ISSN 2669-2023 (print) / ISSN 2538-8959 (on-line) **/ https://doi.org/10.47459/cndcgs.2026.8**

Combat UGVs in Recent Operations: Lessons and Ways Forward

Karel BÖHM[1]*, Jan NOHEL[2], Pavel ZAHRADNÍČEK[2]

[1]*Centre for Security and Military Strategic Studies, University of Defence, Kounicova 65, 602 00, Brno, Czech Republic*
[2]*Department of Tactics, University of Defence, Kounicova 65, 602 00, Brno, Czech Republic*

*Correspondence: *karel.bohm@unob.cz*

Abstract

Unmanned ground systems are increasingly appearing in contemporary operations; however, their practical utility varies depending on the task, operating environment and mode of control. Based on a targeted literature review, a comparison of findings from Syria, Gaza and Ukraine, and a structured expert consultation, this article assesses the main roles of UGV/UGS and their limitations. The findings indicate that UGV/UGS are currently most suitable for support, engineer, reconnaissance, logistics and evacuation tasks. Direct combat employment remains promising, but is constrained by C2, EW, mobility, endurance, operator workload and tactical integration.

KEY WORDS: *ground robotic systems; UGV/UGS; combat operations; lessons learned; human-robot teaming*

Citation: Böhm, K.; Nohel, J.; Zahradníček, P. Combat UGVs in Recent Operations: Lessons and Ways Forward. In Proceedings of the Challenges to National Defence in Contemporary Geopolitical Situation, Brno, Czech Republic, 7-10 September 2026. ISSN 2538-8959, https://doi.org/10.47459/cndcgs.2026.8

1. Introduction

Unmanned ground vehicles and unmanned ground systems (UGV/UGS) have increasingly moved in recent years from the domain of technological demonstrators to serious considerations of their operational employment. Their tasks may include reconnaissance, protection of facilities, engineer support, transport of supplies, casualty evacuation and direct combat support. This development is linked to a broader transformation of the land battlefield, which is increasingly shaped by robotisation, digitalisation, rapid information sharing and the need to reduce risk to personnel [2], [14].

Although some UGV/UGS capabilities in reconnaissance, logistics, engineer support and casualty evacuation are relatively well described, their actual contribution to combat operations remains context-dependent and unevenly verified. Current literature often focuses either on the technical parameters of individual platforms or on isolated experimental and simulation scenarios. Less attention is paid to systematically linking these findings with empirical experience from recent conflicts, particularly with regard to limitations in command and control (C2), electronic warfare (EW), mobility, sustainment and tactical integration.

At the same time, the mere presence of a robotic platform does not in itself create a fully developed combat capability. UGV/UGS must be understood as part of a wider system that includes the operator, command and control, communication architecture, sensor equipment, logistic support and tactical procedures. From the perspective of military employment, it is therefore important to distinguish between remotely controlled, partially autonomous and autonomous systems, as each level of control creates different requirements for personnel, technology and organisational integration [7], [8].

Available academic and experimental sources indicate that the practical utility of UGV/UGS differs significantly depending on the task, environment and mode of employment. Direct combat employment may be promising, but it places high demands on mobility, resilient communications, operator situational awareness and integration into the manoeuvre of land forces. For example, a virtual simulation experiment with attritable UGVs showed that modular ground robotic systems may, under certain conditions, disrupt or slow the advance of a mechanised adversary, particularly when reconnaissance, anti-tank and loitering-mine modules are combined [11].

By contrast, support tasks currently appear more practically feasible and more suitable for near-term employment. UGVs can reduce risk to personnel during the transport of supplies, casualty evacuation, engineer activities, reconnaissance or operations in hazardous areas. Studies focused on CASEVAC/MEDEVAC indicate that distributed employment of UGVs can shorten evacuation times, enable casualty prioritisation and reduce the exposure of medical and combat personnel to direct threats [12], [13]. Moreover, publicly available evidence from recent operations remains fragmented and unevenly verifiable, which requires combining academic literature, experimental results, technical studies and cautiously interpreted open sources [10], [14].

This article addresses the identified gap by linking findings from academic literature, experimental and simulation studies, and three distinct operational environments: Syria, Gaza and Ukraine. The aim is not merely to describe UGV/UGS capabilities, but to identify the conditions under which these systems generate actual operational effect. The article therefore focuses on the main UGV/UGS roles, recurring technical, tactical and organisational limitations, and practical recommendations for the further development of land forces. In addition to a targeted review and comparison of case-based findings, the article is supported by a structured expert consultation aimed at verifying the practical relevance of the identified trends, limitations and recommendations. Selected military practitioners assessed key statements on a scale from 1 to 5 and had the opportunity to add a short comment on UGV/UGS employment.

The main research question is:

Which UGV/UGS roles demonstrate the highest degree of practical utility across different operational environments, and what technical, organisational and tactical limitations constrain their effective employment in contemporary land operations?

The initial assumption of the article is that the greatest near-term potential of UGV/UGS lies in tasks that reduce risk to personnel, rather than in the direct replacement of infantry or combat vehicles [11], [13].

2. Theoretical Background and Analytical Framework

For the purposes of this article, UGV/UGS are understood as ground robotic or unmanned systems designed to perform military tasks without the direct physical presence of a crew on the platform. They may be remotely controlled, partially autonomous or autonomous to a limited degree. However, robotisation should not be equated with full autonomy. The ALFUS framework emphasises that autonomy is not a one-dimensional attribute, but depends on mission complexity, environmental difficulty and the level of interaction between humans and the system [7].

This distinction is also important for assessing current experience from combat operations. Many platforms referred to as UGVs are, in fact, predominantly remotely operated. Their utility therefore depends not only on the design of the platform itself, but also on the quality of communications, sensor picture, operator situational awareness and the ability to integrate the system into command and control. Requirements for a ground control station for heterogeneous robotic systems show that the key capabilities include movement planning, monitoring the status of assets, sharing imagery and sensor data, and supporting the commander’s decision-making process [8].

From the perspective of military employment, UGV/UGS can be divided into several main roles. These include engineer and EOD tasks, protection of facilities and perimeters, ISR and reconnaissance tasks, logistics, CASEVAC/MEDEVAC and direct combat support. Each of these roles places different demands on mobility, autonomy, communications, resilience and operation. For example, UGS used for the protection of static facilities may operate in a relatively defined area and report intrusions to a quick reaction force, whereas combat UGVs in contact with the adversary must cope with faster changes in the situation, higher attrition and greater C2 requirements [3], [11].

Available sources indicate that support tasks are currently more practically feasible than the direct replacement of infantry or combat vehicles. In the field of CASEVAC/MEDEVAC, UGVs can shorten evacuation times, enable casualty prioritisation and reduce personnel exposure to direct threats. Simulation studies also show that front-line evacuation UGVs are likely to face a significant risk of losses and should therefore be designed as low-cost, functionally sufficient and attritable assets [12], [13].

Direct combat employment of UGVs is promising, but more demanding. An experiment with the attritable Laykka UGV showed that small modular UGVs can disrupt or slow the advance of a mechanised adversary in a defensive scenario, particularly when reconnaissance, anti-tank and loitering-mine modules are combined [11]. Related work on swarm manoeuvre of combat UGVs indicates that the effective employment of multiple platforms requires the planning of coordinated manoeuvre axes, time synchronisation of movement, and consideration of terrain, weather and the disposition of friendly and enemy forces [5]. These findings, however, should not be interpreted as evidence that combat UGVs are generally ready to replace manoeuvre units. Rather, they indicate that combat UGVs have potential as coordinated, attritable and task-oriented assets, provided that they are integrated into C2 and tactical planning.

One of the most significant limitations is communication and resilience against interference. Practical experiments with the VIGILANT platform showed that radio communication can be substantially limited by terrain, obstacles and electronic interference. In the tests, the connection between the UGV and the ground control station could be completely blocked by jamming. Mobile data networks, including 5G, may provide low latency and wider range in covered areas, but they are not in themselves a universal solution for the combat environment [14].

Another limitation is mobility and navigation in terrain. Ground systems operate in an environment characterised by microrelief, vegetation, obstacles, cover and concealment, and limited visibility. Studies focused on GNSS and navigation show that positioning accuracy may be significantly degraded in forested and complex terrain. It is therefore necessary to develop combinations of GNSS/INS, sensor fusion, passive sensors and vision-based navigation for environments in which GNSS is unavailable, jammed or unreliable [6], [10].

Assessing UGV/UGS therefore requires more than examining the platform, its armament or payload capacity. It is necessary to assess the entire system of employment: the task, environment, level of control, communication resilience, operator workload, logistic sustainability and acceptable attrition. This article therefore uses the analytical framework presented in Table 1. The same framework is also used for the structured expert consultation, the purpose of which is to verify the practical relevance of the identified trends and limitations.

Table 1.

Analytical framework for assessing UGV/UGS employment

Assessment category	**Assessment focus**	**Main analytical question**	**Examples of relevant sources**
System role	Engineer/EOD tasks, facility protection, ISR, logistics, CASEVAC/MEDEVAC, direct combat support	What task is the UGV/UGS used for and what problem is it intended to solve?	[3], [13]
Level of control and autonomy	Teleoperation, partial autonomy, autonomy, human role in the decision-making cycle	Is the system dependent on the operator, or can it perform part of the task independently?	[7], [8]
C2 and communications	GCS, COP, data flows, quality of communications, coordination of multiple platforms, EW, jamming, degraded mode	Can the system perform the task independently or as part of a group under limited communications or jamming?	[5], [8], [14]
Mobility and environment	Terrain, vegetation, urban environment, obstacles, GNSS-denied conditions	Is the platform capable of movement and navigation in a real operational environment?	[6], [10]
Operational effect	Risk reduction for personnel, time savings, coordinated manoeuvre, disruption of the adversary, sustainment, attritability	Does the system provide a measurable or practically significant advantage in a specific tactical task?	[5], [11], [12]

The proposed framework is not intended merely for the descriptive classification of findings, but as an analytical tool for identifying the relationship between technological potential and operational utility. By combining the individual categories, it is possible to assess the conditions under which the capabilities of a system overlap with the requirements of a specific tactical task. This approach makes it possible to move beyond a purely platform-centred assessment and to focus on the system-level employment of UGV/UGS. Direct combat employment should therefore not be assessed solely on the basis of a platform's armament or payload capacity, but according to its system integration, resilience, sustainability and tactical utility.

3. Methodology

The article is based on a targeted structured review of academic literature, a qualitative comparison of selected cases and a structured expert consultation. It is not a fully systematic review in the PRISMA sense, but an analytically oriented overview focused on the current utility of UGV/UGS in combat and support roles. Sources were identified through targeted searches in academic databases and publishing platforms, particularly Web of Science and Google Scholar, and were supplemented by relevant academic and open sources. The selection focused primarily on the period 2023–2026, while older sources were used where they provide theoretical or terminological grounding, for example in the field of autonomy. Academic literature was used mainly to define UGV/UGS roles, autonomy, C2, navigation, mobility, CASEVAC/MEDEVAC and the experimental verification of selected modes of employment [7], [14]. Open sources serve primarily as an additional layer for placing the findings into the current operational context.

The cases were selected deliberately. Syria was chosen as a case that makes it possible to distinguish between engineer and combat employment of ground robotic systems. Gaza was included due to the urban, perimeter-security and protection-related character of operations, although publicly verifiable information on the specific employment of UGVs is more limited in this case. Ukraine represents the most dynamic case, as it shows the rapid adaptation of unmanned systems in an environment of intense electronic warfare, high attrition and growing UAS/UGV cooperation. For each case, the categories defined in the analytical framework were examined: UGV/UGS role, mode of control, degree of autonomy, C2 requirements, communication and EW limitations, terrain mobility, operator workload, attrition, logistic sustainability and linkage to land forces. This approach makes it possible to compare not only individual platforms, but above all the way in which they are integrated into the activities of land forces.

Special attention was paid to experimental, simulation and modelling studies, as these provide more structured data than most open sources from ongoing conflicts. Studies focused on combat employment of UGVs make it possible to assess their potential to disrupt or slow an adversary, while work on swarm manoeuvre of combat UGVs broadens the perspective on the planning and coordination of multiple platforms in the tactical space [5], [11]. Studies on CASEVAC/MEDEVAC then demonstrate the potential use of UGVs in casualty evacuation and risk reduction for personnel [13]. These sources, however, are not interpreted as direct evidence of operational effectiveness under all conditions, but rather as partial findings from modelled or experimental scenarios.

Given the different evidential value of the sources, an implicit hierarchy of evidence was applied during interpretation. Experimental, simulation and modelling studies were given the greatest weight because they provide more structured data and more clearly defined scenarios. Technical studies were used primarily to identify limitations related to mobility, navigation, communications and endurance. Open sources concerning recent conflicts were treated as a contextual layer that helps capture current developments, but often does not allow full verification of the scale, circumstances or outcomes of specific employment [10], [14].

The structured expert consultation was used as a supporting validation element. Ten military practitioners participated in the consultation. Its aim was not statistical generalisation, but the verification of the practical relevance of the identified trends, limitations and recommendations. Respondents assessed eight statements on a scale from 1 to 5, where a higher value indicated a higher degree of agreement or relevance. They then selected up to three UGV/UGS roles with the greatest potential for short-term implementation. The results of the consultation were used as an interpretative layer for the literature review and case comparison, not as a standalone quantitative survey.

The results are processed qualitatively. The case-based section first summarises findings from Syria, Gaza and Ukraine. These findings are then compared across cases and transformed into a synthesis of the main trends. The discussion interprets which UGV/UGS roles are currently the most practically applicable, which limitations hinder their broader combat employment, and what steps can be recommended for the further development of land forces. The aim is to identify recurring findings, compare them within a unified analytical framework and formulate practically applicable conclusions for the further development of land forces.

4. Results: Case-Based Findings

This section presents findings from three analytically selected cases: Syria, Gaza and Ukraine. These cases are not treated as directly comparable, as they differ significantly in the intensity of conflict, technological context and availability of verifiable data. The analysis therefore applies a comparative triangulation approach, in which each case represents a different evidential perspective. The aim is not quantitative comparison, but the identification of recurring patterns, limitations and UGV/UGS roles across different operational environments.

4.1 Syria

The Syrian case is relevant to this article primarily because it makes it possible to distinguish between relatively tangible engineer employment of UGV/UGS and more ambitious direct combat employment. Publicly available information on this conflict is limited and often has the character of open sources rather than systematically verified data. Nevertheless, the case supports the broader conclusion that, in the near term, ground robotic systems are more suitable for tasks that are hazardous but relatively clearly defined, such as mine clearance, reconnaissance, handling of hazardous objects or engineer support. This conclusion is consistent with broader findings on robotics for engineer operations, where the primary aim is to reduce risk to specialists and enable operations in areas where human deployment would be too dangerous [9].

Syria also shows that direct combat employment of UGVs faces a different set of problems than support tasks. A combat platform must be able to move in complex or urban terrain, maintain stable communications, provide a sufficient sensor picture and be integrated into the unit decision-making process. If these conditions are not met, a combat UGV becomes a technically interesting but tactically limited asset. Practical experiments with UGVs also indicate that radio communication, mobility, endurance, camera imagery and operator workload are among the decisive factors that can substantially limit platform usability under real conditions [14].

The main finding from the Syrian case is therefore the difference between tasks in which a slower tempo, greater preparation and a controlled environment can be accepted, and tasks requiring rapid decision-making in contact with the adversary. The higher the dynamics and uncertainty of the operational environment, the more pronounced the limitations of current UGV/UGS become, particularly in communication, situational awareness, mobility and tactical integration. Support and engineer tasks therefore appear more practically feasible than direct combat employment.

4.2 Gaza Strip

Gaza represents the case with the lowest level of publicly verifiable evidence on the specific employment of combat UGVs. Its relevance for this article therefore lies not in quantifying the platforms used, but in the character of the operational environment. Dense urban terrain, short distances, obstacles, limited observation, underground infrastructure and a high risk of contact with the adversary create conditions in which the limitations of ground robotic systems become particularly pronounced. Such an environment increases the relevance of robotics for reconnaissance, checking suspicious areas, perimeter protection, engineer support and activities in which reducing the direct exposure of soldiers to risk is desirable.

In this sense, Gaza supports the conclusion that UGV/UGS may be valuable primarily as support and security assets, rather than necessarily as an independent combat force. Ground robotic systems for the protection of static facilities or perimeters can complement human patrols, extend the surveillance area and provide information to a quick reaction force

[3]. Similarly, robotics for engineer operations shows potential for activities in unknown, hazardous or difficult-to-access environments, where the primary aim is to reduce risk to personnel [9].

The Gaza case must, however, be interpreted with particular caution, as publicly available sources do not allow the reliable determination of the scale, frequency or operational effect of specific UGV/UGS employment. Its contribution lies rather in the fact that it represents a “stress model” of the urban environment, in which key UGV/UGS limitations accumulate: limited visibility, obstacles, short distances, high risk of contact, difficult communications and low verifiability of available data.

4.3 Ukraine

Ukraine represents the most dynamic case in the current development of UGV/UGS. Compared with Syria and Gaza, it offers a broader range of publicly available examples and an environment in which unmanned systems are rapidly adapting to frontline needs. Academic and open sources indicate that combat UGVs in Ukraine are not an isolated phenomenon, but part of a wider unmanned ecosystem that includes UAS, reconnaissance, electronic warfare, data connectivity, logistics and improvised strike assets. At the same time, many ground systems remain predominantly remotely operated, and their effectiveness depends heavily on communications, resilience to EW, the availability of operators and the ability to repair or replace systems rapidly [4].

The Ukrainian case strongly supports the thesis that UGV/UGS are currently most suitable for support and high-risk tasks. These include transport of supplies, casualty evacuation, reconnaissance, engineer activities, ammunition delivery and operations in areas where human movement would be too dangerous. Studies focused on evacuation UGVs indicate that, under certain conditions, these systems can enable evacuation to begin even during ongoing combat activity, while also requiring acceptance of a high risk of losses and a design philosophy based on low-cost, functionally sufficient and attritable systems [12].

Direct combat employment of UGVs in Ukraine is significant, but should be interpreted cautiously. Experimental sources show that attritable modular UGVs can create disruption, slow an adversary’s advance and act as a force multiplier in a defensive scenario [11]. Experience from Ukraine, however, also suggests that this effect depends on integration with reconnaissance, command, operators, tactics and the ability to adapt rapidly. A UGV is not, by itself, a replacement for infantry or combat vehicles. Its value increases when it forms part of a wider system that can exploit its advantages and compensate for its vulnerabilities.

Ukraine also highlights the importance of electronic warfare, communications and sustainment. UGVs operating close to the line of contact must be expected to face loss of communication, jamming, limited endurance, demanding repairs and a high probability of damage or destruction. Practical experiments with UGVs confirm that without reliable communications, backup modes, sufficient endurance, simple maintenance and an adequate sensor picture, the utility of a ground robotic system is significantly reduced [14]. This supports the requirement for modular, low-cost, repairable and attritable designs.

4.4 Cross-case synthesis

The synthesis of the cases suggests that the utility of UGV/UGS is not primarily a function of the technological maturity of the platform, but of the degree of alignment between the character of the task, the operational environment and the limitations of the system. Comparison of the three cases reveals several recurring trends. First, UGV/UGS are most useful in tasks that reduce risk to personnel and do not require full autonomy in dynamic contact with the adversary. Second, direct combat employment is possible, but requires a higher level of system integration, C2, resilient communications and training. Third, publicly available evidence is uneven: Ukraine provides the broadest evidence base, Syria mainly illustrates the distinction between engineer and combat employment, and Gaza highlights the specific demands of the urban environment and the limits of data verifiability.

Table 2.

Cross-case synthesis of UGV/UGS employment

Case	Main UGV/UGS roles	Main contribution	Main limitations	Strength of evidence	Implications for the article
Syria	Engineer support, EOD, selected attempts at combat employment	Risk reduction for specialists; use in hazardous but relatively clearly defined tasks	C2, mobility, sensors, control in urban terrain	Medium / limited	Support and engineer roles are more practically feasible than direct combat employment
Gaza Strip	Protection, reconnaissance, urban/perimeter security, potential engineer support	Possibility to reduce risk in an urban and restricted-access environment	Low verifiability of data; urban terrain; obstacles; communications	Low	The case serves more as an indication of urban-environment requirements than as hard evidence of effectiveness
Ukraine	Logistics, CASEVAC/MEDEVAC, ISR, reconnaissance,	Rapid adaptation; risk reduction for personnel;	EW, communications, endurance,	Medium to higher	Best illustrates the trend towards low-cost, modular, network-

	strike and combined UAS/UGV employment	possibility of attritable employment	attrition, repairs, operator workload		integrated and attritable UGVs

The case-based synthesis shows that current UGV/UGS should not be assessed only by whether they can carry weapons or operate independently against the adversary. More important is their ability to fit into a specific tactical task. In support roles, they can provide practical effects relatively quickly: reducing risk to personnel, extending reconnaissance, supporting evacuation, protecting facilities or delivering supplies. Direct combat employment has greater potential to alter the balance of forces, but at the same time requires more robust C2, better situational awareness, operator training, tactical procedures and realistic acceptance of losses [11], [14].

This synthesis provides the basis for the discussion section and is further confronted with the results of the structured expert consultation.

5. Discussion: Lessons and Ways Forward

The previous case-based synthesis suggests that the main question is not whether UGV/UGS have military potential, but in which roles, under what conditions and at what level of risk they can generate actual operational effect. Current findings show that the greatest practical value lies in tasks in which UGVs reduce personnel exposure to danger, extend situational awareness or enable activities in areas where human presence would be too risky. This applies particularly to engineer support, EOD, facility protection, reconnaissance, logistics and casualty evacuation [3], [13]. The findings also indicate the need for a conceptual shift in thinking about UGV/UGS. Rather than asking whether they can replace existing platforms, it is more appropriate to analyse how they can restructure the distribution of risk within a unit. UGVs can therefore be understood as a means of redistributing exposure between humans and technology: humans retain decision-making, tactical judgement and responsibility, while the robotic asset assumes part of the physical risk in hazardous areas.

The first key lesson is therefore pragmatic: in the short term, UGV/UGS should not be viewed as a replacement for infantry or combat vehicles, but as assets for taking over risky, repetitive or attritable tasks. Direct combat employment may have a significant effect, especially if the platform is low-cost, modular and designed to disrupt the adversary's advance. A virtual experiment with the Laykka platform showed that small attritable UGVs can slow or disrupt the advance of a mechanised adversary in a defensive scenario, particularly when reconnaissance, anti-tank and loitering-mine modules are combined [11]. This result, however, should not be understood as universal evidence that combat UGVs are ready for all types of operations.

The second lesson concerns the difference between combat potential and actual operational utility. A UGV may carry a sensor, payload or weapon, but its real value depends on its ability to function in a specific environment and within a specific tactical system. If the platform loses communications, has a limited sensor picture, becomes immobilised in terrain, requires excessive operator attention or is not integrated into C2, its practical value decreases rapidly. Experimental findings from ARTEX and REPMUS indicate that communications, mobility, endurance, teleoperation and operator situational awareness are among the decisive factors affecting UGV usability under real conditions [14].

The third lesson concerns C2 and electronic warfare. UGV/UGS cannot be introduced merely as standalone platforms. They must be designed as part of a wider system that includes GCS, COP, sensor data transmission, task planning, backup communication channels and degraded-mode procedures. Requirements for a ground control station for heterogeneous robotic systems show that commanders and operators need not only to control the platform, but also to understand its position, status, communications, sensor picture and relationship to other assets [8]. Without this layer, combat UGVs become difficult to control and tactically fragile.

Another direction of development is the ability to employ multiple UGVs in a coordinated manner within a single tactical task. Swarm or group manoeuvre of combat UGVs should not be understood merely as a technological ambition, but as a problem of planning, synchronisation, task allocation and integration into the digital battlefield. Work on the planning of swarm manoeuvre of combat UGVs shows that the effective employment of multiple platforms requires the calculation of manoeuvre axes, consideration of terrain passability, force disposition and time coordination of approach to the target [5]. For land forces, this means that the further development of UGV/UGS must include not only platforms, but also tools for tactical planning and decision support.

The effectiveness of UGV/UGS is also influenced by adversary adaptation. The adversary can actively disrupt communications, target system vulnerabilities, destroy operator and retransmission elements, or adapt its own tactics. UGVs must therefore be understood as part of a dynamic interactive environment, not as a static capability. This further reinforces the requirement for resilient C2, backup modes of control, low cost, repairability and the ability to rapidly replace lost assets.

The fourth lesson concerns attrition. UGVs operating close to the line of contact must be designed with a realistic assumption of damage or destruction. A study of evacuation UGVs in a defensive scenario showed a high loss rate, but also the possibility of successfully conducting part of the evacuation before the complete end of combat activity [12]. This implies that, for selected tasks, the aim is not to create an expensive and difficult-to-replace platform, but a low-cost, functionally sufficient, modular and repairable asset. UGVs operating close to contact should therefore be understood more as *attritable assets* than as conventional protected combat vehicles. From this perspective, the loss of a platform does not necessarily represent system failure if the asset fulfils its task, reduces risk to personnel or disrupts adversary activity.

The fifth lesson relates to human-robot teaming. Even a relatively simple UGV requires a clear division of roles between the commander, operator, infantry unit, engineers, medical element or ISR element. If the operator is overloaded, if the unit does not understand the platform's capabilities and limitations, or if tactical procedures for human-robot cooperation are not established, the system's contribution decreases. The introduction of UGV/UGS should therefore be accompanied by SOP development, training, safety rules, tactical drills and realistic field experiments [1], [14].

From the perspective of further land-force development, an evolutionary rather than a disruptive approach can therefore be recommended. In the first phase, priority should be given to roles with a clear benefit and relatively lower autonomy requirements: logistics, CASEVAC/MEDEVAC, EOD, engineer support, facility protection and reconnaissance. Only on the basis of acquired experience, established SOPs and verified C2 should employment be gradually expanded into more direct combat roles. This approach reduces the risk that UGVs will be procured as technically attractive platforms without clear tactical anchoring.

For practical decision-making, a simple role-suitability matrix can be used. Its aim is not to quantify effectiveness precisely, but to show clearly which roles are currently the most practically applicable and which require further development, experimentation and validation. The matrix combines two perspectives: the level of practical/technical readiness and the level of combat risk or exposure.

Table 3.

Indicative matrix of UGV/UGS role suitability and combat exposure

UGV/UGS role	**Practical/technical readiness**	**Combat risk / exposure**	**Interpretation for implementation**
EOD / mine clearance	High	Medium	Suitable for priority implementation; clear contribution to risk reduction
Facility protection / perimeter security	Medium to high	Low to medium	Suitable for controlled environments and SOP development
ISR / reconnaissance	Medium	Medium	Suitable when integrated with C2 and other sensors
Logistics / resupply	Medium	Medium to high	Suitable as attritable support in high-risk areas
CASEVAC / MEDEVAC	Medium	High	Promising, but requires integration with medical and C2 systems
Coordinated/swarm manoeuvre of combat UGVs	Low to medium	High	Promising direction; requires C2, manoeuvre planning, synchronisation and further validation
Direct fire support	Low to medium	High	Requires further experimentation, training and C2/EW solutions
Loitering-mine / expendable UGV	Medium	High	Suitable as a disruptive and attritable asset
Autonomous attack / replacement of infantry	Low	Very high	Currently a long-term direction rather than a short-term priority

This matrix supports the main conclusion of the article: the most promising applications are not necessarily the most ambitious combat applications, but those roles that solve a specific problem of land forces while corresponding to current technical possibilities. UGV/UGS have the greatest near-term potential where they reduce risk, save time, extend the reach of the unit or enable action in hazardous areas. Direct combat employment is relevant, but should be developed gradually, based on experiments, realistic training and verified tactical procedures [11], [14].

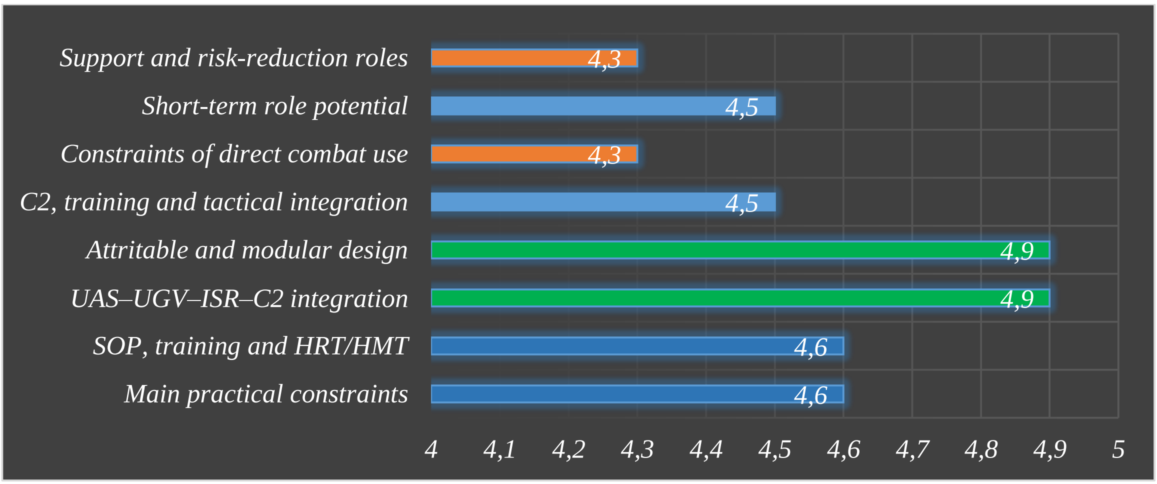

Fig. 1. Mean expert assessment of UGV/UGS employment-related statements (n = 10, scale 1–5)

The structured expert consultation supported the main findings of the article (Fig. 1). The overall mean score of the eight assessed statements reached 4.58 out of 5, indicating a high level of agreement among respondents with the identified trends and recommendations. The strongest agreement was achieved for the requirement that UGV/UGS operating close to the line of contact should be low-cost, modular, repairable and attritable. An equally strong level of support was expressed for the need to develop UGV/UGS together with UAS, ISR and digital C2.

The selection of priority roles further confirmed the pragmatic direction of UGV/UGS implementation. Logistics/resupply was selected most frequently, by 9 out of 10 respondents. This was followed by CASEVAC/MEDEVAC and EOD/engineer support, each selected by 5 respondents, followed by facility protection/perimeter security and ISR/reconnaissance. Direct fire support was selected by only 2 respondents, loitering-mine/attritable UGV by 1 respondent, and autonomous attack or replacement of infantry was not selected by any respondent. This supports the conclusion that the near-term potential of UGV/UGS is perceived primarily in support and high-risk tasks, rather than in the autonomous replacement of manoeuvre units.

From an application perspective, five recommendations can be formulated. First, UGV/UGS should initially be introduced in roles with a clear and measurable contribution to reducing personnel risk. Second, requirements for C2, EW resilience and degraded-mode operation must be defined already at the conceptual stage, not only after platform acquisition. Third, systems intended to operate close to the line of contact should be modular, repairable and attritable. Fourth, UGV/UGS must be developed together with UAV, ISR and digital C2, rather than as isolated assets. Fifth, implementation must be linked to training, SOPs, experimentation and continuous assessment of effects in realistic scenarios.

Overall, UGV/UGS represent an important direction in the development of land forces, but their greatest value does not lie in the robotic platform itself. The decisive factor is the ability to turn the platform into a functional combat or support capability. This requires the integration of technology, tactics, training, C2, logistics and a realistic approach to losses. Only this combination can enable ground robotic systems to generate actual operational effect rather than merely serve as technological demonstrations.

6. Limitations

This article has several limitations that must be taken into account when interpreting the results. The first limitation concerns the character of the source base. Findings from recent operations are partly based on open sources, whose degree of verifiability differs significantly across the selected conflicts. The most extensive information is available on Ukraine, whereas publicly verifiable data on the specific employment of UGV/UGS are more limited in the cases of Gaza and, to some extent, Syria. The results should therefore not be understood as a complete overview of all platforms employed or as a quantitative assessment of their operational effectiveness.

The second limitation concerns the different character of the evidence used. The article combines academic literature, experimental and simulation studies, technical sources and open-source findings from conflicts. Each type of source has a different evidential value. Simulation and experimental studies provide more structured data, but they are limited by a specific scenario, simplifying assumptions and a modelled environment [11], [12]. Technical studies describe limitations related to mobility, navigation, communications or endurance more precisely, but they do not in themselves demonstrate operational effect under combat conditions [10], [14]. Open sources are current, but often do not allow reliable verification of the scale, frequency or outcome of specific employment.

The third limitation concerns the scope of the case comparison. Syria, Gaza and Ukraine were not selected as fully comparable conflicts, but as different evidential layers that make it possible to identify recurring trends and limitations. For this reason, the findings cannot be transferred mechanically from one conflict to another. Syria is useful mainly for distinguishing between support and combat employment, Gaza for discussing the urban and security environment, and Ukraine for analysing the rapid adaptation of unmanned systems in an environment of intense electronic warfare. This diversity is useful for qualitative synthesis, but it limits the possibility of direct quantitative comparison.

The fourth limitation is that the article does not assess specific national acquisition programmes, the technical parameters of all available UGV/UGS, or a complete organisational model for their introduction into land forces. It focuses on general lessons learned and practical ways forward. The recommendations are therefore conceptual in nature and must be further verified under specific conditions, for example through military experiments, tactical exercises, simulations, interoperability testing and sustainment assessment.

The structured expert consultation had a supporting role. It involved 10 military practitioners, whose responses were evaluated anonymously and in aggregated form. The results cannot be interpreted as a representative quantitative survey or statistically generalised to the armed forces as a whole. Their value lies primarily in the practical verification of the relevance of conclusions derived from the review, case comparison and experimental studies.

Further research should focus primarily on the systematic verification of UGV/UGS under realistic conditions. Priority areas include C2 resilience in an electronic warfare environment, reliable communications, real mobility in urban and complex terrain, operator workload, sustainment, endurance, field repair, attrition and measurable operational effect. Human-robot teaming also deserves particular attention, because without appropriate SOPs, training and tactical procedures, the platform itself cannot be expected to generate a usable combat capability.

7. Conclusions

The main conclusion of this article is that current UGV/UGS do not represent a revolutionary replacement for existing combat systems, but rather an evolutionary extension of land-force capabilities. Their real value lies in their ability to take over high-risk tasks, extend the reach of a unit, support situational awareness and enable operations in highly hazardous environments. Findings from Syria, Gaza and Ukraine, complemented by academic literature, experimental results and a structured expert consultation, support a pragmatic rather than revolutionary view of their implementation.

Support, engineer, reconnaissance, logistics and evacuation tasks currently appear to be the most suitable areas of employment. UGV/UGS can provide practical effects in EOD and mine clearance, facility protection, reconnaissance, supply transport, CASEVAC/MEDEVAC and other activities where it is desirable to limit soldiers' direct exposure to risk. At the same time, simulation and experimental studies show that even support roles require realistic solutions for communications, endurance, mobility, maintenance and integration into command and control [12], [13], [14].

Direct combat employment of UGVs remains promising, but it is technically, tactically and organisationally more demanding. Experiments with attritable and modular UGVs suggest that such assets may disrupt or slow the adversary's advance and act as force multipliers [11]. Further development may move towards the coordinated or swarm employment of multiple combat UGVs; however, this requires advanced manoeuvre planning, time synchronisation, resilient C2 and verification in realistic scenarios [5]. This potential should therefore be developed gradually and in connection with tactical procedures, training, interoperability and the ability to accept platform losses.

From the perspective of further land-force development, the introduction of UGV/UGS should begin with roles that have a clear and practically verifiable benefit. At the same time, requirements for C2, EW resilience, degraded-mode operation, endurance, sustainment, training and SOPs must be defined already at the conceptual stage. Systems intended to operate close to the line of contact should be low-cost, modular, repairable and attritable, and should be developed in connection with UAS, ISR and digital C2.

The main contribution of this article lies in the development of an analytical framework that makes it possible to assess UGV/UGS not according to their technological attractiveness, but according to their actual operational utility. The decisive question is not whether the platform is robotic or armed, but whether it solves a specific problem for land forces, whether it can be integrated into C2, whether it is sustainable in the field and whether its employment provides a proportionate effect in relation to risk, cost and attrition. This pragmatic conclusion was also supported by the structured expert consultation, in which respondents most frequently preferred logistics, CASEVAC/MEDEVAC, EOD/engineer support, facility protection and reconnaissance as the roles with the greatest short-term potential. This approach may provide a useful basis for further experimentation, conceptual work and the gradual introduction of ground robotic systems into military practice.

Acknowledgements. The authors would like to thank the military experts who participated in the structured expert consultation. Their practical insights contributed to the validation of the identified trends, limitations and recommendations concerning the employment of UGV/UGS in land operations.

References

1. **Hrdinka J., Nohel J., Zezula J., Mazal J.** Možnosti podpory činnosti pěších jednotek bojovými bezosádkovými prostředky za útoku. Vojenské rozhledy, 2025, 34(1), p.120–135. https://doi.org/10.3849/2336-2995.34.2025.01.120-135
2. **Hrnčiar M., Kompan J., Nohel J.** The future of the battlefield: Technology-driven predictions in the land domain. Revista Científica General José María Córdova, 2025, 23(49), p.277–296. https://doi.org/10.21830/19006586.1323
3. **Nohel J., Srb D., Hrdinka J., Hrnčiar M.** Možnosti využití pozemních robotických systémů jako prvku ochrany statických vojenských objektů. Vojenské rozhledy, 2025, 34(2), p.179–200. https://doi.org/10.3849/2336-2995.34.2025.02.179-200
4. **Zahradníček P., Hrdinka J., Böhm K.** Current challenges for utilization of combat unmanned ground vehicles. Vojenské reflexie, 2025, 2025(3), p.45–56. https://doi.org/10.52651/vr.a.2025.3.45-56
5. **Nohel J., Stodola P., Flasar Z., Křišťálová D., Zahradníček P., Rak L.** Swarm Maneuver of Combat UGVs on the Future Digital Battlefield. In Modelling and Simulation for Autonomous Systems. MESAS 2022. Eds. Mazal J., Fagiolini A., Vašík P., Bruzzone A., Pickl S., Neumann V., Stodola P., Lo Storto S. Springer, Cham, 2023, LNCS 13866, p.209–230. https://doi.org/10.1007/978-3-031-31268-7_12
6. **Rybanský M., Kratochvíl V., Dohnal F., Gerold R., Křišťálová D., Stodola P., Nohel J.** GNSS Signal Quality in Forest Stands for Off-Road Vehicle Navigation. Applied Sciences, 2023, 13(10), 6142. https://doi.org/10.3390/app13106142
7. **Huang H.-M., Pavek K., Albus J., Messina E.** Autonomy Levels for Unmanned Systems (ALFUS) Framework: An Update. In Proceedings of the 2005 SPIE Defense and Security Symposium, Orlando, Florida, 2005.
8. **Nohel J., Rak L., Zezula J., Flasar Z., Hradský L., Křišťálová D.** The Requirements of Commanders on Ground Control Station of Heterogenous Swarm Robotic Systems. In Modelling and Simulation for Autonomous Systems.

MESAS 2024. Ed. Mazal J. et al. Springer, Cham, 2026, LNCS 15761, p.3–18. https://doi.org/10.1007/978-3-031-99732-7_1
9. **Lopez-Toledo I., Miranda-Ramirez J., Charter D., Soylemezoglu A. Robotics** for Engineer Operations. In Modelling and Simulation for Autonomous Systems. MESAS 2024. Ed. Mazal J. et al. Springer, Cham, 2026, LNCS 15761, p.111–134. https://doi.org/10.1007/978-3-031-99732-7_8
10. **Nowakowski M.** Development Challenges of Unmanned Ground Vehicles for Special Purpose Use. In Modelling and Simulation for Autonomous Systems. MESAS 2024. Ed. Mazal J. et al. Springer, Cham, 2026, LNCS 15761, p.211–223. https://doi.org/10.1007/978-3-031-99732-7_14
11. **Andersson C.A., Halme K., Laine M., Hulkko V., Virtanen K.** Effectiveness of an Expendable Unmanned Ground Vehicle Stalling a Mechanized Infantry Company's Primary Combat Units—A Virtual Simulation Experiment. Journal of Field Robotics, 2025, 42, p.1125–1142. https://doi.org/10.1002/rob.22442
12. **Halme K., Andersson C., Laine M., Okkonen J., Virtanen K.** Feasibility of evacuation from the front line using unmanned ground vehicles during platoon-level defensive combat. BMJ Military Health, 2026, 0, p.1–5. https://doi.org/10.1136/military-2025-003188
13. **Procházka D., Šedivcová V., Melichar J., Tesař A., Schvach H.** Autonomous ground vehicles for MEDEVAC: capability assessment based on agent-based modelling. BMJ Military Health, 2025, 0, p.1–6. https://doi.org/10.1136/military-2024-002885
14. **Candido B., Santos N.P., Moutinho A., Zacchi J.-V.** Uncrewed Ground Vehicles in Military Operations: Lessons Learned from Experimental Exercises. In Proceedings of the 2025 IEEE International Conference on Autonomous Robot Systems and Competitions (ICARSC), 2025, p.21–26. IEEE. https://doi.org/10.1109/ICARSC65809.2025.10970121