

FLYING CHEAP, HITTING HARD: HOW LOW-COST DRONES ARE REWRITING TACTICAL WARFARE IN UKRAINE

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ABSTRACT

The Russo-Ukrainian conflict initiated in 2022 represents the first instance of large-scale use of low-cost unmanned aerial vehicles (UAVs) in a high-intensity interstate war. This article analyses how low-cost drones – including adapted commercial drones, First Person View (FPV) drones, and heavy multicopter platforms – have influenced the conduct of tactical operations, with a focus on reconnaissance and surveillance missions, artillery fire correction, direct strikes, and associated defensive adaptations. The integrating analytical framework combines the Cost-Exchange Ratio (CER) instrument for assessing financial asymmetry with the Tactical Network-Centric Warfare (T-NCW) model for understanding the restructuring of command-and-control logic at sub-unit level. Drawing on open-source analysis, security-institute reports, and recent academic literature, the article tests four working hypotheses concerning the enhancement of tactical observation capability, the specific vulnerabilities of low-cost platforms, the defensive adaptations generated, and the indicators of an emerging Revolution in Military Affairs (RMA). The findings confirm all four hypotheses and support the thesis of an RMA in progress, driven by the proliferation of miniaturised and accessible aerial systems, while stopping short of validating a complete and irreversible transformation.

KEYWORDS:

Cost-Exchange Ratio, FPV drone, low-cost drone, emerging RMA, combat tactics

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1. Introduction

The conflict initiated in Ukraine in 2022 quickly drew the attention of military analysts through the scale and pace at which unmanned aerial systems were integrated into tactical operations. Unmanned Aerial Vehicles (UAVs) are not a novelty in the military domain, yet their deployment at the scale observed in the current conflict and the diversity of missions executed justify a dedicated analysis. Kunertova (2023) articulates this particularity precisely: prior to the Russian invasion of 2022, security studies scholarship systematically underestimated the enabling functions and tactical benefits of small drones in high-intensity interstate conflicts – a gap that the conflict in Ukraine exposes with clarity.

A defining feature of this war is the large-scale integration of low-cost drones – a term used to designate UAV platforms with significantly lower costs compared to conventional military systems – including adapted commercial drones, artisanal or small-batch First Person View (FPV) drones, and heavy multi-rotor platforms. These systems have been employed both for reconnaissance and surveillance missions and for locating adversary positions, correcting artillery fire, assessing strike effects, and, in numerous instances, for directly attacking personnel and military equipment. Bradford et al. (2023) synthesise this reality: the conflict in Ukraine has functioned as a real-time laboratory for the use of commercial UAVs in combat, with both sides resorting to commercial drones to an unprecedented degree.

Operational experience from the conflict demonstrates that technological accessibility and relatively low costs have enabled the use of these systems at a pace difficult to anticipate. Whereas in previous conflicts – including the 2020 Nagorno-Karabakh war – the emphasis fell on dedicated military systems such as the Bayraktar TB2, available to state actors with significant resources, the Russo-Ukrainian conflict has demonstrated that such capabilities can also be generated at tactical level, including through the adaptation of commercial solutions available on the civilian market (Huțan, 2025). Furthermore, Minculete and Păstae (2024) note that a single F-35 multirole aircraft costs the financial equivalent of approximately 55,000 DJI Mavic 3 drones – a difference of orders of magnitude that explains the operational appeal of low-cost solutions.

Recent literature on the impact of drones structures a debate between enthusiasts – who identify in the large-scale integration of FPV systems a catalyst for a Revolution in Military Affairs (RMA) – and sceptics, who caution that drones remain complementary instruments rather than singular determinants of victory (Hutto & Rogers, 2026; Barbu, 2024). Bojor and Grigore (2025) propose the analytical framework of Tactical Network-Centric Warfare (T-NCW) – a decentralised, bottom-up combat model in which intelligence, surveillance and reconnaissance (ISR), decision-making, and strike execution are integrated within small, autonomous units – arguing that the effect of FPV drones transcends the instrumental level, restructuring command-and-control logic at the micro-unit level. The present article adopts an intermediate position: the available empirical data does not permit confirmation of a complete RMA, yet the structural indicators – technological, organisational, and doctrinal – support the hypothesis of an emerging RMA.

The proliferation of low-cost UAV systems has also generated a dynamic cycle of adaptation and counter-adaptation. The intensive use of electronic warfare, modification of concealment procedures, dispersion of forces, and the emergence of dedicated counter-drone solutions – including the transition to fibre-optic guided FPV

drones to circumvent electromagnetic jamming (Chaari, 2025) – demonstrate that the introduction of a new capability inevitably generates adversarial reactions. From this perspective, the impact of drones must be analysed not in isolation, but in relation to the broader dynamics of the confrontation.

The purpose of this article is to analyse how the use of low-cost drones in the Russo-Ukrainian conflict has influenced the conduct of tactical and operational activities, with a focus on reconnaissance missions, fire correction, direct strikes, and associated defensive adaptations. The analysis integrates two complementary theoretical frameworks: cost asymmetry, operationalised through the Cost-Exchange Ratio (CER) instrument, and the T-NCW model, to highlight simultaneously why these systems are adopted at scale and how they restructure the conduct of tactical operations. Beyond synthesising existing findings, the article makes three specific contributions, developed in Section 5.1: an explicit two-axis assessment framework coupling cost asymmetry (CER) with operational-effectiveness indicators; the articulation of a causal link between cost-driven proliferation, tactical network-centric adaptation, and a revolution in military affairs in progress; and a set of testable propositions for validating the CER–T-NCW model. The article is structured as follows: Section 2 presents the theoretical context and literature review, including the working hypotheses; Section 3 describes the methodology; Section 4 analyses results concerning system categories, cost-effectiveness, tactical uses, vulnerabilities, and adaptations; Section 5 formulates conclusions, original contributions, and directions for future research.

2. Theoretical Context and Literature Review

2.1. UAV Use in the Literature Prior to the Ukraine Conflict

Unmanned Aerial Vehicles (UAVs) have been present in military doctrine for several decades, undergoing a progressive evolution from exclusive reconnaissance and surveillance missions toward target designation roles and, subsequently, direct strike capabilities. The conflicts in the Middle East and the 2020 Nagorno-Karabakh war constituted important comparative references, demonstrating that systems such as the Bayraktar TB2 can overcome conventional air defences and achieve decisive effects at lower costs than traditional aviation. Huţan (2025) highlights that these experiences demonstrated how drones reduce barriers of access to high-impact operations: *“These examples demonstrate how drones shift the power balance by lowering entry barriers to high-impact operations”*. Nevertheless, the focus of specialised literature remained predominantly on large, costly platforms – employed by state actors with significant resources – systematically underestimating the tactical potential of small systems in high-intensity interstate conflicts. Kunertova (2023) articulates this limitation directly: *“Before Russia’s 2022 invasion of Ukraine, security studies scholars were myopic about small drones’ enabling functions and tactical benefits”*. Hutto and Rogers (2026) confirm that prior literature treated the tactical, strategic, and economic aspects of UAV employment separately, without integrating them into a unified analysis of concrete operational impact – a gap that the conflict in Ukraine exposes with clarity.

2.2. The RMA Debate: Enthusiasts versus Sceptics

Recent literature on the impact of drones in the Russo-Ukrainian conflict is structured around a persistent debate between two camps. Enthusiasts argue that the

large-scale integration of First Person View (FPV) systems represents a catalyst for a Revolution in Military Affairs (RMA) – a fundamental and discontinuous transformation in the nature and conduct of war, generated by the synergy between technological innovation, new operational concepts, and organisational adaptation. Bojor and Grigore (2025) argue that *“the widespread adoption, tactical integration, and doctrinal institutionalization of FPV drones in Ukraine constitute the catalyst of a new Revolution in Military Affairs”*, indicating that the effect of these systems transcends the instrumental level, restructuring command-and-control logic at the micro-unit level. Renic and Christensen (2024) add that small, low-cost drones have democratised air power, conferring on tactical units capabilities previously reserved exclusively for advanced aviation. Barbu (2024) situates this evolution within the broader framework of military science transformation, arguing that we find ourselves at an inflection point in the redefinition of doctrine, strategies, and operational planning. Zagorodnyuk (2026) applies an explicit definitional criterion, finding that developments in Ukraine meet the parameters of an RMA through the structural modification of how military power is generated and employed, while Turret (2025) places dronisation in historical perspective, comparing it as a transformative principle to the motorisation and mechanisation of the previous century.

Sceptics counter-argue that drones remain complementary instruments rather than singular determinants of victory. Hutto and Rogers (2026) nuance the debate, cautioning that *“whether drones can be considered the primary determinant of victory on a contemporary battlefield depends on the type of war conducted, the political objectives involved, and the tactical capabilities deployed”*, and that *“in conventional wars fought by two modern industrialised militaries, drones alone will not offer victory; no single military technology can”*. The positions synthesised above belong to the existing literature. Building on them, the present article adopts an intermediate position of its own, justified by the available empirical evidence: data from the Russo-Ukrainian conflict does not permit confirmation of a complete and irreversible RMA, yet the structural indicators – technological, organisational, and doctrinal – support the thesis of an RMA in progress, generated by the proliferation of miniaturised and accessible aerial systems.

2.3. Theoretical Framework, Case Study Justification, and Working Hypotheses

The Russo-Ukrainian conflict initiated in 2022 constitutes the optimal case study for testing the RMA-in-progress hypothesis, owing to the unprecedented scale of low-cost UAV system employment, the diversity of platforms involved, and the significant volume of data available from open sources, institutional reports, and academic analyses. Bondar (2025) documents how Ukraine constructed a commercial-first acquisition ecosystem oriented toward the rapid multiplication of tactical capabilities through the integration of Commercial Off-The-Shelf (COTS) components – a model that itself constitutes an indicator of the organisational transformation associated with an RMA. An emerging direction of this transformation is the gradual integration of artificial intelligence (AI) in the coordination of unmanned systems, visible both in the algorithmic coordination of FPV swarms and in the development of the first generations of autonomous smart munitions tested at scale in conflict – a tendency with direct implications for hypothesis H4.

The analysis rests on two complementary theoretical frameworks. The first is cost asymmetry, operationalised through the analytical instrument of the Cost-Exchange Ratio (CER), developed by Kamal et al. (2026) to quantify the financial imbalance

between the cost of a low-cost attack system and the cost of neutralising or destroying the intended target. The second framework is the Tactical Network-Centric Warfare (T-NCW) model, introduced by Bojor and Grigore (2025), defined as “a decentralized, bottom-up combat model in which ISR (Intelligence, Surveillance and Reconnaissance), decision-making, and strike execution are integrated within small, autonomous units”. The two frameworks are not mutually exclusive: CER explains why these systems are adopted at scale, while T-NCW explains how they restructure the conduct of tactical operations and sub-unit organisation. NATO (2025) and the NATO Communications and Information Agency (2024) confirm the institutional relevance of these lessons, treating the Ukrainian experience as a reference for the development of counter-UAS capabilities and the adaptation of allied doctrine.

From the analysed literature and the adopted theoretical framework, four working hypotheses follow logically. H1: the use of low-cost drones has contributed to the enhancement of tactical observation capability and the execution of precision strikes at reduced costs. H2: the effectiveness of these systems is significantly influenced by their vulnerability to electronic countermeasures and the technical limitations specific to low-cost platforms. H3: the integration of low-cost drones has generated defensive tactical adaptations, such as force dispersion, intensification of concealment measures, and extensive use of electronic warfare means. H4: the observed trends – organisational restructuring, doctrinal modifications, and the integration of artificial intelligence – constitute indicators of an emerging RMA, generated by the proliferation of miniaturised and accessible aerial systems.

The article contributes theoretically by linking economic asymmetry (CER) to decentralised tactical adaptation (T-NCW), arguing that cost-driven proliferation creates the conditions for tactical network-centric warfare and, cumulatively, for a revolution in military affairs in progress.

3. Research Methodology

The present research employs a qualitative approach with comparative descriptive elements, with the Russo-Ukrainian conflict and the use of low-cost drones – a term used to designate UAV (Unmanned Aerial Vehicle) platforms with relatively low costs compared to conventional military systems – in tactical operations as its case study. The objective is not the exhaustive quantification of the effectiveness of all systems employed in the conflict, but the identification of observable operational trends, the assessment of associated tactical implications, and the testing of the hypothesis of an emerging Revolution in Military Affairs (RMA), generated by the proliferation of miniaturised and accessible aerial systems.

3.1. Case Study Justification

The Russo-Ukrainian conflict represents the first context of large-scale use of small drones in a high-intensity interstate war (Kunertova, 2023). Bradford et al. (2023) synthesise this particularity as follows: “*The war in Ukraine has been a real-world laboratory for the use of commercial UAVs in warfighting, with both the Russian military and Ukrainian defenders using commercial UAVs to an unprecedented degree*”. This characteristic renders it an analytical framework with superior empirical relevance compared to other recent conflicts, in which the use of low-cost drones has been more limited or less documented.

3.2. Methods and Data Validation

The research combines three main methods. The first is documentary analysis, applied to academic literature, reports from security- and defence-research institutes, and publicly available official sources – a stage that enabled the delineation of the theoretical framework and the identification of principal trends regarding UAV use in conflict. The second method is comparative analysis, employed for assessing the operational characteristics of the main categories of low-cost drones and for the indicative comparison of their costs with conventional target-engagement systems, through the analytical lens of the Cost-Exchange Ratio (CER); the financial values used are exclusively indicative in nature, serving a comparative rather than an accounting purpose. The third method is interpretative analysis of tactical implications, through the correlation of identified data with observable adaptations at the level of tactical operations, interpreted through the Tactical Network-Centric Warfare (T-NCW) framework as a reference model for understanding the restructuring of command-and-control logic at sub-unit level.

Literature was selected on three explicit criteria: thematic relevance to low-cost UAV employment in the Russo-Ukrainian conflict; novelty of perspective and contemporaneity, with priority given to sources published between 2023 and 2026; and source type, favouring peer-reviewed studies and reports issued by established security- and defence-research institutions, supplemented where necessary by official primary sources and specialist defence reporting for technical and cost data. Because a substantial part of the empirical base consists of open-source (OSINT) material, data were validated through cross-source triangulation: a factual claim was retained only when corroborated by at least two independent sources, or when it originated from an official primary source such as a ministry release or a procurement record; single-source claims are identified as such. Platform performance and cost figures are treated as indicative rather than definitive and, wherever possible, were cross-checked against more than one source.

3.3. Assessment Framework: Cost and Operational Effectiveness

The analysis assesses low-cost drones along two explicit and complementary axes, so that military effectiveness is not treated as an abstract quality but is anchored in observable operational indicators.

The first axis is economic and is quantified through the Cost-Exchange Ratio (CER) developed by Kamal et al. (2026), which expresses the financial imbalance between the cost of a low-cost attack system and the cost of neutralising or destroying the intended target. The CER is applied comparatively, using indicative open-source cost values rather than accounting figures.

The second axis is operational effectiveness, assessed through three categories of indicator documented in the conflict rather than through a subjective rating. The first is temporal – the compression of the sensor-to-shooter cycle (kill chain), benchmarked against the threshold of under five minutes reported for drone-corrected artillery engagement (Renic & Christensen, 2024; Minculete & Păstae, 2024). The second is logistic – the reduction in artillery ammunition expenditure enabled by drone observation and fire correction (Kunertova, 2023). The third is manoeuvre denial – the reduction in the survivability of forces moving in the open, benchmarked against the reported window of no more than ten minutes (Minculete & Păstae, 2024; Zagorodnyuk, 2026).

These indicators are treated as qualitative-comparative benchmarks derived from documented operational reporting, not as a closed or exhaustive metric of combat effectiveness; they capture the operational effects most directly attributable to low-cost drones. Read together with the CER axis, they permit a structured cost-versus-effectiveness assessment: the economic axis explains why these systems are adopted at scale, while the operational axis establishes what tactical effect that adoption produces. The correlation between the two axes underpins the interpretation of results in Section 4 and the testing of the working hypotheses.

3.4. Selection of Analysed Systems

Five representative categories were selected: DJI Mavic 3, Autel EVO Max 4T, custom FPV (First Person View) drones, fibre-optic FPV drones, and heavy multicopter platforms. The selection criteria were the documented frequency of use in the conflict, the availability of public data, and representativeness for the low-cost spectrum. The use of these categories is documented in Chaari (2025) and Minculete and Păstae (2024), which confers on the selection a verifiable empirical basis. The four working hypotheses guiding the analysis are those derived from the literature and the theoretical framework in Section 2.3 (H1-H4); they are tested against the results presented in Section 4.

3.5. Research Limitations

The present study presents several limitations that must be taken into account when interpreting the conclusions. First, the data derive from open sources, susceptible to variations in accuracy and currency, and the research does not include primary data such as practitioner interviews or direct observation. Second, the dynamic character of the conflict implies that some information may have been superseded by developments subsequent to the moment of analysis. Third, and specific to the information environment of this war, open-source data are exposed to propaganda, deliberate disinformation, and selective disclosure by both belligerents, while independent battlefield verification is frequently impossible; manufacturer-stated performance figures, as well as loss and casualty estimates, were therefore treated as indicative rather than definitive and cross-checked wherever sources allowed. A future direction for consolidating the results could involve the application of the Delphi method – a structured procedure of iterative expert consultation frequently used in security studies to validate qualitative assessments – which would allow the operational-effectiveness benchmarks and the RMA indicators to be anchored in a verifiable expert consensus.

4. Results and Discussion

4.1. Categories of Low-Cost Drones Analysed

The analysis distinguishes between five representative categories, selected on the basis of their frequency of appearance in the conflict and their direct tactical relevance. Chaari (2025) highlights that the diversification of these categories – from adapted commercial platforms to locally produced systems in large volumes – has generated a permanent low-altitude aerial threat presence. Minculete and Păstae (2024) describe FPV operation: *“During operation, the FPV drone (a quadricopter that can quickly reach high speeds, even over 100 km/h) is operated and controlled by the operator using non-military equipment”*.

Tourret (2025) adds the industrial dimension: “*The drone thus becomes a consumable and reconfigurable tool, combining mass deployment with ease of use. The shift is not only conceptual, but also industrial and operational*”. Scale data confirm operational relevance: over one million FPV drones supplied to the Armed Forces of Ukraine in the first seven months of 2025, with over two million contracted for the same year (Ministry of Defence of Ukraine, 2025a). The associated institutional restructuring – the creation of a dedicated structure for unmanned systems and the adoption of the commercial-first model (Bondar, 2025) – represents a first indicator of the organisational transformation associated with hypothesis H4.

Table no. 1

Comparative characteristics of the main categories of low-cost drones analysed

System / Category	Platform Type	Estimated Cost (USD)	Control/Link Range	Payload	Primary Tactical Use	Observations
DJI Mavic 3	Commercial multi-rotor	2,000–5,000	8–15 km	low	Observation, target identification, fire correction	Adapted commercial platform; proximity ISR
Autel EVO Max 4T	Commercial multi-rotor	5,000–12,600	up to ~20 km	low	Tactical observation, ISR support	Commercial alternative; anti-jam military firmware in service
Custom FPV	Improvised FPV	400–1,500	~5–15 km	0.5–3 kg	Precision direct strikes	Low cost; operator and radio-link dependency
Fibre-optic FPV	FPV with fibre cable	1,000–3,000	~5–41 km (up to ~50 km experimental)	0.5–3 kg	Strikes in high-jamming environments	Immune to jamming; range/manoeuvres limited by spool
Heavy multicopter “Baba Yaga”	Heavy-lift multicopter	8,500–20,000	~10–20 km	5–15 kg	Tactical bombardment, night strikes, mining, logistics	Reusable; higher payload; increased detectability

(Source: Own processing)

Note. Control/link range denotes the effective control or transmission (link) range, not the maximum airframe flight distance. Values are indicative and drawn from: DJI Mavic 3 – DJI (2024) and Minculete and Păstae (2024); Autel EVO Max 4T – Autel Robotics (2023) and Army Recognition (2025); custom FPV – Bengo and Guy (2025) and Chaari (2025); fibre-optic FPV – The War Zone (2025), Defense Express (2025), and Liuksikov (2025); heavy multicopter “Baba Yaga” – Army Recognition (2026) and Hambling (2025)

4.2. Comparative Cost-Effectiveness

Cost asymmetry is one of the structural explanations for the extensive adoption of low-cost drones. Zagorodnyuk (2026) defines the process as the “democratisation of precision”: *“Ukraine has, in effect, democratized precision and made its mass employment feasible. In this respect, the historical importance of the country’s drone revolution is about reinventing precision through widespread dispersion at relatively low cost”*. The concept of Cost-Exchange Ratio (CER), developed by Kamal et al. (2026), quantifies this asymmetry: intercepting a low-cost system frequently requires two interceptor missiles, doubling the cost of defence per engagement. The data are illustrative at multiple levels: Chaari (2025) notes that *“The missile’s cost is 27 times the Shaheed drone’s cost”*; Minculete and Păstae (2024) observe that a single F-35 is financially equivalent to 55,000 DJI Mavic 3 drones; Bengo and Guy (2025) provide the most direct tactical comparison: *“An armed FPV drone costs approximately \$500. Assuming only 20% hit probability, successful strikes cost around \$2,500. Comparative analysis: Javelin missile: ~\$78,000... Hellfire missile: ~\$150,000”*. Cody (2026) synthesises the structural logic: *“When a system costing hundreds of dollars can reliably destroy assets costing millions, or neutralize trained personnel whose replacement requires months or years, the governing variable is no longer skill, bravery, or platform sophistication, but cost curves under attrition”*. The Royal United Services Institute (2024) cautions, however, that FPV platforms effective against protected targets may require additional sensors and payload, qualifying the cost advantage in certain operational contexts.

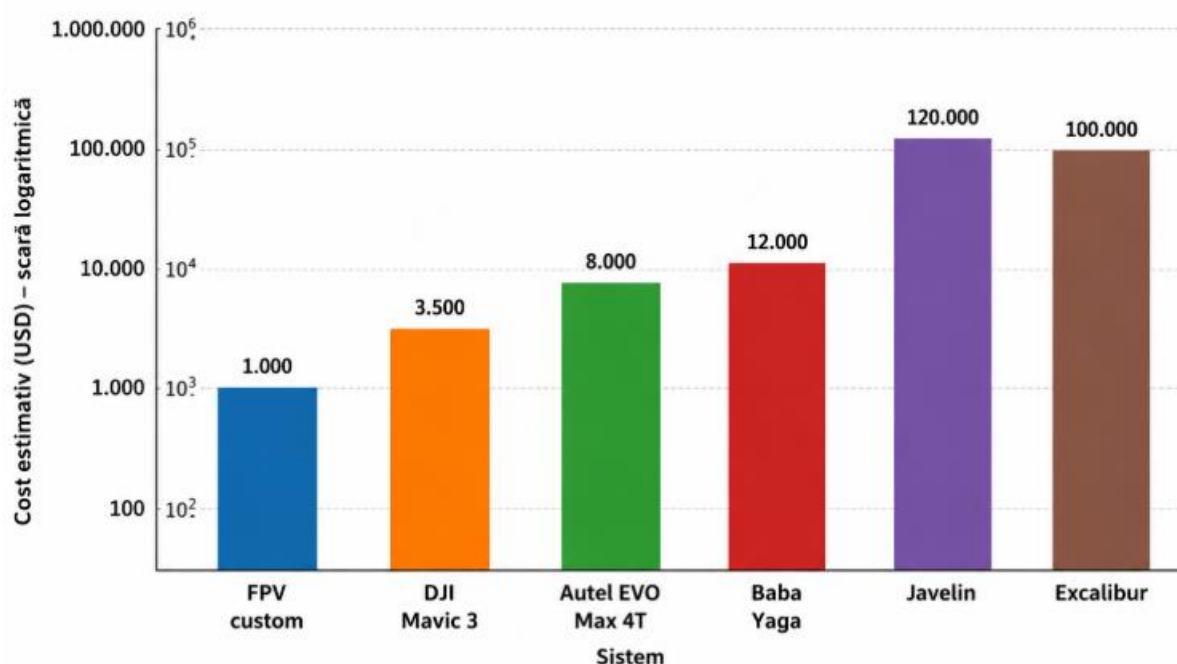


Figure no. 1: Comparative estimated costs of low-cost UAV systems and selected conventional precision engagement systems
(Source: Own processing)

Note. Values are indicative and used exclusively for comparison. Cost figures are drawn from Bengo and Guy (2025) (FPV ≈ USD 500; Javelin ≈ USD 78,000; Hellfire ≈ USD 150,000), Chaari (2025) (a cruise missile ≈ 27× the cost of a Shaheed drone), and Minculete and Păstae (2024) (one F-35 ≈ 55,000 DJI Mavic 3 units)

4.3. Observed Tactical Uses

Bradford et al. (2023) describe the conflict in Ukraine as a real-world laboratory for the use of commercial UAVs at an unprecedented scale. Niță (2025) highlights that *“Small drones have proven vital for ISR missions, collecting substantial volumes of reasonably high-quality data with minimal chance of detection, outperforming costlier systems in penetrating air-defense zones”*. Zagorodnyuk (2026) adds that *“the air domain is increasingly fragmented into multiple vertical and functional layers. Control in one layer does not guarantee control in others”*, explaining why low-altitude drones operate independently of classical air superiority. For fire correction, Kunertova (2023) notes that *“The overall effect of drone intelligence and strikes contributes to reducing the number of shells needed, lowering the logistical burden, and increasing the pace of artillery fires”*, while Renic and Christensen (2024) quantify the effect: the kill chain compressed *“to less than 5 minutes”*. The relevance of low-cost drones results from the simultaneous integration of multiple functions – observation, target confirmation, fire correction, and precision strikes – with reduced resources, a characteristic fully compatible with the T-NCW model.

Table no. 2

Tactical uses of low-cost drones in the Russo-Ukrainian conflict

Tactical Use	Systems Employed	Operational Advantages	Main Limitations
Observation, reconnaissance, and target identification	DJI Mavic 3, Autel EVO Max 4T	Low cost, proximity aerial imagery, continuous ISR collection (Niță, 2025; Bradford et al., 2023)	Vulnerability to jamming, limited autonomy, weather dependency
Artillery fire correction	Commercial multi-rotor drones	Kill chain compressed to under 5 minutes; reduction in required shell expenditure (Renic & Christensen, 2024; Kunertova, 2023)	Exposure to electronic warfare; communications dependency
Precision direct strikes	Custom FPV, fibre-optic FPV	Maximum cost asymmetry: FPV ~\$500 vs. Javelin ~\$78,000 (Bengo & Guy, 2025); sensor-to-shooter loop reduced from hours to minutes	Limited payload; high operator dependency
Tactical bombardment and point logistics	Heavy multicopter “Baba Yaga”	Higher payload; night missions; support for hard-to-reach positions	Increased detectability; sensitivity to weather conditions

(Source: Own processing)

4.4. Vulnerabilities, Technological and Tactical Adaptations

The advantages of low-cost drones must be analysed alongside their vulnerabilities. The principal vulnerability – electromagnetic jamming – has generated a direct adaptation: Chaari (2025) confirms that *“To bypass these highly effective jammers, both adversaries have turned to fiber-optic drones”*, while Bengo and Guy (2025) detail the effect: *“The transition to fiber-optic control systems has rendered the FPV platforms immune to jamming and interception”*.

Ito (2025) and Donnelly et al. (2024) demonstrate that vulnerabilities are not exclusively technical but also organisational: the inability of the Russian military to rapidly adapt its response to small drones reflects rigid bureaucracy and a top-down reporting culture. Nasehi (2025) provides quantifiable data: *“Dynamic role allocation reduced mission failure by 37% by assigning leader/follower roles based on real-time battery levels and proximity to targets”*. Chaari (2025) synthesises the general direction: *“The fight against FPV and next-generation drones is no longer just about jamming; it now involves multi-layered kinetic defense and coordination amid rapidly evolving drone technology”*.

At tactical level, the adaptations generated by the presence of drones have reinforced existing military principles. Minculete and Păstae (2024) justify their urgency: *“currently, an advancing tank or troop column can be detected within 3 to 5 minutes and hit in another 3 minutes... The survival rate of forces in motion is no more than 10 minutes”*. Zagorodnyuk (2026) confirms the consequence: *“ground maneuver in Ukraine has become extremely difficult in areas saturated with drones. Movement is detected quickly. Troop concentrations attract immediate strikes”*. Bengo and Guy (2025) formalise the new manoeuvre paradigm: *“Operations no longer rely on deep maneuver by massed forces, instead executing through dispersed ‘arrows’ – short-range thrusts by mechanized platoon-sized task forces or small infantry assault groups”*. Tourret (2025) adds that *“To survive on a battlefield saturated with sensors and firepower, forces have de-mechanized and dispersed”*. Dee et al. (2025) highlight that Ukrainian adaptations emerge organically through personal networks and direct handovers between generations of soldiers – an informal adaptation speed that surpasses classical doctrinal systems and supports hypothesis H4. An additional dimension is psychological: the constant presence of drones generates a paralysing cognitive pressure, the sensation that there is nowhere to hide.

Table no. 3

Tactical adaptations associated with the extensive use of low-cost drones

Tactical Adaptation	Operational Justification	Intended Effect
Dispersion of personnel and equipment	Compact formations are easily detected and engaged through drones or corrected fire	Reduction of vulnerability to observation and strikes
Reduction of dwell time in exposed positions	Identified positions can be struck within minutes; maximum survival rate of 10 minutes (Minculete & Păstae, 2024)	Enhanced survivability through mobility
Camouflage and anti-drone protection	Optical sensors rapidly identify equipment and shelters; FPV drones attack through direct impact	Delayed identification; reduced probability of being struck
Electromagnetic discipline and electronic warfare	Radio emissions can locate forces; drone radio links can be disrupted	Limitation of EM exposure; delay of adversary drone control

Tactical Adaptation	Operational Justification	Intended Effect
Permanent own-UAV observation	The adversary drone threat necessitates continuous surveillance	Early detection; rapid response
Adaptation of movement to night-time / reduced visibility	Drone presence increases the risk of daytime visible movement	Reduction of exposure to aerial observation

(Source: Own processing)

4.5. Synthesis of Results

The results of the analysis confirm a visible and structured impact of low-cost drones on tactical observation, target identification, fire correction, and precision strikes (H1), demonstrate that the effectiveness of these systems is conditioned by significant technical and organisational vulnerabilities (H2), identify systematic defensive tactical adaptations generated by their presence (H3), and support the hypothesis that the Russo-Ukrainian conflict represents the incipient phase of a Revolution in Military Affairs generated by miniaturised and accessible aerial systems (H4). This argument is not merely asserted by the authors but is supported by independent sources that converge toward the same structural conclusion. Zagorodnyuk (2026) applies the definitional criterion: developments in Ukraine “*meet the criteria for what military strategists refer to as a revolution in military affairs (RMA): a structural shift in warfare in which new technologies drive the development of novel operational concepts and doctrines, fundamentally altering how military power is generated and employed*”. Bojor and Grigore (2025) identify FPV drones as the “*catalyst of a new Revolution in Military Affairs*”. Tourret (2025) situates the process in historical perspective: dronisation is “*a transformative principle, comparable to motorization and mechanization in the past century*”, with the transition from the “war of engines” to “the war of servers and processors”. Bengo and Guy (2025) observe that classical military doctrine “*is collapsing under the persistent, lethal surveillance of miniaturized drones*”.

The three structural indicators of H4 converge. At the technological level, economic asymmetry and kill-chain compression represent a qualitative rupture, not an incremental evolution (Cody, 2026; Bengo & Guy, 2025). At the organisational level, the creation of a dedicated structure for unmanned systems and the commercial-first model (Bondar, 2025) indicate deep institutional adaptations. At the doctrinal level, Kreetz et al. (2025) show that the speed of innovation has surpassed the capacity of classical doctrinal systems, imposing new instruments – doctrinal wiki platforms and real-time lessons-learned networks – to manage the pace of change. Zagorodnyuk (2026) confirms this structural limit: “*The classical model of defining requirements, issuing a tender, developing a system, testing it, producing it, and then fielding it is too slow to remain relevant in a rapidly evolving environment such as the one in Ukraine*”.

The fourth indicator of H4 – the integration of artificial intelligence – does not represent an exclusively future vector, but an already observable and measurable process in the available conflict data. Nasehi (2025) documents that “*Dynamic role allocation reduced mission failure by 37% by assigning leader/follower roles based on real-time battery levels and proximity to targets*” in algorithmically coordinated FPV drone swarms – a concrete operational result, not a projection.

Bondar (2025) documents the institutionalisation of the Delta system in Ukraine, an AI-based battlefield management platform that integrates in real time ISR data from drones, ground sensors, and communications into tactical decisions at sub-unit level. Chaari (2025) confirms that AI integration directly addresses the operational limits of the human operator: autonomous drone guidance in high-jamming environments – where radio control fails and fibre optics are insufficient – becomes the solution for operational continuity. Tishan (2026) consolidates this conclusion: the conflict in Ukraine is “*the world’s first large-scale drone-centric war*”, a context in which systems no longer depend on human decision within the engagement loop. Taken as a whole, AI is not prefigured as a next step – it is already present as a functional indicator of transformation, albeit at a limited scale and in an incipient stage of operational maturity.

Analytical caution remains necessary. Hutto and Rogers (2026) remind that “*in conventional wars fought by two modern industrialised militaries, drones alone will not offer victory; no single military technology can*”. The impact of low-cost drones and integrated AI depends profoundly on the type of conflict, the level of adversary countermeasures, and the institutional capacity to rapidly absorb innovation. The position of the present article is that the four indicators of H4 – the technological rupture, organisational restructuring, doctrinal pressure, and AI integration already operational at an incipient scale – together support the hypothesis of an RMA in progress, not a completed one: the structural signals are clear and measurable, the transformation process is ongoing, and the conflict in Ukraine remains the most relevant contemporary empirical laboratory for observing this transition.

5. Conclusions

The analysis of the use of low-cost drones in the Russo-Ukrainian conflict confirms an observable and structured impact of these systems at tactical level, distributed across four directions corresponding to the formulated working hypotheses.

The first hypothesis (H1) is confirmed. Adapted commercial drones have provided sub-units with rapid access to proximity aerial observation, facilitating the identification of adversary positions, the adjustment of artillery fire, and the assessment of strike effects. FPV drones have enabled the engagement of precision targets at costs in the order of hundreds or a few thousand dollars – compared to tens or hundreds of thousands in the case of conventional precision-strike systems. This difference of orders of magnitude explains their large-scale adoption, confirmed by supply volumes: over one million FPV drones supplied to the Armed Forces of Ukraine in the first seven months of 2025, with over two million contracted for the same year. The conclusion is that low-cost drones do not replace conventional systems, but offer a favourable cost-effect ratio in observation, fire correction, and precision-strike missions, reducing barriers of access to aerial capabilities at tactical level.

The second hypothesis (H2) is confirmed. Classical FPV drones prove sensitive to radio jamming, dependent on the quality of the control link, and on operator proficiency. The emergence of fibre-optic guided FPV drones illustrates the adaptation – counter-adaptation logic specific to this conflict: fibre optics reduce exposure to electronic warfare, but introduce constraints regarding operational range and operational complexity. Vulnerabilities are not exclusively technical – the inability of certain military structures to rapidly adapt their response to the small-drone threat also reflects organisational rigidities with direct operational consequences. The

effectiveness of low-cost systems is therefore conditioned both by the technical characteristics of the platforms and by the institutional capacity to rapidly integrate innovations.

The third hypothesis (H3) is confirmed. The extensive use of low-cost drones has increased operational pressure on already established tactical principles – dispersion, concealment, mobility, and communications discipline – without fundamentally creating them. The novelty lies in the frequency and rigour with which they must be applied, and in the reduced tolerance for apparently minor tactical errors. Continuous and inexpensive aerial surveillance, accessible at lower tactical levels, also adds a psychological dimension: the sensation that there is nowhere to hide generates a persistent cognitive pressure that surpasses the immediate physical threat. The observed adaptations therefore respond both to the direct threat and to this cognitive pressure.

The fourth hypothesis (H4) is partially confirmed. The available evidence supports the hypothesis of a Revolution in Military Affairs (RMA) in progress, not a completed one. The structural indicators are visible at three levels: at the technological level, the compression of the sensor-to-shooter cycle from hours to minutes and the structural economic asymmetry represent a qualitative rupture; at the organisational level, the creation of a dedicated military structure for unmanned systems in Ukraine and the adoption of the commercial-first acquisition model indicate deep institutional adaptations; at the doctrinal level, the speed of integration of new capabilities has surpassed the capacity of classical doctrinal systems, imposing new instruments for managing the pace of innovation. The tendency toward autonomous AI-guided swarms describes a trajectory that reaches the classical dimensions of an RMA. Nevertheless, analytical caution remains necessary: the impact of drones depends on the type of conflict, the level of adversary countermeasures, and the institutional capacity for adaptation – no single military technology can alone decide victory in a high-intensity conventional war.

5.1. Original Contributions

Beyond synthesising the existing literature, this article makes three original contributions. First, it introduces an explicit two-axis assessment framework that couples the economic axis of cost asymmetry (CER) with an operational-effectiveness axis anchored in observable indicators – kill-chain compression, reduction of ammunition expenditure, and manoeuvre denial – thereby assessing military effectiveness through documented operational effects rather than abstract judgement. Second, it articulates a causal link between these dimensions, arguing that cost-driven proliferation creates the conditions for tactical network-centric warfare (T-NCW) and, cumulatively, for a revolution in military affairs in progress: the CER axis explains why the systems are adopted at scale, while the T-NCW model explains how they restructure sub-unit command-and-control. Third, it derives from this integration a set of testable propositions that translate the CER–T-NCW model into an agenda for empirical validation. Taken together, these contributions provide a unified perspective absent from the literature that preceded the Ukraine conflict.

5.2. Limitations and Future Research

The limitations of the research derive from the exclusive use of open sources, from the dynamic character of the conflict, from the information-environment constraints discussed in Section 3.5, and from the absence of primary data. These limitations define a concrete agenda for further work aimed at validating the CER–T-NCW model: comparative studies across other drone-intensive theatres, to test whether the observed cost-effectiveness dynamics generalise beyond Ukraine; simulation and wargaming of cost-exchange dynamics under varying electronic-warfare conditions; and experimental exercises measuring sensor-to-shooter compression in controlled settings. A structured Delphi expert panel would allow the operational-effectiveness benchmarks and the RMA indicators to be anchored in a verifiable expert consensus. Complementary directions include a more detailed analysis of the interaction between low-cost drones and electronic-warfare systems, the assessment of real production, maintenance, and attrition costs, and the integration of lessons from Ukraine into the training and military planning of NATO member states.

Author Contributions

Conceptualization, F.V.I. and L.B.; methodology, F.V.I. and L.B.; validation, L.B. and I.V.; formal analysis, F.V.I. and L.B.; investigation, F.V.I., L.B. and I.V.; resources, F.V.I., I.V. and S.P.; data curation, F.V.I. and L.B.; writing – original draft preparation, F.V.I. and L.B.; writing – review and editing, F.V.I., L.B., I.V. and S.P. All authors have read and agreed to the published version of the manuscript.

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