Krisztián Végh, Oszvald Viktor Juhász

TOOLS OF SUPPORTING RISK AVOIDANCE IN MODERN WARFARE: DRONES – DOES NOVEL WARFARE PRESUPPOSE NOVEL LOGISTICS?

DOI: 10.35926/HDR.2026.1.4

ABSTRACT: *In modern conflicts, unmanned aerial vehicles (UAVs) have become central instruments of risk-averse warfare, enabling the conduct of reconnaissance, strike, information gathering, and electronic operations without the direct endangerment of human life. The study presents the rapid development of drone technology and highlights the significance of the emergence of autonomous capabilities. The employment of drones not only provides operational advantages but also fundamentally transforms the logistical dimension of warfare. The central focus of the research is the assumption that the effective employment of drone-based warfare can be ensured through a decentralized, adaptive, and technology-oriented logistics system. We achieve this by doctrinal comparison, coupled with and proven by published, real-life experience. The authors also emphasize the new technology-oriented and adaptive logistics that must be the basis of future planning processes.*

KEYWORDS: *modern warfare, risk-averse operations, unmanned aerial vehicles, military logistics, sustainment*

ABOUT THE AUTHORS:

- *Krisztián Végh is a PhD student at the Ludovika University of Public Service, Doctoral School of Military Engineering. (ORCID: 0000-0001-6969-968X; MTMT: 10096868)*
- *Oszvald Viktor Juhász is a PhD student at the Ludovika University of Public Service, Doctoral School of Military Engineering. (ORCID: 0009-0001-5595-1925; MTMT: 10094880)*

INTRODUCTION

The security environment of the 21st century has undergone a fundamental transformation, in which the boundaries between conventional and unconventional warfare have gradually become blurred. As early as 2018, NATO stated that "we face a dangerous, unpredictable, and fluid security environment, with enduring challenges and threats from all strategic directions; from state and non-state actors; from military forces; and from terrorist, cyber, and hybrid attacks."[1]

Armed conflicts and wars have never been waged for their own sake. Behind every form of confrontation lies a political, economic, or social objective, the achievement of which is pursued through the organized use of violence.

[1] Brussels Summit Declaration 2018, 2.

At the same time, understanding the inherent laws of modern warfare is impeded by the perception of war as a phenomenon, conceived by the image commonly held in public thinking, as manifesting strictly through campaigns, operations, and battles. This image fundamentally reflects the characteristics of direct warfare. Public perception generally equates war with direct (maneuver-centric) warfare.

However, if the attritional characteristics of indirect (resource-centric) warfare are taken into account, complemented by the opportunities inherent in modern technology, the information domain, cyberspace, and the media, a system of instruments emerges that makes it clear that achieving the objectives of war no longer necessarily or exclusively depends on the destruction of the adversary's military forces or the occupation of territory.

From a practical perspective, modern conflicts can also be interpreted as the aggregate of effects produced in pursuit of objectives. The range of activities supporting these effects, primarily as a result of technological development, has undergone a significant transformation in recent years. For these reasons, we ourselves maintain that military and non-military instruments, complementing and reinforcing one another, serve the realization of strategic objectives, the achievement of which hinges on a carefully selected combination of effects. Such complex effects may focus, for example, on influencing the adversary's decision-making, gaining information superiority, undermining societal morale, or directly dismantling the opposing party's military capability. These effects, in turn, are functions of the successful execution of specific actions. In this study, the examination of the means employed in such actions focuses on UAVs.

In our view, the examination of this topic may contribute to the correct determination of the level, areas, and means of defense or protection. Furthermore, our objective is to analyze potential risk-avoidance aspects of modern warfare, including the logistical support of operations, in order to highlight possible differences and propose new approaches to the implementation of logistical support.

Methodologically, the study applies a qualitative, comparative analytical approach. It combines doctrinal analysis of NATO sustainment concepts with examination of contemporary operational experiences – primarily derived from the Russo–Ukrainian conflict – in order to identify structural differences between conventional and drone-based warfare logistics. The research does not aim to provide quantitative modeling; rather, it seeks to establish a conceptual framework that supports adaptive and risk-averse logistical thinking in modern warfare.

For the purposes of this study, the term 'drone' is used as a general designation, while 'unmanned aerial vehicle' (UAV) is applied in a technical sense.

TOOLS OF RISK AVOIDANCE IN MODERN WARFARE: DRONES

Conflicts of the 21st century, such as the Russo–Ukrainian conflict, ongoing since 2014/2022, are often characterized as complex hybrids of attritional warfare, conventional warfare, or multiple proxy relationships. Alongside traditional military power, the exploitation of information warfare, cyberattacks, disinformation, and propaganda has become increasingly evident. These instruments, similarly to cyber warfare, are inherently risk-averse in nature. They are capable of achieving objectives independently or of complementing and reinforcing the effects of conventional military operations, thereby supporting the attainment of strategic goals.

In the context of this study, risk aversion is interpreted not merely as casualty avoidance but as a multidimensional operational principle encompassing the reduction of human exposure, the minimization of critical vulnerabilities within support systems, and the deliberate dispersion of decision-making and sustainment nodes. Consequently, risk aversion functions as an active force-shaping mechanism rather than a purely defensive posture.

Drones, as autonomous weapon systems, essentially embody the "post-heroic" mindset.[2] Their risk-avoidant character manifests on multiple levels:

- Elimination of physical risk: the most evident factor in the employment of drones is the complete absence of direct human presence in the target area.
- Psychological distancing: the military application of artificial intelligence – particularly in the case of autonomous systems – removes humans from the battlefield not only physically but also psychologically, which may lead to the objectification and dehumanization of the adversary.[3]

The employment of drones can be regarded as one of the most important instruments of risk avoidance, alongside cyber capabilities. Drone technology enables the execution of tactical, operational, and strategic level activities, including reconnaissance, strike operations, electronic disruption, psychological, information, or deception activities, while operational effectiveness is not diminished but rather enhanced. This, in turn, allows commanders to assume greater risks.

Consequently, the deployment of drones does not merely provide a tactical advantage but also serves as a protective umbrella: their use makes it possible to avoid direct human confrontation while sustaining pressure and influence, as well as the destruction of the adversary's military capabilities.

THE EVOLUTION OF DRONES

With regard to the drone toolkit, the combat employment of COTS[4] drones does not represent a really new phenomenon, as they appeared in the arsenals of non-state and terrorist groups shortly after the turn of the millennium. Their initial use focused primarily on close-range ISR[5] tasks among other roles. They were also employed to guide S/VBIEDs[6] toward unobstructed targets by exploiting the advantages of real-time live video feeds from a safe distance.

Concurrently, the concept of delivering various types of IEDs by drone emerged. This idea was subsequently further developed, and with the increase in drone payload capacity, the precise employment of HEAT[7] charges against armored targets also became feasible. At present, a significantly broader range of application modes is known, which are fundamentally attributable to the availability and adaptability of COTS drones.

2 Luttwak 1995.
3 Johnson 2022.
4 COTS: Commercial Off-The-Shelf.
5 ISR: Intelligence, Surveillance, Reconnaissance.
6 S/VBIED: Suicide/Vehicle-Borne Improvised Explosive Device.
7 HEAT: High-Explosive Anti-Tank.

The Russo–Ukrainian conflict has drawn particular attention to drones modified for strike missions and equipped with various explosive devices. Initially employed at short, tactical ranges, these systems enabled the delivery of explosive payloads along non-ballistic, adaptable flight paths, with variable speed and altitude, followed by the detonation of the payload in close proximity to the selected target.

The multitude of attacks presented online as successful, their observable effects, and the minimal risk associated with their employment have drawn global attention to the potential inherent in drones. As a result, their continuous presence on the modern battlefield is now accepted as ubiquitous. According to the lessons drawn from daily reporting, not a single day passes in the Russo–Ukrainian conflict without the deployment of drones.

The initial capabilities of drones have undergone extraordinary development. First, advancements are evident in their range and operational altitude; second, their early ISR and short-range task sets have been expanded to include the capability to designate and adjust targets for artillery strikes. Strike operations conducted with OWA[8] drones now pose threats to critical infrastructure at strategic depth,[9] while their employment has also been extended to include EW-related[10] mission sets.

Experience from the Russo–Ukrainian conflict indicates that the capabilities of drones employed by Ukraine are largely comparable to those of the opposing side, particularly in terms of their operational use, and in several cases, their innovations have preceded Russian developments.[11] Particular attention should be given to loitering munition (LM) systems of various ranges, which are drones optimized for strike missions and, depending on the type, possess autonomous target acquisition, identification, and limited decision-making capabilities.[12] Notably, the achievement of all these capabilities required less than two decades.

Machine-based decision-making capabilities, such as those of drones supported by AI[13] and sensor systems, appear to be one of the driving forces of technological development. However, they already raise questions concerning human decision-making, particularly from the perspective of risk avoidance.[14] In this regard, key issues include target identification and engagement, as well as positioning[15] in GNSS-D[16] environments and the Return-to-Home function, which serves as a system safety response in the event of communication disruption. Among these functions, target identification and destruction are especially sensitive, carrying significant ethical and strategic dimensions, as they directly affect the protection of human life, the allocation of responsibility in decision-making, and the extent of military risk-taking.

In practice, drones primarily serve to reduce operational risks, as they enable intervention without endangering human life. At the same time, however, the automation of decision-making introduces new types of political, military, and moral risks since the link between action and responsibility may become blurred.

8 OWA: One-Way Attack.
9 Kovács 2024.
10 EW: Electronic Warfare.
11 Pettyjohn 2024.
12 Végh – Daruka 2025.
13 AI: Artificial Intelligence.
14 Lucas 2017.
15 Boda 2022.
16 GNSS-D: Global Navigation Satellite System Denied.

Based on the level of human supervision, drones can be divided into three main categories:[17]

- Remote-Controlled (Human-in-the-Loop): One operator usually controls one drone. If there are multiple drones, several operators handle their respective units. This is the conventional method that is still in use for the most valuable assets.
- Automated (Human-on-the-Loop): The drone flies along a set route or task. A person supervises the operation and can intervene or stop the mission if needed.
- Autonomous (Human-out-of-the-Loop): The swarm acts as an independent entity. It uses AI and machine learning for target selection, navigation, and task allocation. It can also adjust to changes in the environment without needing further instructions from a human.

From an ethical and strategic perspective, the expansion of autonomous decision-making capabilities introduces a critical tension between operational efficiency and accountability. While autonomous systems may significantly reduce reaction times and human exposure, they simultaneously complicate the attribution of responsibility, particularly in cases of misidentification or unintended collateral effects. This ethical ambiguity represents a latent strategic risk that may undermine the political legitimacy of military operations, even when tactical objectives are successfully achieved.

The first type represents a typical example of risk-averse operation, as it maintains human control and thereby reduces the likelihood of bad decisions and unintended consequences. In contrast, the third model seeks to enhance rapid response and efficiency by expanding decision-making autonomy at the expense of human control, thereby generating new and more difficult-to-manage security and ethical risks. This aspect is likely to become a major issue in the near future.

The security environment of the 21st century is characterized by the blurring of boundaries between conventional and unconventional warfare, creating new types of multidimensional challenges for decision-makers and operational planners.

We maintain that drones are capable of providing numerous advantages to their users. However, in parallel, they also generate a range of issues, at times ethical or technical in nature, and at other times highly practical, such as the logistical support of drone operations. Accordingly, in the following sections, we examine how the logistical support of operations conducted with drones is structured, what conditions it requires, and, based on these considerations, we formulate principles and requirements for the development and implementation of adaptive, appropriately flexible logistics.

LOGISTICAL SUPPORT SYSTEM FOR DIFFERENT FORMS OF WARFARE

To illustrate the specifics of the logistical support of modern warfare and highlight and understand its differences, we consider it worth briefly introducing the logistics support of conventional warfare in the theatre.

At the doctrinal level, in NATO, the definition of logistics used to be as follows:

[17] https://uav-defence.com/the-future-of-autonomous-drone-swarms-in-modern-warfare/

"Logistics is the science of planning and carrying out the movement and maintenance of forces. In its most comprehensive sense, the aspects of military operations which deal with:
- design and development, acquisition, storage, movement, distribution, maintenance, evacuation and disposition of materiel;
- transport of personnel;
- acquisition, construction, maintenance, operation and disposition of facilities;
- acquisition or furnishing of services; and
- medical and health service support."[18]

It is worth noting that the newer AJP-4 doctrine now uses a broader concept of sustainment as an umbrella term, which includes logistics, but also treats personnel, medical support, military technical support, finance, and contractual support as separate functions. It defines sustainment as "the provision of personnel, logistics, medical support, military engineering support, finance and contractor support necessary for Alliance operations and missions."[19]

The former document interprets logistics quite broadly. It says that logistics is "the science of planning and carrying out the movement and maintenance of forces", so it treats logistics as a kind of umbrella term, which includes almost all non-combat, support activities necessary for the maintenance of combat forces. The latter AJP-4 doctrine, which is already about "Sustainment of Operations", gives a much narrower definition of logistics. The most obvious difference is that the new definition lacks an explicit mention of the entire life cycle of materiel (design, development, scrapping), a focus on personnel transport, a list of detailed activities related to facilities, and, most importantly, medical support. The new definition focuses on four key activities: supply, movement, maintenance, and services.

The difference between the two definitions is not only at the level of words but also reflects a fundamental doctrinal rearrangement. Instead of the previous, very broad concept of logistics, NATO has introduced a more differentiated "sustainment" framework based on several independent functions, in which logistics appears as an important element that no longer includes everything else. This change is likely to build on operational experience and a better understanding of the specifics of different support areas, more in line with the increased civilian presence in modern warfare.

In accordance with the new doctrinal principles, the principles of logistical support are as follows:[20]
- Responsiveness to requirements: Sustainment planning and execution should be oriented towards the current and anticipated needs of an operational commander.
- Reliability: Assured sustainment is critical to the success of operations. Availability and delivery of sustainment should be resilient to the effects of degradation, competition, and diverse threats and hazards.
- Collective: Collective sustainment is undertaken by NATO and individual allies to cooperatively plan, generate, deconflict, and synchronize the provision of sustainment for an operation.
- Unity of effort: Sustainment is achieved through cooperation, collaboration, interoperability, interchangeability, integration, and shared visibility at all levels and across all

[18] NATO Standardization Office 2018.
[19] NATO Standardization Office 2025.
[20] NATO Standardization Office 2025.

domains. This enables the optimization of national, multinational, and collective sustainment resources to provide a seamless transition from peace to crisis and/or conflict.
– Integrity & ethics: Sustainment should be executed in a manner that is consistent with the NATO code of conduct, including accountability and the responsible use of resources, to maintain moral legitimacy and preserve integrity in relationships with diverse stakeholders upon which sustainment depends. Sustainment relies heavily on military and civil support; consequently, its operations could be severely impacted by corruption and other unethical behaviors.

It is very important to highlight that, in line with the moral courage dimension of risk-averse warfare, the principle of "Integrity & ethics" appears among the principles of sustainment, requiring that sustainment be carried out responsibly and ethically in accordance with NATO values. This includes accountability and careful management of resources to maintain moral credibility and prevent corruption. Although the aim of this publication is not to analyze the change in logistics approach, it is important to emphasize that adaptation to the special requirements of drone warfare has already taken place on a doctrinal level. It is also important to emphasize that logistics should not be treated as an independent entity or as a sub-capability element broken down into parts.[21]

LOGISTICAL SUPPORT FOR CONVENTIONAL (LINEAR) WARFARE

As mentioned in the introduction, drone warfare is often referred to as "unconventional." For this reason, we will briefly introduce what characterizes the logistical support of conventional warfare.

The theatre of war, or operational area in modern terminology, is never just a thin line on a map. Rather, it is a complex, deeply articulated, multi-layered system, which is made up of geographically and functionally distinct bands. Understanding this structure is fundamental to the planning and conduct of operations. In geographical terms, the battlefield can be divided into several zones by moving backwards from the line of contact (i.e., the *Forward Edge of the Battle Area* – FEBA). At the very front is the tactical zone, where direct combat takes place. This is the area of maneuvering forces (armored vehicles, mechanized infantry) and direct fire support artillery, where the goal is to physically combat enemy forces and take possession of territory. This is where the defensive positions, minefields, and lower-level, outpost combat positions can be found.

Behind this zone lies the much deeper operational zone, which is the actual "engine room" of operations. Although direct combat is less frequent here, its strategic importance is invaluable. It is home to higher-unit headquarters, key logistics centers (bases), field hospitals, and airports. It plays a critical role in deploying operational reserves that are ready to take advantage of a breakthrough or eliminate enemy infiltration. This zone is the launch area for long-range fire strikes (e.g., ballistic missiles, rocket artillery) but is also their target area (!).

Finally, the strategic zone (i.e., the hinterland) is inseparably linked to the battlefield. This will provide the industrial capacity to sustain the war effort, the training of recruits, and the political-military leadership at the national level.

[21] Juhász 2025.

However, these geographical zones of the theater of war are networked and operated by three basic functional systems. The first is the combat system (in American doctrine, the *Movement and Maneuver* and *Fires* battlefield functions). The second is the Command and Control (C2) system. This is the "nervous system" of the battlefield, which consists of the commanding positions and the communication networks connecting them. The eyes and ears of this system are the ISR devices that were partially presented earlier, from drones through satellites to radio electronic interception. The task of the C2 system is to continuously maintain situational awareness and to deliver commands to the implementing elements. The third is the logistics and maintenance system *(Sustainment)*. This is responsible for ensuring that the combat elements are constantly supplied with ammunition, fuel, food, and spare parts. The backbone of the system is the Lines of Communication (LOC) running from the strategic zone to the tactical zone, which are closely linked to technical and medical support.

In summary, a theater of war is a dynamic system, where the success of battles in the tactical zone is fundamentally determined by the efficiency of the C2 and logistics systems operating at the depth of operations. Thus, in a theatre set up for linear, conventional warfare, the logistical support system takes the shape of a theatre of war and develops a full support capability in its depth and breadth. This is done in several stages:

– by supplying the combat subunits with their own logistical stocks;
– by the establishment of forward logistics bases corresponding to the size and needs of the subunits to be supported;
– by battlefield supply bases.

The location of the various supply bases, their responsibility for supply by materiel type[22] or classes of supply,[23] as well as the size and composition of the stocks to be established and maintained by them are determined by the logistical part of the operational order (either organically or in an annex), fitting into the basics of the command concept and the pace of operations. In military operations, one of the main objectives of the enemy, in addition to withdrawing the fighting forces from combat, is to obstruct and destroy the logistical support system. In order to increase survivability, supply must be decentralized as much as possible, more (main, alternate, transverse) supply lines must be planned, logistical stocks must be dispersed, the mobility of individual elements must be increased, active and passive camouflage devices and procedures must be used, and efforts must be made to increase redundancy as much as possible.

However, it must be seen that no matter how much the battlefield logistics leadership strives to use them to increase survivability, since the forces to be supplied are in one place and in large numbers, higher-level supply points have correspondingly larger stocks in one place, so a higher supply turnover is expected both at the beginning and at the end of the support chain. In addition, to facilitate planning, supply is carried out at a predetermined time and in large quantities for a lot of logistics materiel or many classes of supply, especially in the case of easily standardized demands. Taking all this into account, it can be stated that in the case of linear warfare, no matter how much we strive to increase survivability,

[22] 20/2021 (V. 19.) Decree by the Ministry of Defence on the Order of the Budgetary Management of National Defence Organisations, Annex 1.

[23] NATO Logistics Handbook 2025, Appendix A.

due to the characteristics of the forces to be supplied, great damage and disruptions can be caused in logistics supply in some places, in case of appropriate enemy reconnaissance.

DRONE OPERATIONS – SPECIFICS OF LOGISTICAL SUPPORT FOR RISK-AVERSE WARFARE

As we have previously shown, one of the basic characteristics of drone warfare is long-range (indirect) warfare. Drone pilots are farther away from the site of the strike, so the controllers are separated from the target on the battlefield. The absence or blurring of front lines is also typical. The use of drones allows controllers to be constantly present on the battlefield without having to hold definite front lines. The drones used in the Russo-Ukrainian conflict have a range of 4–8 km to even 1400–4000 km, so they can attack targets at strategic depths.

A really important factor is the asymmetrical location. While in linear warfare, both sides are physically present on the battlefield, in drone warfare, one of the parties (the drone operator) participates from a distance, and only the equipment is physically present.

One of its peculiarities is the emphasis on the vertical dimension in the management of the ground forces, as well as its impact on air force activities due to the saturation of the airspace. Until now, explosives from the ground forces could be delivered to the enemy targets mainly through ballistic trajectories, and defense against these devices was very expensive. With the use of drones, the method, time, and spatial projection of explosives have changed, and protection against them also requires new methods and tools.

Taking all this into account, it can be seen that the logistical support for operations carried out with the mass deployment of drones should differ significantly from the classic patterns of linear warfare, especially in terms of theatre location, material supply needs, supply infrastructure, and risk aversion. In conventional warfare, logistics operate as a centralized system that requires a significant amount of personnel, munitions, fuel, food, and other supplies to be concentrated in one place. In contrast, drone-based warfare requires a decentralized and adaptive logistics strategy that reduces the need for mass logistics supply in line with operational needs, ensuring supply in a dispersed structure through smaller logistics bases.[24] Risk aversion is present throughout this first dimension: the dispersion of the supply system fundamentally reduces the losses during an attack and the exposure to operational critical points.

The logistics system for drone warfare should be designed in a fundamentally decentralized manner, which is directly linked to the principles of a risk-averse strategy. The infrastructure needed to launch, control, and maintain drones – such as a command center, control units, and charging stations – is mostly geographically separated, often hidden or mobile.[25] This arrangement is beneficial in reducing the vulnerability of logistics targets and significantly increases resilience. With more independent, flexible logistics depots, it is more difficult for the attacker to disrupt the supply chain, which greatly improves the survivability of the system.[26] The decentralized structure allows the entire logistics system to be less detectable by the enemy, which becomes another critical dimension of risk aversion.

[24] Preston 2020.
[25] Peck 2025.
[26] Camargo 2025.

In this case, there is no need for supplies affecting thousands of soldiers in a small area as opposed to linear warfare involving the front line. The experience of the Russo-Ukrainian conflict shows that drones are often controlled by remote operators who are not necessarily at the scene of the fighting, so there is no need for large amounts of food, water, medicine, or personal equipment directly near the front line. This striking difference in the scope and nature of logistical support fundamentally changes the logic of the organization of supply. The logistics supply system will have to concentrate mainly on technological components, batteries, repair equipment, software updates, communication infrastructure, and very little fuel – technological supplies will become a priority instead of traditional munitions.[27] As a result, the weight of logistics shipments is significantly reduced, and transport requirements are substantially simplified, which directly reduces the physical presence of logistics units (electromagnetic and physical signature) and thus the risk of discovery.

One of the bases of this type of logistical support is the security of energy supply,[28] which is a special aspect of this risk-averse approach mentioned above. Since the operation of smaller drones and control centers requires electricity, charging stations, and batteries, energy supply must be a priority. Logistical planning of energy storage, such as portable or modular batteries, opens up new supply tasks – especially in a risk-averse theatre where disrupting and eliminating energy supplies is more important than attacking actual manpower. The dispersion of energy supply units is fundamentally different from a centralized supply model operating with high resource consumption; therefore, a distributed energy storage system is necessary for the strategic implementation of risk aversion. Additionally, the independence of energy sources reduces the vulnerability of the supply chain: if one energy point is damaged, the others can continue to operate independently. Devices for electromagnetic protection (e.g., anti-interference protection solutions, communication redundancy) must also become part of the logistical supply, as they ensure the operational continuity of the system.

Instead of traditional, large, front-line logistics bases – where significant amounts of supplies, vehicles, weapons, and personnel are stored – drone warfare requires decentralized, dispersed, mobile logistics points. These bases have a smaller capacity, can be relocated quickly, and often the necessary infrastructure is only deployed for a short period of time (e.g., for start-up). In the Russo–Ukrainian conflict, the parties have learned that static logistics depots become preferential targets for drone-based attacks. According to theories, the parties are already exposed to drone attacks 20 miles behind the front line.[29] This realization has fundamentally transformed logistics thinking. Supply models that take full advantage of mobility reduce the vulnerability of bases and allow logistical support to adapt to current tactical challenges.[30] The logic of supply routes must also change: movement between bases is faster and more flexible, so routes must not be fixed, but change on demand and quickly, which thus becomes an integral part of risk reduction.

In drone warfare, the use of autonomous logistics units, such as automated supply drones, which can deliver spare parts, fuel, or food to units close to the front, can be of particular importance. Autonomous transport systems minimize human presence in hazardous areas and increase supply chain redundancy. The autonomous supply approach basically contrib-

[27] Thornton – Gallasch 2018.
[28] McLachlan – Goodson 2025.
[29] McLachlan – Goodson 2025.
[30] Müller – Sumlenny 2025.

utes to risk aversion because human pilots and machine operators are not directly exposed to battlefield danger.[31] The use of a decentralized logistics system, diverse transport routes, and autonomous devices significantly increases the resilience of the supply chain. With the use of redundant, almost unlimited air supply routes and small mobile depots, the loss of a logistics point or a means of transport does not paralyze the entire operation. This is especially important in asymmetric warfare, where the enemy can target familiar logistics hubs.

Thus, logistics support must increasingly rely on technological innovations such as local (embedded) production and maintenance. The use of additive manufacturing (3D printing) at logistics points near the front line can enable rapid production of spare parts, increase the flexibility of supply, and reduce dependency on remote supply.[32] This approach fundamentally changes the logistics dependency chain: drones do not need a large, centralized operational depot, which represents a new type of risk mitigation strategy. In-situ production reduces the vulnerability of the supply chain, as critical components are not exposed to transport risks, and protection against disruptive (electronic warfare) operations is also easier when supplies come from local, decentralized sources.

For example, the forward deployment of containerized additive manufacturing units enables the rapid replacement of frequently damaged drone components such as propellers, housings, and mounting brackets. This capability not only reduces dependence on vulnerable supply routes but also shortens repair cycles, thereby increasing operational tempo while maintaining a minimal logistical footprint.

The organization of supply chains must enable the use of predictive logistics, which is based on the forecasting of needs (artificial intelligence, sensor networks). This makes supply more predictable and optimizable, avoiding overstocking and logistical overload. Integrated management should allow drones, logistics bases, and personnel to be connected in a networked system. In such systems, the flow of information is real-time, and decision-making is faster, which fundamentally reduces the vulnerability of the system to errors due to information delay. In addition, the predictive approach should allow for a so-called "forward-looking logistics" principle, according to which supply nodes should be optimally positioned by predicting supply demand, thus minimizing concentrated warehousing.

In conclusion, we demonstrated that the logistical support of drone warfare should be characteristically different from traditional, mass-based, linear warfare logistics. It should be built on a decentralized, mobile, energy-based, and technology-oriented supply, based on redundancy and adaptivity, which offers more efficient and flexible solutions in terms of both material requirements and logistics footprint. Risk aversion in this context is not only a passive defense strategy, but an active, proactive approach: the dispersion of logistics infrastructure, continuous mobility, minimization of information and physical visibility, and the use of autonomous systems all reduce the vulnerability of the supply system in addition to maintaining the operational capability of the system. A change in the mindset of logistics units is also needed: it is no longer enough to think in terms of a static defensive position, but they must operate, recognize, and avoid threats in the same way as operational units.[33] Operational flexibility, adaptability of supply routes, digital support, and in-situ manufacturing should all become key components of future military logistics in the context of drone

[31] Choi 2017.
[32] Camargo 2025.
[33] Camargo 2025.

warfare. Overall, the logistical support of drone warfare should create an economical use of resources, operational security, and a unique synthesis of risk aversion.

CONCLUSION

In our scientific study, we examined the complex phenomenon of drones in modern warfare, focusing on two main areas: their risk-averse nature and the specifics of their logistical support.

Our analysis establishes that 21st-century conflicts can be characterized by the coordinated use of military, economic, informational, and cyberspace tools. A prominent focus of the research is the role of drones as the most important tools for risk aversion, enabling long-distance operations to be carried out without the risk of human presence.

Finally, the study presents the decentralized, adaptive needs-based nature of logistics support for the use of drones, in which it must break with traditional, mass-based supply models and offer technology-oriented, flexible solutions.

Beyond its practical implications, this study contributes to the theoretical discourse on modern warfare by conceptualizing logistics as an active enabler of risk-averse operational design. In drone-based warfare, logistics is no longer a predominantly reactive support function but becomes an integral element of force protection, resilience, and strategic adaptability.

We have shown that the logistical support of drone warfare, if properly designed, adapts to the form of warfare in all dimensions. We emphasized that in modern drone warfare, it is necessary to break with the "this is how we usually do it" procedures in almost all areas, and perhaps even with the doctrinal foundations. Everything must be done to prevent the operational commander from developing the feeling of "everything is logistics" that is often experienced in linear warfare. Like the combat units, the logistics support system must be maximally decentralized and fully adaptable to needs, flexible and almost imperceptible – ensuring full logistical support and protection of logistics forces, because this mode of warfare requires adaptive and technology-oriented supply, which in many cases is shifted from mass supply to technological components and innovations.

To summarize, the authors would like to highlight and emphasize that all future planning processes must part with static paradigms and implement the adaptive thinking of modern warfare.

BIBLIOGRAPHY

- 20/2021 (V. 19.) Decree by the Ministry of Defence on the Order of the Budgetary Management of National Defence Organisations, Annex 1.
- Boda, Mihály: *A hibrid háború etikája: az igazságos hibrid háború elmélete.* [The ethics of hybrid warfare: The theory of just hybrid war.] A hadtudomány aktuális kérdései, Vol. 1, 2022, 95–108.
- *Brussels Summit Declaration*. Issued by the Heads of State and Government participating in the meeting of the North Atlantic Council in Brussels, 11–12 July 2018. https://www.nato.int/cps/en/natohq/official_texts_156624.htm
- Camargo, Danilo: *Hybrid Logistics: Lessons from Brazil's VIKING Experience for the War in Ukraine*. Small Wars Journal by Arizona State University, 2025.

- Choi, Jacob: *Autonomous Resupply: Drones for the Supply Chain Reinforce the Kill Chain*. Australian Army Research Centre (AARC), 2017.
- Johnson, James: *The AI Commander Problem: Ethical, Political, and Psychological Dilemmas of Human-Machine Interactions in AI-enabled Warfare*. Journal of Military Ethics, Vol. 21, No. 3–4 (2022), 246–271. DOI: 10.1080/15027570.2023.2175887
- Juhász, Oszvald Viktor: *The conceptual interpretation of logistic capability in military air forces*. Katonai Logisztika, Vol. 33, No. 3–4 (2025), 136–162. DOI: 10.30583/2025-3-4-136
- Kovács, Ferenc: *The Strategic Role of Critical Infrastructure in the Russo-Ukrainian War*. Hadtudomány, Vol. 34, No. 3 (2024), 29–39.
- Lucas, George: *Ethics and Cyber Warfare. The Quest for Responsible Security in the Age of Digital Warfare*. Oxford University Press, 2017.
- Luttwak, Edward N.: *Toward Post-Heroic Warfare*. Foreign Affairs, Vol. 74, No. 3 (1995), 109–122.
- McLachlan, Sean – Goodson, Todd: *Best Practices on Operationalizing Battlefield Energy*. U.S. Army, 2025.
- Müller, Wolfgang – Sumlenny, Sergej: *Additive Manufacturing: A Key Enabler Of Low-Cost Modern Warfare*. The Defence Horizon Journal, 2025.
- *NATO Logistics Handbook*. 2025. Online: https://www.nato.int/docu/logi-en/logist97.htm
- NATO Standardization Office: *NATO Standard AJP-4 – Allied Joint Doctrine for Logistics*. Edition B Version 1, NSO, 2018.
- NATO Standardization Office: *NATO Standard AJP-4 – Allied Joint Doctrine for Sustainment of Operations*. Edition C Version 1, NSO, 2025.
- Peck, Michael: *Why Army Logistics Need to Think Like Combat Units to Survive Drones*. Army Times, 2025.
- Preston, Alexander J.: *Requirements for unmanned aerial logistics in the support of the United States Marine Corps*. Thesis, Naval Postgraduate School, Calhoun, 2020.
- Thornton, Sam – Gallasch, Guy Edward: *Swarming Logistics for Tactical Last-mile Delivery*. International Conference on Science and Innovation for Land Power (ICSILP), 2018.
- Végh, Krisztián – Daruka, Norbert: *The Challenge of Technology-Enabled Unmanned Aircraft Systems*. Hungarian Defence Review, Vol. 153, No. 1 (2025), 80–91.