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SUPPLYING FOOD TO SMALL GROUPS OF SOLDIERS USING UNMANNED AERIAL VEHICLES

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Abstract.
The organisation of food supply during military operations presents a significant challenge, as every action taken to ensure soldiers' food security must be precisely analysed and planned. In particularly difficult conditions, when the tactical situation requires small groups of soldiers to operate away from their parent units, alternative food supply methods should be considered. The research niche of this article concerns the insufficient number of studies that propose, develop or evaluate alternative solutions for supplying dispersed, small groups of troops with food in conditions where conventional supply lines are disrupted or pose excessive risk. The purpose of the article is to examine the possibilities of supplying small groups of soldiers with food using unmanned aerial vehicles (UAVs). The methodology included literature analysis, synthesis, induction, and deduction, as well as experimental tests involving payload transport and aerial drops using a commercially available UAV. The results confirmed the hypothesis that UAVs can deliver food to units at designated locations, at a specified time and in specified quantities, while minimising the risk to human life. The findings indicate that food delivery via UAVs is technically feasible, operationally beneficial, and may enhance supply security in high-risk conditions. Drones can transport rations to soldiers, achieving high delivery accuracy at zero forward speed and noticeably reduced accuracy during forward flight. The conclusions highlight the need for further technological improvements, the adaptation of UAV platforms to military logistics requirements and advanced operator training. The study provides a basis for further research on UAV-supported military food supply.

Keywords:
soldiers; nutrition; food ration; supply; unmanned aerial vehicle

Introduction

The transport of food is one of the most crucial aspects of logistics, as it is essential for human survival and the proper functioning of the human body. The primary objective of food transport is to deliver goods in a condition that does not endanger the health or life of the consumer. This is governed by a range of legal regulations that apply to suppliers. Compliant food transportation prevents contamination, infection and damage to food products (Focker et al. 2022; Ryan 2017). When transport is carried out under typical conditions, adherence to these regulations is the key to successful food delivery. However, under exceptional circumstances such as armed conflicts, various challenges can arise, potentially hindering the effective delivery of food supplies to consumers (Jasiński and Wesołowski 2023).

Organising food supply during military operations is a challenging task, where each action aimed at ensuring soldiers' food security must be carefully analysed and planned. The process of delivering, preparing and distributing food to troops must be efficient to ensure that each soldier receives a nutritionally balanced ration that supports effective combat performance (Kler et al. 2022). The approach to food supply during combat depends on the tactical situation, as well as the climatic and terrain conditions that affect the operations. Soldiers can be supplied with food prepared from fresh ingredients, from wartime reserves, or rations made at food processing plants or field feeding points (FFPs). In particularly difficult conditions, when the tactical situation forces small groups of soldiers to operate away from their parent units, or when the enemy effectively disrupts supply and evacuation routes, alternative methods for feeding soldiers should be considered.

This publication aims to examine the possibilities of supplying food to small groups of soldiers using unmanned aerial vehicles (UAVs). To accomplish this, the following research question was formulated: can small groups of soldiers conducting independent operations be supplied with food using UAVs, and if so, how?

The research hypothesis of the study was formulated as follows: the use of unmanned aerial vehicles to supply small groups of soldiers will increase the safety of performing combat tasks while minimising the risk of loss of life and supplies, delivered to the planned location, at the planned time and in the planned quantity.

The subjects of the research are soldiers operating in small groups, operating away from their own logistical support. The study focuses on selected individual food rations and specific military, transport, and agricultural UAVs. The theoretical research methods applied include literature analysis, synthesis, induction and deduction. The article begins by outlining the research background, followed by a proposed solution for supplying food to small groups of soldiers on missions away from supply sources. The study then proceeds to evaluate the practical feasibility of utilising UAVs for food delivery, based on experimental methods and scientific observation, supplemented with computational techniques. The results demonstrate that UAVs can be successfully utilised to deliver food to troops in designated locations, timeframes and quantities, while minimising the risk to human life.

Literature review

In recent years, the production of unmanned aerial vehicles has experienced rapid global growth. This expansion is largely driven by the increasing demand for UAVs in various sectors, including military operations, logistics, healthcare, agriculture, geodesy and recreational activities (Ahmed et al. 2022; Mohsan et al. 2022). In the context of this study, it is particularly important to emphasise that increasingly advanced UAV designs enable their effective use in operations that require speed, precision and the ability to function in difficult terrain and weather conditions (Velusamy et al. 2022). UAVs have become crucial for military operations, not only for reconnaissance and combat missions but also for logistical support, making them an integral component of modern warfare (Jordan 2021).

A number of studies have explored UAVs, examining their potential, challenges, and technical aspects such as design, technologies, and innovative solutions (Telli et al. 2023; Islam et al. 2021). Research has also been conducted on drone communication and power supply (Jin et al. 2023), identifying issues related to energy availability and transmission power due to the drone's weight, along with environmental safety concerns (Laghari et al. 2022). Additionally, other studies have compared various models for food delivery services, including UAVs, combustion vehicles, and electric vehicles (BEVs) (Yowtak et al. 2020). These studies suggest that, in the long term, UAVs offer significant potential in the area of food delivery, particularly in terms of their environmental impact (Li et al. 2025; Chiang et al. 2019). Other research has shown the feasibility of using UAVs in combination with refrigerated ground vehicles (RGVs) to ensure the freshness of perishable food products during transport (Lee et al., 2022). The literature highlights the use of UAVs in military tactical operations, with a particular focus on battlefield reconnaissance and the potential to inflict damage on the enemy (Wang et al. 2020; Udeanu et al.,2016). Some authors emphasise the challenges associated with such applications (Criollo et al. 2024; Gargalakos 2021), including the psychological stress experienced by operators, primarily due to the nature of the mission (Saini et al. 2021; Wallace et al. 2020). Research has also been conducted on the use of UAVs in mountainous areas, where operational conditions require strong mobility and the ability to operate in isolated regions, demonstrating UAVs' potential to reduce casualties and increase safety in military operations (Szulc 2023). The commercial sector has also seen a rise in the use of UAVs for logistics and transportation (Eskandaripour and Boldsaikhan 2023; Garg et al. 2023). Companies such as Amazon and UPS have embraced UAVs for delivery services. Amazon's Prime Air service uses drones for the express delivery of goods purchased online (Engadget 2023). Meanwhile, UPS, specifically its subsidiary UPS Flight Forward (UPSFF), has launched commercial air operations using drones for fast transport of medical supplies, including COVID-19 vaccines, especially during the pandemic (Sobczuk and Borucka 2024; UPS 2021).

Considering the potential demonstrated by UAVs across multiple industries, as well as the challenges and limitations identified, it would be valuable to explore the feasibility of using UAVs to deliver food supplies to small groups of soldiers in remote combat zones. Such an analysis is especially relevant in light of the current geopolitical situation, including the Russian-Ukrainian conflict and the migration crisis on Poland's eastern border. In the face of these threats, UAVs are a promising solution for supplying food to soldiers, contributing to the maintenance of national security and military readiness. Therefore, investigating the feasibility of using UAVs to deliver food to soldiers in operational zones is of critical importance.

Research background

In the face of contemporary security threats, one of the most critical challenges for military food services is the delivery of food supplies. In direct combat zones, this process involves the retrieval of supplies from designated sources, their transportation and delivery to the recipients (Ministry of National Defence, 2020). The events unfolding at Poland's eastern border, particularly the Russian-Ukrainian conflict and the migration crisis at the Belarus border, which is also the eastern border of the EU, highlight the need to reassess existing military logistics solutions developed and refined during training. Ongoing clashes with Russian forces and the tense situation in the conflict zone result in an unstable and irregular supply of fresh food. It is worth noting that while during the armed conflict in Ukraine, food distribution points have been established to provide meals for larger groups of soldiers, these points pose significant risks to soldiers' safety:

- Concentrations of troops and supply convoys become easy targets for air strikes, as they can be quickly detected and targeted, further complicating food deliveries to the frontline;
- The use of fresh food at such points is challenging, as it must be transported and stored under non-standard conditions, increasing the risk of spoilage;
- The necessity of using open fires to prepare hot meals poses a hazard on the modern battlefield, where the enemy has advanced reconnaissance systems capable of detecting and eliminating heat sources via thermal imaging.

Considering the instability and unpredictability of the current geopolitical landscape, it is crucial to implement proactive measures to support potential future combat operations. Of particular importance is the search for alternative food supply methods that will ensure timely delivery of high-quality sustenance to soldiers.

Proposed solution for delivering food to small groups of soldiers operating away from supply sources

Modern military operations require the Polish Armed Forces to conduct missions in complex and inaccessible environments, where conventional supply chains may be inefficient or unfeasible (Kalbarczyk et al. 2023). Small units deployed in such environments must rely on self-sufficiency or innovative, unconventional supply methods that ensure essential logistical support and maintain their required combat capability. Food provision is a crucial component of these operations, as it is critical for sustaining operational effectiveness.

Field-packaged rations are a vital component of military nutrition during tactical operations, offering several advantages. The elimination of meal preparation requirements shifts focus to the supply chain as the main concern. In the context of tactical operations, the timely and reliable distribution of these rations is particularly crucial (Kler and Kalbarczyk 2019). As conventional methods of battlefield food supply face increasing susceptibility to disruption, the demand for innovative strategies to improve the security and efficiency of military logistics continues to grow. One promising solution is the use of unmanned aerial vehicles, commonly referred to as UAVs for delivering ration packs. These are remotely controlled or autonomously operating aircraft (e.g. following a pre-determined route), which can be classified based on various criteria, including their intended application, as well as parameters such as empty weight, maximum take-off weight, maximum flight altitude, flight duration and communication range (Sobczuk 2024; Hristov et al. 2016).

To develop an effective food delivery solution, it is first necessary to define the concept of a “small group of soldiers” and establish the precise quantity and mass of dry rations required to sustain such a group over a 24-hour period. For the purposes of creating a conceptual framework for this study, a small group of soldiers is defined as a six-person special operations unit conducting combat missions in challenging terrain, where conventional food supply methods may be challenging or entirely impractical. Under the adopted supply proposal, the S-RG ration pack is considered as the daily nutritional requirement per soldier, with the rations being supplied in bulk packaging (cardboard boxes) (Figure 1).

Figure 1. S-RG individual ration pack
Source: Kler and Kalbarczyk, 2019

Given that an S-RG ration pack weighs 2.1 kg (Military Centre for Research and Implementation of Food Services 2020), it is possible to calculate the total payload required for delivery to the unit's deployment area.

$$Load\ mass = ration\ mass \times \text{number of soldiers} = 2.1\ \text{kg} \times 6 = 12.6\ \text{kg} \quad (1)$$

Accounting for the additional packaging mass, the final transportable payload amounts to 14 kg.

To identify viable delivery solutions, an analysis was conducted on unmanned aerial vehicles (UAVs) capable of transporting ration packs. These UAVs can generally be classified into three categories, as illustrated in Figure 2.

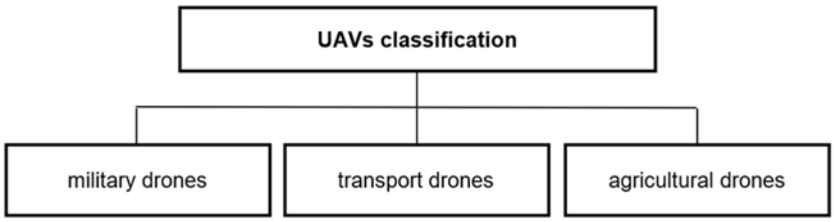

Figure 2. Classification of UAVs based on their food transport capabilities
Source: own study

Due to the ongoing war between the Russian Federation and Ukraine along Poland's eastern border, military applications of UAVs deserve special attention. Drones have been widely employed for multiple purposes in this conflict, being used for explosive payload delivery, medical supply transport and reconnaissance. Repurposing combat drones deployed in Ukraine for logistics - including the delivery of essential supplies - greatly improves operational effectiveness, reducing personnel risks and expediting supply chain processes.

A notable example of a UAV that could be adapted for battlefield logistics is the Ukrainian-manufactured Vampire drone, which has been informally dubbed "Baba Yaga" by Russian forces since it has proven to be extremely effective. The Vampire is capable of carrying explosive payloads up to 20 kg over a distance of 10 km. Although the construction of this drone was initially a closely guarded secret, it was eventually captured by the Russian Federation's army. Upon inspection, it was found to be a straightforward design that can be quickly modified and adapted to a wide range of battlefield requirements. Although the technology has been seized by the Russian military, the UAV remains a promising option for securing the battlefield supply chain due to its flexible modifiability. The primary challenge lies in the unavailability of commercially accessible spare parts, as these are custom-manufactured by the Ukrainian producer. Consequently, their availability on the commercial market is practically non-existent. Nonetheless, its proven effectiveness and reliability in combat conditions, especially in the European climate zone, remains a significant advantage.

Another interesting UAV category is transport drones, with one notable example being the H20, made by the Chinese company SATUAV. The H20 is a flying unit capable of covering a round trip of approximately 50 km with a payload of up to 20 kg. Due to its adaptability, it is commonly used for security patrols, traffic monitoring, energy infrastructure patrols, small cargo deliveries and terrain reconnaissance. Its design allows it to work in extreme weather conditions, with an operating range from −10°C to +50°C. Notably, the manufacturer also offers models capable of carrying heavier loads (30-50 kg) (SATUAV 2023).

Another interesting model in this UAV category is the FlyCart 30, produced by the well-known company DJI, which is available on the Polish market. The basic specifications of this model make it suitable for delivering food rations to small groups of soldiers. It is capable of transporting a 30 kg payload over a distance of 16 km (with a smaller payload, the maximum range, according to the manufacturer, can reach up to 28 km). An additional advantage is the ability to install a second battery and equip the drone with a dedicated winch, which allows the delivery of cargo to areas where landing is impossible. The drone can be operated by two pilots, each with their own control station, and control privileges can be easily transferred between pilots, significantly increasing the flight range (DJI 2024).

Another group examined includes agricultural drones, which play a key role in farm management. The use of this technology improves efficiency and reduces farming operational costs. Therefore, drones primarily intended for fertilization and spraying, which also offer high payload capacity, merit further analysis. One example is the SATUAV H120L, capable of operating over distances up to 10 km with a payload of up to 120 kg (SATUAV 2021). The H120L features a structure made of carbon fibre and aviation-grade aluminium alloy, making it lightweight, durable and relatively easy to transport. However, its standard operational range limits its use to the final stage of the supply chain, i.e. from the last secure point to the operational area. The installation of additional batteries and the improvement of communication systems between the controller and the UAV would increase its range, thereby enhancing its usefulness on the battlefield.

The use of unmanned aerial vehicles for military purposes, despite numerous advantages, presents various risks, including:

- Communication disruptions (e.g. GPS signal interference) that may result in a loss of control over the drone or cause it to malfunction;
- The potential for cyberattacks in combat zones, which could allow the enemy to gain control over the UAV, causing the loss of the machine and its cargo;
- UAVs may become targets for enemy fire, resulting in a disruption of the supply chain;
- Despite their advanced systems, UAVs may still be impacted by adverse weather conditions, hindering their ability to deliver supplies effectively and safely.

The existing UAV models available on the military and commercial markets ensure their safe use for delivering food rations to small groups of soldiers, without endangering lives. However, drones sourced from non-NATO regions present a risk due to the potential use of technology and components from untrustworthy suppliers. All the listed risks are legitimate when considering operations in war zones, which is why it is crucial to reduce these risks by adapting commercial drones to military needs. This includes a series of modifications and improvements designed to meet the unique operational, technical and safety requirements established by the armed forces.

Practical feasibility of using UAVs for payload transport

The practical part of the study was exploratory in nature and focused on the possibility of executing the supply of a food package to a specific destination using an unmanned aerial vehicle. As a result, the experimental investigation considered a smaller payload and a shorter delivery distance, rather than the payload mass and operational range resulting from the conceptual proposal, which served as the analytical background of this research. The experimental investigation intentionally focused on payload drop phenomena, as this delivery method eliminates the need for UAV landing at the destination point, which is often infeasible or unsafe in combat conditions. At the same time, this solution requires that the delivered payload be dropped at the designated location, or as close as possible to the intended drop point, in order to enable rapid pickup by the soldier and possession of the necessary materials, in this case food.

The experimental tests were conducted using a commercially available UAV, the DJI Agras T10, due to its accessibility. The drone's maximum payload capacity, according to the manufacturer, is approximately 10 kg. A remote release system for suspended payloads was also installed. During the tests, a $m = 3$ kg payload was transported over a distance of $d = 300$ m, followed by a series of drops from a height of $h = 30$ m, with wind speed $V_w = 4$ km/h (as measured by the "UAV Forecast" app, confirmed by the ICM website), and zero speed ($V_{d1} = 0$ km/h). Subsequently, 10 drops were performed with the drone moving at a specified speed of $V_{d2} = 5$ km/h. To ensure precise drops, calculations were performed for both cases – after the drone stopped and while it was in motion at the specified speed. The drop scenario is illustrated in Figure 3.

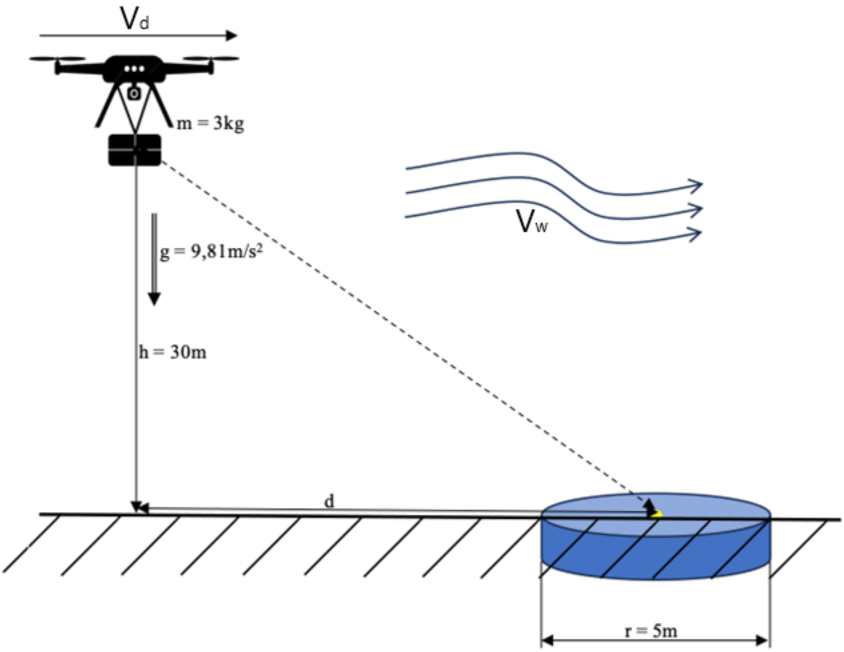

Figure 3. Visualisation of the payload drop scenario with UAV flight parameters and weather conditions

Source: own study

For a stationary UAV, the calculations were conducted as follows:
Wind speed (V_w) conversion to m/s:

$$V_w = 4\frac{\text{km}}{\text{h}} \times \frac{1000\,\text{m}}{1\ \text{km}} \times \frac{1\,\text{h}}{3600\,\text{s}} = \frac{4000\,\text{m}}{3600\,\text{s}} = 1.11\ \text{m}/\text{s} \qquad (2)$$

Calculation of the falling time (t) assuming no air resistance, with the fall height $h = 30$ m, and gravitational acceleration $g = 9.81$ m/s^2:

$$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2 \times 30 \text{ m}}{9.81 \text{ m/s}^2}} = \sqrt{\frac{60}{9.81 \text{ s}^2}} = \sqrt{6.12 \text{ s}^2} = 2.47 \text{ s} \tag{3}$$

Calculation of horizontal range (d):

$$d = V_w \times t = 1.11 \text{m/s} \times 2.47 \text{s} = 2.74 \text{m} \tag{4}$$

Thus, when dropping a package with the given mass and height, assuming the UAV has zero forward speed, a correction of $d = 2.74$ m should be made in the direction of the wind.

Let us consider a similar case, but accounting for the UAV's forward speed $V_{d2} = 5$ km/h (1.39 m/s):

Calculation of the total horizontal speed (V_h), which in this case is the sum of the wind speed (V_w) and the UAV's forward speed (V_{d2}):

$$V_h = V_w + V_{d2} = 1.11 m/s + 1.39 m/s = 2.5 m/s \tag{5}$$

The horizontal range (d) can be determined from the following equation:

$$d = V_h \times t = 2.5 m/s \times 2.47 s = 6.18 m \tag{6}$$

In order to illustrate the adjustments that must be considered when planning the drop of a load at a specific point (defined by the centre of a circle with a radius of 5 m), the impact of the UAV's speed on the drop parameters was determined, as shown in Figure 4. The calculations were performed assuming a constant wind speed of 1.11 m/s.

Based on the presented calculations and results, it can be observed that the drop distance from the target point rapidly increases with the UAV's speed, drastically reducing the probability of delivering the cargo to the desired point. While this scenario may seem straightforward and simply requires calculating the distance and dropping the load at the designated point, it should be noted that this analysis pertains to laboratory conditions, which are rarely replicable in real life. As a result, in order to generalise the findings, additional empirical research was conducted, involving a series of drops under real-world conditions, considering external factors beyond the control of the UAV operator. The results are displayed in Figure 5.

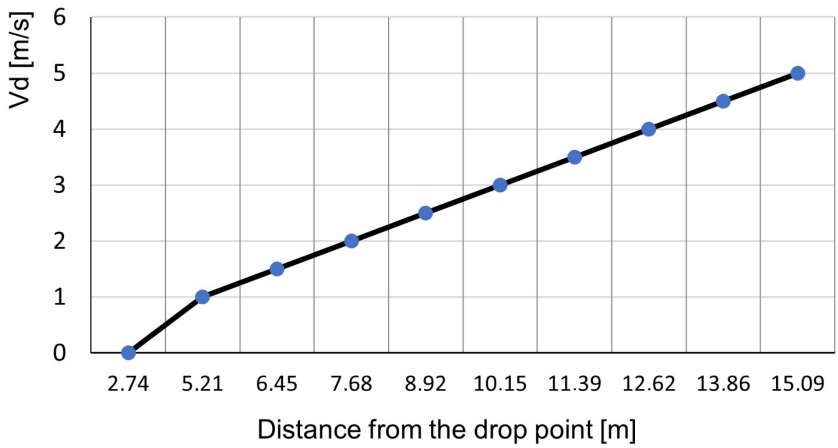

Figure 4. Drop distance variations as a function of UAV speed
Source: own study

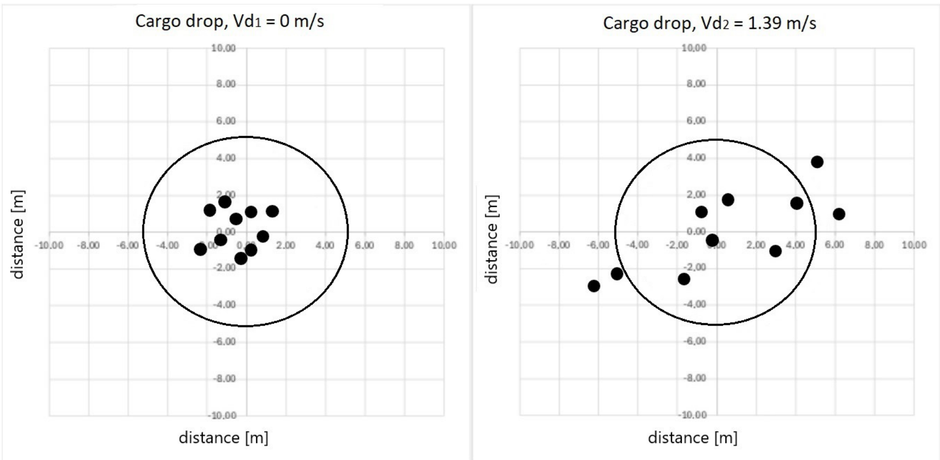

Figure 5. Comparison of payload drop results at UAV forward speeds V_{d1} and V_{d2}
Source: own study

Additionally, the results of the practical drops were subjected to analysis in terms of the success of delivering the package to the designated point – the most suitable for pickup by soldiers. The obtained results taking into account two situations of UAV movement are presented in Table 1.

Table 1. Summary of drop tests in terms of delivering the package to the designated point

Parameter	Situation (forward speed)	
	V_{d1} = 0 km/h	V_{d2} = 5 km/h
wind speed (V_w) [km/h]	4	4
drop height [m]	30	30
total number of drops	10	10
number of high-accuracy drops (<2 m from the designated point)	8	3
number of successful drops (<5 m from the designated point)	10	6
number of unsuccessful drops (>5 m from the designated point)	0	4
median distance error [m]	1.25	3.70
mean distance error [m]	1.40	3.75
maximum distance error [m]	2.50	6.50
minimum distance error [m]	0.75	0.50

Source: own study

The conducted research demonstrated that when a UAV drops a load with no specified forward speed ($V_{d1} = 0$ km/h), almost all landing points fall within a circle with a radius of 2 metres, confirming the feasibility of precise delivery even in challenging terrains, such as forested areas. In contrast, with a specified forward speed, this area becomes significantly larger. The studies further revealed that even with a small UAV flight speed (V_{d2} = 5 km/h), the likelihood of mission success decreases substantially, and in some cases (e.g. at higher flight speeds), the probability of mission success may become very low. Various factors affect both the UAV and the load being transported. These include:

- The mass and shape of the load, which affect the falling time – a key parameter for calculating the drop point;
- The limited ability to precisely position the moving UAV in the wind direction without appropriate sensors;
- The inability to accurately measure wind speed without specialised measuring equipment. In this study, wind speed was determined using the weather application "UAV Forecast", which is used to assess weather conditions before drone flights. The application can estimate wind gust strength but does not provide data on the timing of gusts, which can interfere with determining the drop distance relative to the planned landing point at a given moment;

- The limited ability to measure the actual horizontal distance between the UAV and the drop point. In the case of high UAV speeds, this becomes practically impossible without proper navigation equipment.

All the aforementioned factors undoubtedly affect the quality of task execution and the success of the mission. Finally, it should be noted that the practical part of the study was conducted using a commercially available DJI Agras T10, transporting a lighter payload over a reduced delivery distance. Despite these investigation conditions, the obtained results provide insight into general relationships governing the effectiveness and accuracy of food supply using unmanned aerial vehicles on the modern battlefield. In particular, the identified dependencies between UAV forward speed, environmental conditions, and payload drop accuracy are not specific to the applied example platform but are characteristic of drone-based logistics operations in general. Therefore, the conclusions drawn from the experimental part of the study may also be applicable under different conditions, when higher payload capacities and longer operational ranges are required to ensure full food supply for small soldier units, such as those presented in the adopted conceptual proposal.

Conclusions

Contemporary military operations increasingly require flexibility and the ability to conduct missions in difficult-to-access terrain, where conventional methods of supplying troops may be limited or impractical. In such conditions, the development of technologies enabling rapid and effective delivery of essential supplies, including food, becomes crucial. The aim of this research was to examine the possibilities of supplying food to small groups of soldiers using unmanned aerial vehicles. Particular emphasis was placed on conceptual analysis and the preliminary practical verification of the proposed food delivery process. The publication first presents the research background, followed by the proposed solution for food delivery. It then proceeds to evaluate the practical feasibility of utilising UAVs for food transport. This approach helped resolve the identified research problem and achieve the study's objective. The results confirmed the hypothesis that UAVs can deliver food to units at designated locations, at a specified time and in specified quantities, while minimising the risk to human life. At the same time, it should be noted that in the case of proposed solution, drone achieved high delivery accuracy at zero forward speed and noticeably reduced accuracy during forward flight.

This study was limited to an exploratory investigation of drone-based food supplies to a soldiers' unit. The practical component focused on payload transport and drop accuracy tests conducted with a 3 kg load over a distance of 300 m using a commercially available UAV (DJI Agras T10). The adopted conceptual framework assumes a six-person unit operating at distances of approximately 20–30 km from supply sources. However, at this stage of the investigation, these parameters served only to define the operational context and were not subject to full-scale practical validation. At the same time, with the growth of this emerging transport sector, UAV capabilities are expected to increase substantially. From the perspective of the analyses and experiences drawn from the situation in Ukraine, it can be concluded that when adapting civilian equipment to military needs, the following points should be considered:

- Separating communication and navigation drone signals to prevent interference and attempts by the adversary to seize control;
- Application of advanced data encryption methods to prevent interception or manipulation of information;
- Extending the flight range by boosting signals and enabling dual-pilot control (from the launch site and from the destination);
- Equipping UAVs with supply drop systems (e.g. winches, parachute drop mechanisms);
- Adding advanced sensors (night-vision, thermal cameras, radar systems, advanced detection systems);
- Increasing autonomous capabilities, including AI-driven algorithms that facilitate independent decision-making in fast-changing environments or in the case of communication loss with the operator;
- Developing and implementing specialised training programmes for drone operators that reflect the specific demands of military operations;
- Comprehensive access to maintenance services and spare parts.

The experimental research conducted revealed that the most crucial aspects regarding food delivery via UAVs are their technical specifications, technological advancement and the expertise of the operator. The UAV used was a general-purpose agricultural device that did not feature specialised measurement instruments. The operator's level of training may have also affected the accuracy of the measurements (despite having the required qualifications, the operator was not a professional drone operator).

The research hypothesis was supported in an exploratory technical-feasibility sense. The experimental tests confirmed that UAV-based food delivery can achieve high drop accuracy under zero forward speed and controlled weather conditions, but accuracy decreases when the UAV moves forward. The study did not fully validate the operational scenario involving a 14 kg food payload over 20–30 km, nor did it directly measure battlefield safety effects, delivery under enemy interference or post-drop integrity of food packages. These elements should be examined in further field trials using military-adapted UAV platforms and payload-protection systems.

Considering these limitations, it is important to emphasise that the conducted research is exploratory in nature. Consequently, it may serve as a starting point for further studies involving advanced technologies that can mitigate potential drawbacks and enable the successful completion of food delivery missions with a high probability of success. Nonetheless, it has been clearly indicated that the use of drones to deliver food to high-risk areas where conventional methods may be impossible or pose significant risks is promising and may become the primary method for supplying small groups of soldiers in the future.

In conclusion, it should be noted that the solutions discussed provide only a framework for the issue of delivering supplies to combat units. The UAV market is rapidly evolving, with new models incorporating increasingly sophisticated technologies entering widespread use, which can significantly impact the safety and quality of mission execution. It is, therefore, essential to continuously monitor and analyse the market in both the civilian and military sector**.**

References

Ahmed, F., Mohanta, J. C., Keshari, A. and Yadav, P. S., 2022. Recent Advances in Unmanned Aerial Vehicles: A Review. *Arabian Journal for Science and Engineering*, 47(1), 7963–7984. DOI: https://doi.org/10.1007/s13369-022-06738-0.

Chiang, W.-C., Li, Y., Shang, J. and Urban, T. L., 2019. Impact of Drone Delivery on Sustainability and Cost: Realizing the UAV Potential through Vehicle Routing Optimization. *Applied Energy*, 242(1), 1164–1175. DOI: https://doi.org/10.1016/j.apenergy.2019.03.117.

Criollo, L., Mena-Arciniega, C. and Xing, S., 2024. Classification, Military Applications, and Opportunities of Unmanned Aerial Vehicles. *Aviation*, 28(2), 115–127. DOI: https://doi.org/10.3846/aviation.2024.21672.

DJI, 2024. Dron DJI FlyCart 30 [online]. Available from: https://dji-tpi.com.pl/produkt/dji-flycart-30/ [Accessed: 24 February 2026].

Engadget, 2023. Amazon plans to start drone deliveries in the UK and Italy next year [online]. Available from: https://www.engadget.com/amazon-plans-to-start-drone-deliveries-in-the-uk-and-italy-next-year-185027120.html [Accessed: 24 February 2026].

Eskandaripour, H. and Boldsaikhan, E., 2023. Last-Mile Drone Delivery: Past, Present, and Future. Drones, 7(2), 77. DOI: https://doi.org/10.3390/drones7020077.

Focker, M., van Asselt, E. D., Berendsen, B. J. A., van de Schans, M. G. M., van Leeuwen, S. P. J., Visser, S. M. and van der Fels-Klerx, H. J., 2022. Review of Food Safety Hazards in Circular Food Systems in Europe. *Food Research International*, 158(1), 111505. DOI: https://doi.org/10.1016/j.foodres.2022.111505.

Garg, V., Niranjan, S., Prybutok, V., Pohlen, T. and Gligor, D., 2023. Drones in Last-Mile Delivery: A Systematic Review on Efficiency, Accessibility, and

Sustainability. *Transportation Research Part D: Transport and Environment*, 123(1), 103831. DOI: https://doi.org/10.1016/j.trd.2023.103831.

Gargalakos, M., 2021. The Role of Unmanned Aerial Vehicles in Military Communications: Application Scenarios, Current Trends, and Beyond. *The Journal of Defense Modeling and Simulation*, 21(3), 313-321. DOI: https://doi.org/10.1177/15485129211031668.

Hristov, G. V., Zahariev, P. Z. and Beloev, I. H., 2016. A Review of the Characteristics of Modern Unmanned Aerial Vehicles. *Acta Technologica Agriculturae*, 19(2), 33–38. DOI: https://doi.org/10.1515/ata-2016-0008.

Islam, N., Rashid, M. M., Pasandideh, F., Ray, B., Moore, S. and Kadel, R., 2021. A Review of Applications and Communication Technologies for Internet of Things (IoT) and Unmanned Aerial Vehicle (UAV) Based Sustainable Smart Farming. *Sustainability*, 13(4), 1821. DOI: https://doi.org/10.3390/su13041821.

Jasiński, G. J. and Wesołowski, A., 2023. Participation of military logistics services in the provision of food in Warsaw in September 1939. *Military Logistics Systems*, 59(2), 231–246. DOI: https://doi.org/10.37055/slw/186390.

Jin, H., Jin, X., Zhou, Y., Guo, P., Ren, J., Yao, J. and Zhang, S., 2023. A Survey of Energy Efficient Methods for UAV Communication. *Vehicular Communications*, 41(1), 100594. DOI: https://doi.org/10.1016/j.vehcom.2023.100594.

Jordan, J., 2021. The Future of Unmanned Combat Aerial Vehicles: An Analysis Using the Three Horizons Framework. *Futures*, 134 (1), 102848. DOI: https://doi.org/10.1016/j.futures.2021.102848.

Kalbarczyk, M., Kler, P., Hlubik, J., and Lipińska, K., 2023. Planning and implementation procedures of Armed Forces' transport operations and the safety of the air transport of dangerous goods. *Military Logistics Systems*, 58(1), 111–128. DOI: https://doi.org/10.37055/slw/176014.

Kler, P. and Kalbarczyk, M., 2019. Possibilities to increase the efficiency of the supply chain of packaged food ration in tactical actions. *Material Economy and Logistics Journal*, 71(5), 243-266. DOI: https://doi.org/10.33226/1231-2037.2019.5.21.

Kler, P., Sobczuk, S., Hlubik, J., and Bertrandt, J., 2022. Proposal of an alternative diet as an element of improving the safety and quality of nutrition for soldiers. *Military Logistics Systems*, 56(1), 53–66. DOI: https://doi.org/10.37055/slw/155066.

Laghari, A. A., Jumani, A. K., Laghari, R.A. and Nawaz, H., 2022. Unmanned Aerial Vehicles: A Review. *Cognitive Robotics*, 3, 8-22. DOI: https://doi.org/10.1016/j.cogr.2022.12.004.

Lee, S. Y., Han, S. R. and Song, B. D., 2022. Simultaneous Cooperation of Refrigerated Ground Vehicle (RGV) and Unmanned Aerial Vehicle (UAV) for Rapid Delivery with Perishable Food. *Applied Mathematical Modelling*, 106(2), 844–866. DOI: https://doi.org/10.1016/j.apm.2022.02.024.

Li, Y., Liu, M., Hu, H. and Jiang, X. A, 2025. Cost Analysis of the Collaborative Delivery Mode of Drones and Riders in Food Delivery Scenarios. *International Journal of Logistics Research and Applications*, 1–30. DOI: https://doi.org/10.1080/13675567.2025.2480636.

Military Centre for Research and Implementation of Food Services (WOBWSŻ), 2020. Food Ration Catalog. Warsaw: Ministry of National Defence.

Ministry of National Defence, 2020. Regulations on military food service activities DU-4.21.1(B). Bydgoszcz: Ministry of National Defence.

Mohsan, S.A.H., Khan, M.A., Noor, F., Ullah, I. and Alsharif, M.H., 2022. Towards the Unmanned Aerial Vehicles (UAVs): A Comprehensive Review. *Drones*, 6(6), 147. DOI: https://doi.org/10.3390/drones6060147.

Ryan, M. J., 2017. *Guide to Food Safety and Quality during Transportation: Controls, Standards and Practices*. Cambridge: Academic Press.

Saini, R. K., Raju, M. S. V. K. and Chail, A., 2021. Cry in the Sky: Psychological Impact on Drone Operators. *Industrial Psychiatry Journal*, 30 (suppl. 1), 15-19. DOI: https://doi.org/10.4103/0972-6748.328782.

SATUAV, 2021. Agricultural spray drone [online]. Available from: https://pl.satuav.com/multi-rotor-drone-rotary-wing-drone/agriculture-spray-drone.html [Accessed: 24 February 2026].

SATUAV, 2023. 20 kg payload drone [online]. Available from: https://pl.satuav.com/multi-rotor-drone-rotary-wing-drone/20kg-payload-drone.html [Accessed: 24 February 2026].

Sobczuk, S., 2024. The importance of unmanned aerial vehicles (UAV) in the face of the COVID-19 pandemic. In: R. Parczewski (Ed.) *Selected elements of state security – the role and tasks of transport*, 19-35. Warsaw: Military University of Technology.

Sobczuk, S. and Borucka, A., 2024. Recent Advances for the Development of Sustainable Transport and Their Importance in Case of Global Crises: A Literature Review. *Applied Sciences*, 14(22), 10653. DOI: https://doi.org/10.3390/app142210653.

Szulc, T., 2023. Possibilities of using unmanned combat assets in tactical operations in the mountains. *Scientific Journal of the Military University of Land Forces*, 55 (2), 112–127. DOI: https://doi.org/10.5604/01.3001.0053.7270.

Telli, K., Kraa, O., Himeur, Y., Ouamane, A., Boumehraz, M., Atalla, S. and Mansoor, W. A, 2023. Comprehensive Review of Recent Research Trends on Unmanned Aerial Vehicles (UAVs). *Systems*, 11(8), 400. DOI: https://doi.org/10.3390/systems11080400.

Udeanu, G., Dobrescu, A. and Oltean, M., 2016. Unmanned Aerial Vehicle In Military Operations. *Scientific Research and Education In The Air Force*, 18(1), 199–206. DOI: https://doi.org/10.19062/2247-3173.2016.18.1.26.

UPS, 2021. UPS to launch first drone supply of COVID-19 vaccines in the U.S [online]. Available from: https://about.ups.com/pl/pl/our-stories/innovation-driven/drone-covid-vaccine-deliveries.html [Accessed: 24 February 2026].

Velusamy, P., Rajendran, S., Mahendran, R.K., Naseer, S., Shafiq, M. and Choi, J.-G., 2022. Unmanned Aerial Vehicles (UAV) in Precision Agriculture: Applications and Challenges. *Energies*, 15(1), 217. DOI: https://doi.org/10.3390/en15010217.

Wallace, D. B., Moss, A. S., Chesney, C. J., Dowling, M. J., Hodges, S. A. and Costello, J. L., 2020. Mental Health in Australian Defence Force Unmanned Aerial Vehicle Operators in Afghanistan. *Military Behavioral Health*, 9(4), 368–374. DOI: https://doi.org/10.1080/21635781.2020.1864531.

Wang, H., Cheng, H. and Hao, H., 2020. The Use of Unmanned Aerial Vehicle in Military Operations. *Man-Machine-Environment System Engineering*, 645(1), 939–945. DOI: https://doi.org/10.1007/978-981-15-6978-4_108.

Yowtak, K. Imiola, J. Andrews, M. Cardillo, K. and Skerlos, S., 2020. Comparative Life Cycle Assessment of Unmanned Aerial Vehicles, Internal Combustion Engine Vehicles and Battery Electric Vehicles for Grocery Delivery. *Procedia CIRP*, 90(1), 244–250. DOI: https://doi.org/10.1016/j.procir.2020.02.003.