg)	Parachute	Blood products
Awad et at., 2021 (Cheskes et al., 2020)	Drone Delivery Canadian, Sparrow X1000, Multi-rotor - octocopter	Canadian (Rural and Remote Areas)	Not provided	Ground landing	Automated External Defibrillators (AED)
Awad et at., 2021 (Cheskes et al., 2020)	Indro Robotics, InDro M210C, Multi-rotor - quadcopter	Canadian (Rural and Remote Areas)	Not provided	Ground landing	Automated External Defibrillators (AED)
Awad et at., 2021 (Suas News, 2014)	TU Delft, Not provided, Multi-rotor - octocopter	Netherlands (Urban)	Mini (<15 kg)	Ground landing	Automated External Defibrillators (AED)
Ayamga et at., 2021 (Sanfridsson et al., 2019)	DJI, Inspire 1, Multi-rotor - quadcopter	Sweden (Urban and Rural)	Mini (<15 kg)	Ground landing	Automated External Defibrillators (AED)
Banik et al., 2023 (Adwibowo, 2021)	Not provided, Not provided, Multi-rotor - quadcopter	Indonesia (Mountainous and Rural)	Small (>15 kg)	Ground landing	Vaccines (COVID vaccine)
Banik et al., 2023 (Nur et al., 2020)	Not provided, "Drone B", Multi-rotor - quadcopter	Not provided (Urban and Rural)	Mini (<15 kg)	Ground landing	Not provided
Braun et al., 2019 (DHL, 2018)	DHL, Parcelcopter 4.0, Hybrid	Tanzania (Remote Areas and Rural)	Not provided	Ground landing	Medications and Medical supplies.
Braun et al., 2019 (Howell et al., 2015)	Flirtey Corporation, Flirtey F2.4, Multi-rotor - hexacopter	USA (Urban and Rural)	Mini (<15 kg)	Dropped by rope	Medications and Medical supplies.
Euchi, 2021 (Amukele et al., 2017a)	DJI - Johns Hopkins Hospital, S900, Multi-rotor - hexacopter	USA (Controlled Environment)	Mini (<15 kg)	Ground landing	Blood products
Euchi, 2021 (Claesson et al., 2017)	Swedish Transportation Agency, Not provided, Multi-rotor - Octocopter	Sweden (Urban and Rural)	Mini (<15 kg)	Ground landing	Automated External Defibrillators (AED)
Fakhrulddin et al., 2019	DJI, Phantom 3 Professional, Multi-rotor - quadcopter	Iraq (Urban)	Mini (<15 kg)	Ground landing	Medical supplies (First aid kit)
Fakhrulddin et al., 2019 (Claesson et al., 2016)	HEIGHT TECH GmbH & Co. KG, Not provided, Multi-rotor - Octocopter	Sweden (Urban and Rural)	Not provided	Parachute, Cargo drop and Ground landing	Automated External Defibrillators (AED)
Flemons et al., 2022	DJI, Mavic Enterprise, Multi-rotor - quadcopter	Canadian (Rural and Remote Areas)	Mini (<15 kg)	Ground landing, Winch system and Cargo drop	Medical supplies (Medical devices, Personal Protective Equipment (PPE), water bottles and blankets)
Flemons et al., 2022	DJI, Matrice 300, Multi-rotor - quadcopter	Canadian (Rural and Remote Areas)	Mini (<15 kg)	Ground landing or Winch system	Medical supplies (Medical devices, Personal Protective Equipment (PPE), water bottles and blankets)
Flemons et al., 2022	DJI, Matrice 600, Multi-rotor - hexacopter	Canadian (Rural and Remote Areas)	Mini (<15 kg)	Ground landing or Winch system	Medical supplies (Medical devices, Personal Protective Equipment (PPE), water bottles and blankets)
Grote et al., 2024	Mugin UAVe Operation Environment, Mugin-5 Pro, Hybrid	United Kingdom (Urban and Rural)	Not provided	Ground landing or Winch system	Medical samples (pathology samples)
Mohd Daud et al., 2022 (Yakushiji et al., 2020)	Mazex Co. Ltd., M1000, Multi-rotor - quadcopter	Japan (Urban and Remote Areas)	Small (>15 kg)	Winch system	Medications, Medical supplies and Automated External Defibrillators (AED)
Naor et al., 2024	Gadfin, Spirit-One, Hybrid	Israel (Urban and Remote Areas)	Small (>15 kg)	Ground landing	Medications, Medical supplies, Blood products and human organ
Naor et al., 2024	Gadfin, Spirit-HD, Hybrid	Israel (Urban and Remote Areas)	Small (>15 kg)	Ground landing	Medications, Medical supplies, Blood products and human organ
Poljak, 2020 (Mesar et al., 2018)	Pulse Aerospace, Vapor 55, Rotary-wing	USA (Remote Areas)	Small (>15 kg)	Ground landing	Medical supplies (tourniquets, bandages, pain relievers) and Blood products (tourniquets, bandages, pain relievers)
Poljak, 2020 (Scalea et al., 2018)	DJI - Universidade de Maryland, M600, Multi-rotor - hexacopter	USA (Urban and Rural)	Mini (<15 kg)	Ground landing	Human organs
Sanz-Martos, 2022 (Jain et al., 2018)	Yuneec International, Yuneec Tornado H920, Multi-rotor - hexacopter	Canadian (Controlled Environment)	Mini (<15 kg)	Not provided	Medical supplies (Victim triage equipment and sensors)
Scott, J and Scott, C, 2018	Flirtey, Not provided, Multi-rotor - quadcopter	USA (Remote Areas)	Mini (<15 kg)	Winch system	Medications

Scott, J and Scott, C, 2018	Matternet - UNICEF and Doctors without Borders, Not provided, Multi-rotor - quadcopter	Haiti, Dominican Republic, Papua New Guinea and Switzerland (Urban and Rural)	Mini (<15 kg)	Ground landing	Medications and Blood products
Shao et al., 2022	Researchers from Chang Jung Christian University e da Chunghwa Telecom Co, Ltd., Not provided, Multi-rotor - hexacopter	Taiwan (Mountainous and Rural)	Mini (<15 kg)	Not provided	Medications
Sharma, S. and Sharma, H, 2024 (The Times of India, 2023)	AIIMS-Rishikesh, AQUILA X2, Hybrid	India (Mountainous and Remote Areas)	Mini (<15 kg)	Ground landing	Medications (Anti-tuberculosis Drugs)
Stierlin et al., 2024 (Amukele et al., 2017b)	Latitude Engineering - Johns Hopkins University School of Medicine e a Mayo Clinic., HQ-40, Hybrid	USA (Controlled Environment)	Mini (<15 kg)	Ground landing	Medical samples

Among the analysed studies, only six provided data on ambient temperature during drone flights (Amukele et al., 2017a, 2017b; Flemons et al., 2022; Hii et al., 2019; Sanfridsson et al., 2019; Scalea et al., 2018; Yakushiji et al., 2020). The recorded temperatures varied significantly, ranging from negative values, such as -1°C in tests conducted by Hii et al. (2019), to a maximum of 36.2°C reported by Mohd Daud et al. (2022). Wind speed was mentioned in five studies (Flemons et al., 2022; Hii et al., 2019; Scalea et al., 2018; Shao et al., 2022; Yakushiji et al., 2020), while relative humidity was documented in only two cases (Amukele et al., 2017; Hii et al., 2019). Atmospheric pressure data were even scarcer, being recorded solely by Hii et al. (2019), who reported values between 1021 and 1022 mbar during operations.

Among the 26 studies analyzed (Table 2), 24 (92.3%) reported the use of a single delivery method per drone, while 2 studies (7.7%) described the employment of multiple methods. In total, 31 drones were reported, with ground landing being the predominant method, observed in 64.5% (20 drones). Additional methods included the winch system, utilized in 6.5% (2 drones), and parachute delivery, observed in 3.2% (1 drone). Combinations of methods were employed in 9.7% (3 drones), such as ground landing or winch system, while more complex approaches, like parachute delivery, ground landing, and cargo drop, were implemented in 6.5% (2 drones). Lastly, 6.5% (2 drones) did not provide sufficient information about the delivery method utilized.

Regarding operational environments, urban and rural areas were the most frequently mentioned, representing 30.8% (8 studies). Next, rural and remote areas were observed in 11.5% (3 studies). The mountainous environment was identified in various combinations, including mountainous and remote areas, mountainous and rural areas, or mountainous, rural, and remote areas, totaling 15.4% (4 studies). Exclusively urban and controlled environments were equally reported, with 11.5% (3 studies) each. Additionally, urban and remote areas were mentioned in 7.7% (2 studies), and exclusively remote environments were reported in 7.7% (2 studies). Finally, 1 study (3.8%) did not specify the operational environment.

Among the drones analyzed, the Mini (<15 kg) category was the most frequently reported, representing 58.1% (18 drones). This was followed by the Small (>15 kg) category, accounting for 19.4% (6 drones). Additionally, 22.6% (7 drones) were classified as Not provided, indicating a lack of specific weight-based categorization for a significant portion of the sample.

In terms of materials transported, the most frequently mentioned items were Automated External Defibrillators (AEDs) and Medications, each reported in 5 studies (19.2%). Medical Supplies were mentioned in 4 studies (15.4%), while Vaccines, Blood Products, and Medical Samples appeared in 2 studies each (7.7%). Unique cases included Human Organs in 1 study (3.8%), and combinations such as Medications and Medical Supplies in 2 studies (7.7%) and Medications, Medical Supplies, Blood Products, and Human Organs in 1 study (3.8%). Lastly, 1 study (3.8%) did not specify the transported materials.

According to Table 3, the results indicated that the flight endurance had a mean of 33.07 minutes and a standard deviation of 36.36 minutes. The drones' range showed a mean of 68.16 km, with a standard deviation of 101.19 km. The average maximum speed was 75.88 km/h, with a standard deviation of 39.61 km/h. For operational altitude, the mean found was 871.45 m, with a standard deviation of 1174.15 m. Finally, the cargo capacity recorded a mean of 5.01 kg and a standard deviation of 4.24 kg.

Table 3: Drone Flight Performance Metrics and Cargo Capacity.

Study (Corpus Static)	Drone Information (Developers, Model, Configuration)	Flight Endurance (min)	Range (for a single battery charge) (km)	Maximal Speed (km/h)	Altitude (m)	Cargo capacity (Kg)
Awad et at., 2021 (Hii et al., 2019)	DJI, Mavic Air, Multi-rotor-quadcopter	7 to 11	0.63 and 0.99	5.4	10	0.194
Awad et at., 2021 (Stanton, 2020)	Volansi, VOLY C10, Multi-rotor - quadcopter	60	80.46	Not provided	Not provided	4.53
Awad et at., 2021 (Vodafone, 2019)	NUI Galway, Wingcopter 178 Heavy Lift, Hybrid	32	43.3	Not provided	Not provided	Not provided
Awad et at., 2021 (Ackerman and Koziol, 2019)	Zipline, Not provided, Fixed Wing	45	160	128	400 to 500	1.75
Awad et at., 2021 (Cheskes et al., 2020)	Drone Delivery Canadian, Sparrow X1000, Multi-rotor - octocopter	25	25	80	900	4.5
Awad et at., 2021 (Cheskes et al., 2020)	Indro Robotics, InDro M210C, Multi-rotor - quadcopter	25	25	55	1000	4
Awad et at., 2021 (Suas News, 2014)	TU Delft, Not provided, Multi-rotor - octocopter	Not provided	100	Not provided	Not provided	4
Ayamga et at., 2021 (Sanfridsson et al., 2019)	DJI, Inspire 1, Multi-rotor - quadcopter	15 to 20	Not provided	Not provided	Not provided	2
Banik et al., 2023 (Adwibowo, 2021)	Not provided, Not provided, Multi-rotor - quadcopter	16 to 50	Not provided	54 to 80	Not provided	3 to 20
Banik et al., 2023 (Nur et al., 2020)	Not provided, "Drone B", Multi-rotor - quadcopter	15	12	Not provided	Not provided	2
Braun et al., 2019 (DHL, 2018)	DHL, Parcelcopter 4.0, Hybrid	40	60	140	Not provided	4
Braun et al., 2019 (Howell et al., 2015)	Flirtey Corporation, Flirtey F2.4, Multi-rotor - hexacopter	10 to 15	1.3	Not provided	152	2.3
Euchi, 2021 (Amukele et al., 2017a)	DJI - Johns Hopkins Hospital, S900, Multi-rotor - hexacopter	26.5	Not provided	36 to 54	100	1,9
Euchi, 2021 (Claesson et al., 2017)	Swedish Transportation Agency, Not provided, Multi-rotor - Octocopter	Not provided	Not provided	75	Not provided	Not provided
Fakhrulddin et al., 2019	DJI, Phantom 3 Professional, Multi-rotor - quadcopter	3.75	Not provided	Not provided	Not provided	Not provided
Fakhrulddin et al., 2019 (Claesson et al., 2016)	HEIGHT TECH GmbH & Co. KG, Not provided, Multi-rotor - Octocopter	8.5	10	70	Not provided	Not provided
Flemons et al., 2022	DJI, Mavic Enterprise, Multi-rotor - quadcopter	< 30	8	Not provided	15 and 40 m	< 1
Flemons et al., 2022	DJI, Matrice 300, Multi-rotor - quadcopter	30 to 45	15	Not provided	15 and 40 m	1 to 8
Flemons et al., 2022	DJI, Matrice 600, Multi-rotor - hexacopter	30 to 45	8	Not provided	15 and 40 m	1 to 8
Grote et al., 2024	Mugin UAVe Operation Environment, Mugin-5 Pro, Hybrid	Not provided	75	65	Not provided	5
Mohd Daud et al., 2022 (Yakushiji et al., 2020)	Mazex Co. Ltd., M1000, Multi-rotor - quadcopter	Not provided	Not provided	58	35 to 1100	17
Naor et al., 2024	Gadfin, Spirit-One, Hybrid	Not provided	250	100	Not provided	5
Naor et al., 2024	Gadfin, Spirit-HD, Hybrid	Not provided	400	100	Not provided	15
Poljak, 2020 (Mesar et al., 2018)	Pulse Aerospace, Vapor 55, Rotary-wing	20.77	12.27	34.03	Not provided	4.5
Poljak, 2020 (Scalea et al., 2018)	DJI - Universidade de Maryland, M600, Multi-rotor - hexacopter	Not provided	4 to 5	67.6	30.5 a 61	9.1
Sanz-Martos, 2022 (Jain et al., 2018)	Yuneec International, Yuneec Tornado H920, Multi-rotor - hexacopter	24	0.7	Not provided	4000	Not provided
Scott, J and Scott, C, 2018	Flirtey, Not provided, Multi-rotor - quadcopter	Not provided	32	Not provided	Not provided	2
Scott, J and Scott, C, 2018	Matternet - UNICEF and Doctors without Borders, Not provided, Multi-rotor - quadcopter	Not provided	10	40	Not provided	2
Shao et al., 2022	Researchers from Chang Jung Christian University e da Chunghwa Telecom Co, Ltd., Not provided, Multi-rotor - hexacopter	12	5.35	Not provided	1245	1
Sharma, S. and Sharma, H, 2024 (The Times of India, 2023)	AIIMS-Rishikesh, AQUILA X2, Hybrid	30	40	Not provided	Not provided	2
Stierlin et al., 2024 (Amukele et al., 2017b)	Latitude Engineering - Johns Hopkins University School of Medicine e a Mayo Clinic., HQ-40, Hybrid	180	258	160	290	4

4 DISCUSSIONS

4.1 Evaluating UAVs in Healthcare: Insights from a Systematic Review

The findings of this systematic review highlight the operational versatility of Class 1 UAVs in healthcare logistics, particularly in challenging environments such as jungles, forests, and remote areas. Based on the analysis of 26 studies, key metrics such as endurance, range, speed, and cargo capacity were identified as critical for selecting suitable drone models for medical supply missions. The inclusion of the snowballing method allowed the incorporation of additional relevant studies (Corpus Static), enriching the dataset with unique insights and reinforcing the robustness of the methodology when combined with PRISMA.

However, as noted in section 3.2 (Risk of Bias), five of the 26 studies showed low methodological quality and high risk of bias (DHL, 2018; Stanton, 2020; Suas News, 2014; The Times of India, 2023; Vodafone, 2019). These sources failed to meet several TREND criteria—such as clarity on sample size, statistical methods, outcome reporting, and participant flow—mainly because they are not peer-reviewed papers, but descriptive reports from websites. Although useful for contextual information, they lack scientific rigor and are limited in supporting data-driven decisions.

Overall, the RSL confirms the feasibility of integrating drone-based medical supply delivery into the COMBATER simulation algorithm. The performance data compiled in Tables 2 and 3 provide real-world parameters that can be used to model realistic logistic scenarios within the simulator.

4.2 Identified Methodological Limitations

This study highlighted several methodological limitations that may influence the interpretation of the findings and their applicability to the COMBATER simulation software. One of the primary challenges was the heterogeneity of the analysed studies, as the experiments were conducted in diverse geographic locations and with different types of drones and equipment. This variability complicates the generalization of results, as the performance of drones may be context-specific, influenced by unique environmental and operational factors.

Another significant limitation was the lack of reported meteorological conditions in the studies. Weather factors, such as wind speed, temperature, humidity, and precipitation, are known to significantly affect drone performance, particularly in terms of range, endurance, and operational altitude. Without this critical information, it becomes difficult to comprehensively evaluate how drones operate under various environmental conditions. This gap limits the ability to model drone performance realistically, especially in scenarios where adverse weather conditions are a likely operational constraint.

Finally, the diversity in reporting standards among the studies analysed also presented challenges. The absence of consistent metrics, such as standardized measures for flight endurance or payload performance, hindered direct comparisons and increased the reliance on averages that may not fully capture the nuances of specific drone categories. Addressing these methodological gaps in future research will be essential to refine the parameters for integration into COMBATER and ensure that simulations are grounded in robust and comprehensive data.

4.3 Delivery Methods and Drone Categories in Healthcare Logistics

The analysis of delivery methods and operational environments highlights an intrinsic relationship between terrain conditions and the choice of technology employed. The predominance of ground landing (64.5%) in urban and rural areas reflects its practicality and reliability in scenarios where terrain access is relatively straightforward. Conversely, more specific methods, such as winch (6.5%) and parachute (3.2%), are used in situations that require adapted solutions for inaccessible terrains or those that minimize ground interaction, such as in remote or mountainous regions.

Technical flexibility is demonstrated by combined methods, such as ground landing and winch (9.7%), which show potential for serving areas with mixed characteristics, enhancing operational efficiency in hard-to-reach locations. However, the lack of information on delivery methods for 6.5% of the drones, points to methodological gaps that could compromise the practical applicability of the results. These findings underscore the need to align the choice of delivery method with the specificities of the operational environment, maximizing logistical efficiency and the effectiveness of operations in challenging contexts.

The relationship between the drone category and the type of material transported shows that Mini drones (<15 kg), representing 58.1% of the analysed drones (18 drones), are better suited for lightweight and low-volume items, such as medications (19.2%) and medical supplies (15.4%). This preference is associated with their agility, lower operational costs, and simplicity of operation, making them ideal for short distances. On the other hand, small drones (>15 kg), which account for 19.4% of the sample (6 drones), are more appropriate for more complex materials, such as blood products (7.7%), vaccines (7.7%), and human organs (3.8%). These items require greater payload capacity and transport precision and are often linked to operations in remote or mountainous areas. Additionally, combinations of materials, such as medications, medical supplies, blood products, and organs (7.7%), highlight the need for more robust drones in the small category to meet diverse logistical requirements.

4.4 Recommendations for Future Applications in COMBATER

As part of the proposed integration of drone data into the COMBATER simulation software, and in alignment with the Doctrinal and Operational Constraints of the Brazilian Army (Brasil, 2024), it is recommended that Mini drones (<15 kg) be employed at the unit level, with operational responsibility assigned to the Command and Support Company. In contrast, small drones (>15 kg) should be allocated at the brigade level, with the Logistics Battalion responsible for their operation.

The analysis of Tables 2 and 3 enabled the identification of specific parameters to be incorporated into the COMBATER simulation software to ensure accurate modeling. For Mini drones (<15 kg), the predominant configuration is the multi-rotor (quadcopter) type, used by 44% (8 out of 18) of the drones analyzed. Brazilian military doctrine establishes a maximum range of 15 km line of sight (LOS) and an operational altitude of up to 140 meters (Brasil, 2024). Additional parameters include a flight endurance of 26.02 minutes, a maximum speed of 73.93 km/h, and an average cargo capacity of 3.63 kg. Recommended materials for transport in this category include medications and medical supplies, due to their lightweight and essential role in unit-level logistical support.

For Small drones (>15 kg), a hybrid configuration is recommended due to its superior flight endurance, as evidenced in studies such as Amukele et al. (2017b). Suggested parameters for this category, consistent with military doctrine, include a range of up to 50 km LOS and an operational altitude of up to 900 meters (Brasil, 2024). The data analyzed indicate an average flight endurance of 61.5 minutes, a maximum speed of 100 km/h, and an average cargo capacity of 5 kg, based on the mean values across all reviewed studies. In this category, recommended cargo includes blood products, vaccines, and human organs, which are heavier and more complex, requiring more robust drones with higher operational capacity.

The incorporation of UAVs into the COMBATER simulator involves more than the mere inclusion of technical parameters such as speed, range, or payload. COMBATER operates as a constructive simulator, based on doctrinal logic and AI-generated behaviors rather than real-time physical replication. As described by Almeida et al. (2023), simulated units in COMBATER act autonomously according to predefined behavior trees and doctrinal rules. Therefore, representing UAV capabilities, such as reconnaissance, aerial delivery, or coordination with other elements, requires the development of specific models within the simulator's internal logic. Without this modeling, the presence of UAVs would be merely symbolic, with no meaningful impact on simulation outcomes. In this context, the parameters identified in the present study constitute a necessary preliminary step toward adapting COMBATER's internal structure to enable more realistic representations of UAV employment in future simulation environments.

5 CONCLUSIONS

This study identified and analysed key operational and doctrinal parameters related to the use of Class 1 Unmanned Aerial Vehicles (UAVs) in military logistics, with a focus on environments such as jungle operations. The systematic literature review, conducted according to PRISMA guidelines, and application of the TREND checklist enabled the selection of relevant studies and extraction of standardized technical data. These parameters form the basis for modelling UAVs in simulation environments.

Among the findings, mini drones (<15 kg) were found suitable for unit-level operations, while small drones (>15 kg) showed potential for brigade-level missions. Suggested applications included the transport of critical materials such as medications, vaccines, and blood products. By identifying these parameters, the study contributes to future adjustments in the COMBATER simulation platform. Rather than modifying the simulator directly, the objective was to provide inputs that support doctrinal modeling and realistic representation of UAV capabilities. The integration of such data is expected to enhance the system's ability to simulate logistical operations and decision-making more accurately.

However, the study faced limitations, such as the heterogeneity of the analyzed studies, the absence of detailed meteorological data, and inconsistent reporting standards. These gaps hinder a comprehensive understanding of UAV performance under diverse conditions and highlight the need for further research. In this context, constructive simulation, as implemented in COMBATER, offers a valuable tool to explore scenarios that are difficult to replicate in real-world experiments.

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