UNIVERSITY OF SPLIT

FACULTY OF ELECTRICAL ENGINEERING, MECHANICAL ENGINEERING AND NAVAL ARCHITECTURE

DOCTORAL STUDY IN ELECTRICAL ENGINEERING AND INFORMATION TECHNOLOGY

QUALIFYING EXAM

# ARTIFICIAL INTELLIGENCE IN THE MILITARY DECISION-MAKING PROCESS: A SYSTEMATIC REVIEW

Darija Jurko

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# 1. INTRODUCTION

Military decision-making process (MDMP) is an iterative planning methodology used at the operational level of command to understand the mission and to develop a course of action (COA) based on the analysis of the situation. Commanders and their staff use this process to conduct planning and produce the operation plan (OPLAN)[1] or operational order (OPORD)[2]. This process is used for various military operations – from basic military engagements, security operations, crisis response operations to combat operation – where time, space, forces, information and risk must be synchronized. These activities occur in environments where commanders and their staff must interpret incomplete information, anticipate enemy action, manage risk, allocate resources and assets, and generate executable plans under time pressure. In contemporary military operations, decision-makers are confronted with huge amounts of data from sensors, communications systems, intelligence sources, cyber and space capabilities, unmanned platforms, simulations, and open-source information. For the commanders, this can create an opportunity, but also a burden: more data can improve understanding, but it can also overwhelm staff and slow down the conversion of data into information and finally into decisions. The accelerated tempo of modern warfare severely restricts the time available for reactions and decisions.

## 1.1. Motivation

Artificial intelligence methods are therefore being examined as technologies that may improve the speed, quality, consistency, and adaptability of military decision support. In this review, AI is treated as the broader set of computational techniques that perform tasks associated with perception, classification, prediction, reasoning, optimization, recommendation, planning, or adaptive behavior. Machine Learning (ML) refers to systems that learn patterns from data, including supervised, unsupervised, and reinforcement learning approaches. Deep learning (DL) refers to machine-learning models based on multi-layer neural networks, including convolutional, recurrent, graph-based, transformer, and other deep architectures. The review focuses on AI as support to human military decision-making and excludes studies focused on autonomous weapons or unmanned systems without a substantive decision-support component.

Military decision-making process provides a useful conceptual structure for this synthesis because it makes visible where AI systems can enter the planning cycle. There are also other military planning methodologies, such as Army design methodology (ADM), Troop leading procedures (TLP), Rapid decision-making and synchronization process (RDSP), Joint planning process (JPP), Operation planning process (OPP), depending on different levels for planning and making decisions or different organizational units that use planning process. For this review, the military decision-making process (MDMP) term will be used. The doctrinal MDMP [1], [2], [3] is commonly described as a seven-step process: receipt of mission; mission analysis; COA development; COA analysis or wargaming; COA comparison; COA approval; and orders production, dissemination, and transition. These steps represent a progressive movement from understanding the mission and operational environment, through generating and testing options, to selecting and communicating a decision. Each of these steps have their input and produce outputs based on activities performed during a particular step.

[1] An OPLAN is a comprehensive military document that translates strategic goals into executable actions. It outlines how forces will deploy, engage and sustain operations.

[2] An OPORD is the direct order issued by a commander to execute approved OPLAN. It puts the forces into action.

Figure 1.1 represents the interaction between the commander and the staff during this seven-step process. In this process, the commander provides his main intent and final decision, while his staff gather information and build detailed plans to turn the commander's intent into action.

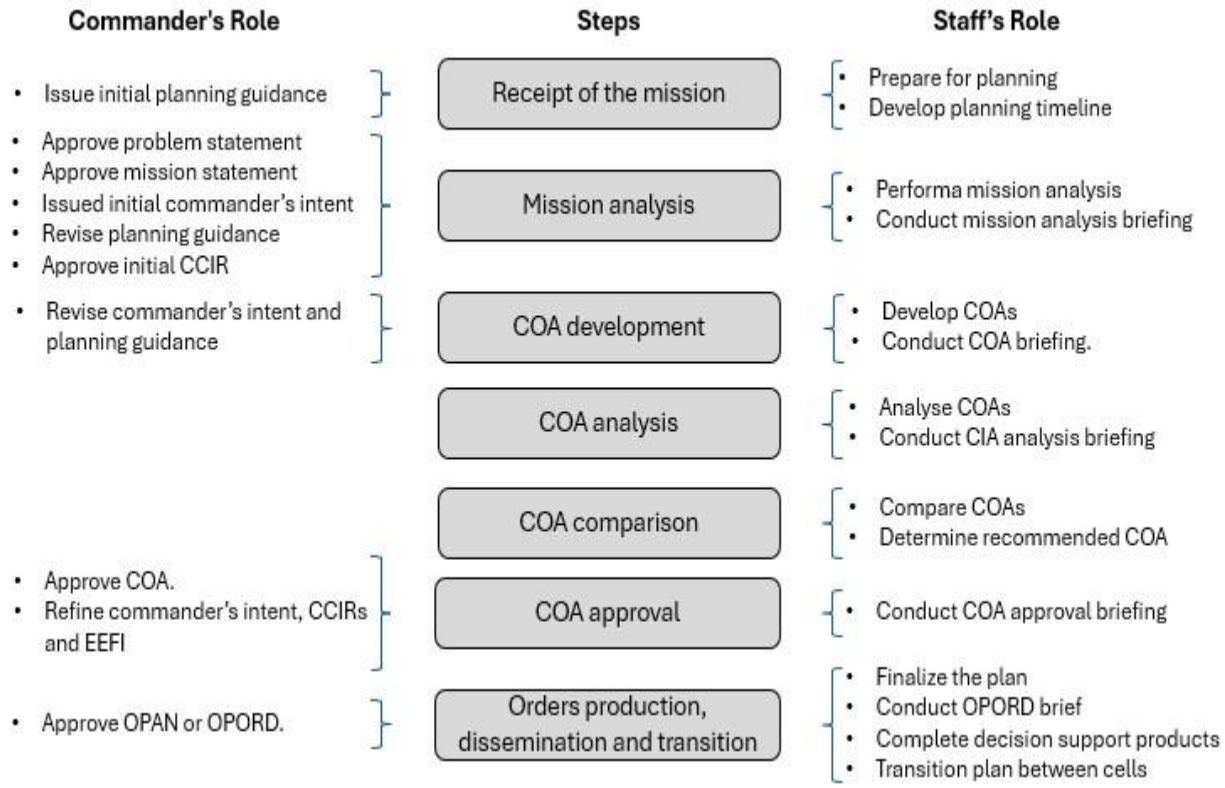


*Figure 1.1. Commander and staff interaction. Adapted from U.S. Department of the Army, Planning and Orders Production (Field Manual No. 5-0), 2024, p.79. In the public domain. [2]*

In addition, it is important to know who in the military can make decisions at which level. The levels of decision-making correspond to the levels of military command, which are defined by the levels of war/warfare. According to different national and international military publications [4], [5] there are three levels of war that characterize specific level responsibility of commander – strategic, operational and tactical, as shown in Figure 1.2. They form a framework for planning, organizing and conducting military activities. These levels connect immediate combat activities to the national objectives, by describing the relationship between strategic objectives, operational approach and tactical tasks.

**The strategic level** establishes national theater and multinational objectives by employing instruments of national power[3], focusing on national policy and the ultimate political outcome. Each nation expresses their national goals in their national security strategies, national defense strategies and joint doctrine. This level of command or decision-making is led by the highest levels

[3] There are four instruments of national power - Diplomatic, Information, Military, and Economic [5]

of government and military leadership, such as Presidents, Prime Ministers, Defense Ministers, and Joint Chiefs of General Staff.

**The operational level** links tactical employment of forces to national strategic objectives through campaigns and major operations within their assigned operational areas. Instead of focusing only on one single battle, operational commanders need to have a broader picture of what impact a series of battles will have over time and space on the enemy. Commanders that make decisions at this level are usually theater-level commanders, combatant commanders, or joint task force commander.

**The tactical level** of warfare focuses on the conduct of tactical operations, actions, battles or other engagements with tactical tasks. It is defined by engaging the enemy directly using immediate fire, maneuver and combat techniques to achieve specific objectives. Decision at this level is made by the command officers on the field and small-team leaders or ship crew (from Division, Brigade, Battalion, Company to the Squad Commanders).

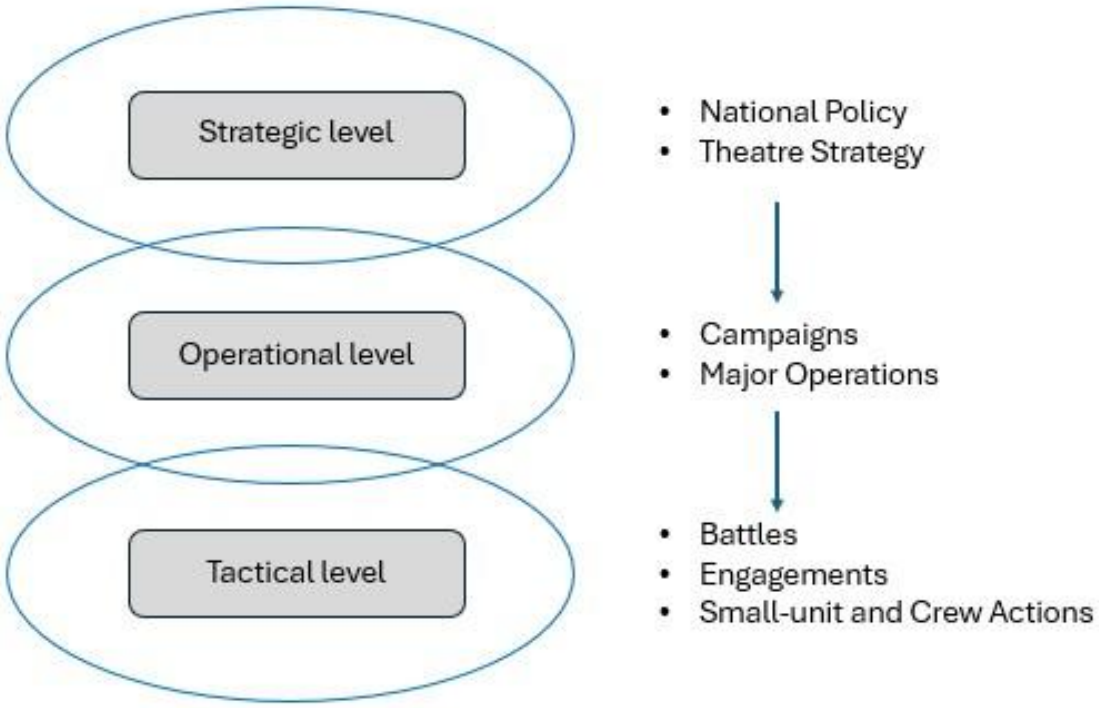


*Figure 1.2. Levels of Warfare. Adapted from U.S. Joint Chiefs of Staff Joint Publication 1 (JP-01), 2017,p.I-7. In public domain. [5]*

Military commanders at all levels of command use military operational functions (also called warfighting or combat functions) to synchronize combat power and achieve mission objectives. Numbers of operational functions vary, depending on the level of warfare and the referent doctrine. Joint level is using 7 operational functions [6] and component services use 6 operational functions [7], [8]. For further analysis in this review, 6 operational functions will be used:

- **Command and Control (C2)** – the authority and direction by the commander over assigned forces that encompasses the systems, networks and communication to synchronize all elements of combat power. This operational function encompasses technological systems that were added to support the commander's decision-making (C3[4], C4I[5], C5ISR[6]). The C2 operational factor includes an OODA loop (Observe, Orient, Decide, Act) which is the cognitive process how decisions are made and executed on the battlefield. Another cognitive mechanism that commander uses in the C2 functions is mission planning with developing and selecting COAs, so studies that cover this MDMP step will be part of this operational function.
- **Intelligence** - activities for understanding the operational environment, enemy's capabilities and vulnerabilities, and civil consideration. The process includes different tools for data gathering and data analysis to get the final product – real time data for full Situational Awareness (SA) that will eventually be fused into Common Operational Picture (COP) that defines the situation of enemy and friendly forces.
- **Fires** – the use of weapons, systems and other capabilities that will have an impact on enemy. If detecting threats and threat identification are tied directly to the tactical targeting cycle (Find, Fix, Track, Target, Engage, Assess) it will be part of this operational function because the detection/identification data feed into a weapons system. If the threat detection is used to understand the battlefield, then it is Intelligence operational function.
- **Movement and Maneuver** – the employment of forces through movement in combination with fires to get an advantage over an enemy, so resource and assets allocation will be part of this operational function.
- **Protection** – survivability of personnel and physical assets (air and missile defense, physical security and defensive cyber operations), usually called Force Protection.
- **Sustainment** – logistic support (supplies, maintenance, and distribution networks), together with personnel support and health service, will enable prolonged operations.

Uncertainty and risk assessment are central to the military decision-making process because every commander's decision is made under conditions of incomplete information, time pressure, adversary adaptation, and operational friction. The Prussian military theorist Carl von Clausewitz, in his book "On War" [9], defined the "fog of war" in the 19th century, a concept that remains valid in modern military doctrine. The term "fog of war" characterizes the structural gap between objective reality on the battlefield and a decision-maker's subjective perception of it, often exacerbated by chaotic environments, communication breakdowns, and psychological stress. In contemporary military research, it can still be used to analyze operational command, tactical decision-making, and the limitations of modern intelligence technologies.

[4] C3 (Command, Control, and Communications) - Connecting the commander to the troops (eq. adding tactical radios and satellite links)

[5] C4I (Command, Control, Communications, Computers, and Intelligence) - Processing speed and enemy data (eq. using computer networks to automatically map friendly and enemy forces).

[6] C5ISR (Command, Control, Communications, Computers, Cyber, Intelligence, Surveillance, and Reconnaissance) - Network security and automated sensor feeds (eq. utilizing cloud computing, defending its networks against cyber-attacks), while streaming live video feeds from drones (ISR) straight to a commander's tablet.

For this review, data on risk and uncertainty are extracted through several recurring categories:

- **Sensor uncertainty** (including sensor noise, inaccuracy, reliability, or incomplete observations)
- **Data uncertainty** (including missing, incomplete, outdated, conflicting, biased, or low-quality data)
- **Data-selection uncertainty** (including uncertainty regarding which data, variables, indicators, or information sources should be considered)
- **Intelligence uncertainty** (including uncertainty regarding the reliability or interpretation of intelligence information)
- **Operational uncertainty** (including uncertainty regarding the operational environment, mission conditions, or development of the operation)
- **Adversary-related uncertainty** (including uncertainty regarding adversary intentions, capabilities, behavior, or actions)
- **AI model-selection uncertainty** (including uncertainty related to the choice of AI or ML **model**)
- **AI model uncertainty** (including uncertainty related to model parameters, predictions, outputs, confidence, reliability, or generalizability)
- **COA uncertainty** (including uncertainty regarding the consequences, effectiveness, or outcomes of alternative courses of action)
- **Human-related uncertainty** (including uncertainty related to human judgement, behavior, interpretation, or interaction with the AI system)
- **System or technological uncertainty** (including software, hardware, communication, network, or decision-support-system reliability)
- **Environmental uncertainty** (including weather, terrain, hydrographic, electromagnetic, or other environmental conditions)
- **Security risks** (cybersecurity, deception, spoofing, or adversarial manipulation risk)
- **Operational risks** (risk to mission success)
- **Safety risks** (risk to personnel, civilians, equipment, or infrastructure)
- **Policy risks** (legal, ethical, escalation, or accountability risk).

These categories show that uncertainty is not limited to technical model performance. It also concerns the quality of input data, the reliability of intelligence, the changing behavior of the adversary, the assumptions used to generate and compare courses of action, and the commander's ability to interpret AI-supported recommendations. It is also important to realize when uncertainty and risk assumption are first introduced during decision-making process, as they can have a substantial impact on mission success.

### 1.2. Contribution

AI-enabled support can be mapped against steps in decision-making process as follows:

- **Receipt of mission**: The commander and staff receive or anticipate a mission, issue initial guidance, begin time management, and identify initial information requirements. AI may support rapid data ingestion, document summarization, alerting, and identification of initial information requirements.
- **Mission analysis**: The staff analyzes the higher headquarters' order, mission variables, intelligence, terrain, weather, civil considerations, constraints, specified and implied tasks, risks, assumptions, and information gaps. This step frames the problem and produces the restated mission, the commander's intent, planning guidance, and initial Commander's Critical Information Requirements (CCIRs). ML and Natural Language Processing (NLP) systems may help structure intelligence, identify constraints, classify threats, detect anomalies, map terrain and sensor data, and support staff estimates.
- **COA development**: The staff develops feasible, acceptable, suitable, distinguishable, and complete courses of action. AI may support option generation, constraint checking, force allocation, route planning, and preliminary feasibility assessment. Planning algorithms, expert systems, reinforcement learning, multi-agent systems, and generative models may propose feasible or distinguishable options for staff review.
- **COA analysis/wargaming**: Each COA is tested against likely enemy actions and operational conditions. Simulation enabled by AI, adversarial models, reinforcement learning, and agent-based methods may estimate likely outcomes, enemy reactions, risks, and implications for resources.
- **COA comparison**: COAs are compared against decision criteria such as mission success, risk, time, logistic demands, expected losses, information advantages, operational tempo, and flexibility. AI may assist with multi-criteria comparison, ranking, and trade-off visualization.
- **COA approval**: The commander selects or modifies COA. AI should support, not replace, command judgment by explaining assumptions, uncertainty, rationale, and consequences.
- **Orders production, dissemination, and transition**: The approved COA is converted into an order, disseminated to subordinate units, rehearsed, synchronized, and adapted as the situation changes. NLP and decision-support systems may help structure orders and detect inconsistencies and update plans as conditions change.

The purpose of this systematic review is to synthesize the current use of AI in the military decision-making process. The review addresses five guiding questions:

- **RQ1:** Which AI methods are most frequently applied to military decision support?
- **RQ2:** Which domains, branches, levels of decision-making, and MDMP-related functions are most represented?
- **RQ3:** What levels of maturity, validation, and human involvement are reported?
- **RQ4:** How frequently are ethical and legal concerns considered?
- **RQ5:** How are risk and uncertainty accounted for in AI-based military decision support, and when are they first introduced in the MDMP process?

### 1.3. Paper organization

The organizational structure of this systematic review is illustrated in Figure 1.3. Section 2 presents the research methodology used for the selection of articles. Section 3 presents the results on different areas of research questions. Section 4 discusses the relevant factors associated with the use of AI in military decision-making process. Furthermore, Section 5 presents the limitations and other information on this review. Finally, Section 6 summarizes the contributions of this work.

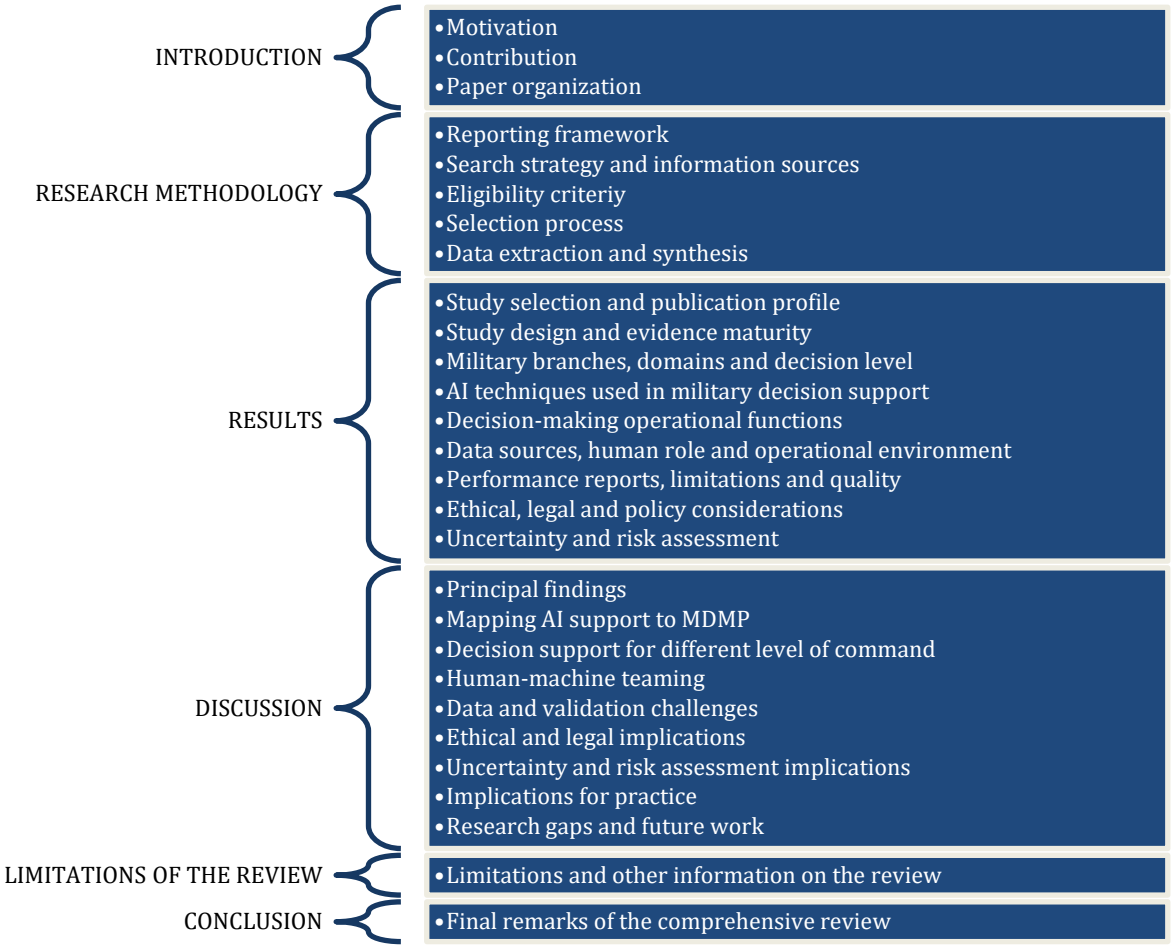


*Figure 1.3. Organizational structure of the review*

# 2. METHODS

## 2.1. Reporting framework

The review was conducted according to PRISMA 2020 reporting principles [10], [11] for transparent reporting of systematic reviews. PRISMA was used to structure reporting, identification, screening, eligibility, inclusion, and synthesis. Screening and extraction were conducted in Covidence systematic review software[7] [12]. The review synthesis was based on extracted data from included studies, and the PRISMA flow diagram, which are all provided in Covidence after the final extraction phase was finished.

## 2.2. Search strategy and information sources

The search strategy was restricted exclusively to publicly available, unclassified, and open-source literature. No classified databases or restricted proprietary military networks were searched. Search strategy included the regular expression: ("machine learning" OR "deep learning" OR "artificial intelligence") AND ("decision-making" OR "decision making" OR "decision support") AND ("crisis management" OR "military operations" OR "warfare"). The databases and sources searched were Scopus [13], ACM Digital Library [14], IEEE Xplore [15], Web of Science [16], JSTOR [17], and grey literature (military scholarly works that have not been published by commercial academic journal networks).

The initial comprehensive search was conducted on July 16th 2025, to establish a baseline dataset. However, due to the rapid technological advancements and evolving paradigms in AI methodologies during the subsequent data extraction period and synthesis, a supplementary search was executed in July 2026 (last day of search on July 20th 2026). This updated search applied identical selection criteria to capture newly published breakthroughs, emerging frameworks, and recent empirical studies. Integrating this secondary search ensures that the synthesized findings accurately reflect the current state of the art and maintain high contemporary relevance. The database-specific syntax was adapted to each source/database as shown in Table 2.1.

[7] Covidence is a web-based collaboration software platform that streamlines the production of systematic and other literature reviews.

*Table 2.1. Bibliographic database search strategy*

| Database/source | Search date or period | Search strategy / limits | No. of Records |
|---|---|---|---|
| **SCOPUS**<br><br>(560 records on 17.07.2026.) | 16.7.2025 | TITLE-ABS-KEY ( ( "machine learning" OR "deep learning" OR "artificial intelligence" ) AND ( "decision-making" OR "decision making" OR "decision support systems" ) AND ( "military operations" OR "warfare" ) | 385 |
| | 17.7.2025 – 17.7.2026 | TITLE-ABS-KEY ( ( "machine learning" OR "deep learning" OR "artificial intelligence" ) AND ( "decision-making" OR "decision making" OR "decision support systems" ) AND ( "military operations" OR "warfare" ) ) AND ORIG-LOAD-DATE AFT 20250717 AND ORIG-LOAD-DATE BEF 20260717 | 175 |
| **ACM Digital library**<br><br>(276 records on 17.07.2026.) | 16.7.2025. | AllField:(("machine learning" OR "deep learning" OR "artificial intelligence" ) AND ( "military decision-making" OR " military decision making" OR "decision support systems" ) AND ( "military operations" OR "warfare" )); ; ACM Full text collection; on 16.7.2025. | 204 |
| | 17.7.2026. | Same syntax with date change<br>to July 2025 (date could not be adapted by the day, just month) | 218 |
| | 17.7.2026. | Same syntax on 20.07.2026. | 276 |
| **IEEE Explore**<br><br>(274 records on 20.07.2026.) | 16.7.2025. | ("All Metadata":"machine learning" OR "All Metadata":"deep learning" OR "All Metadata":"artificial intelligence") AND ("All Metadata":"decision-making" OR "All Metadata":"decision making" OR "All Metadata":"decision support systems) AND ("All Metadata":"military operations" OR "All Metadata":"warfare") | 185 |
| | 20.7.2026. | Same syntax with date change<br>From 17.07.2025. to 20.07.2026. | 89 |
| **JSTOR**<br><br>(88 records on 20.07.2026.) | 16.7.2025. | ("machine learning" OR "deep learning" OR "artificial intelligence") AND ("military decision making process" OR "decision support systems") AND ("military operations" OR "warfare"); ; LANGUAGE; English; ; PUBLICATION DATE; FROM; up TO 2025/06/17; Journal Filter; Narrow by discipline and/or journal; Communication Studies; Computer science; Engineering; General Science; Management and Organizational Behavior; Military… | 85 |
| | 20.7.2026. | Same syntax with date change;<br>PUBLICATION DATE; FROM; 2025/06/18 TO 2026/07/20 | 3 |
| **Web of Science**<br><br>(238 records on 20.07.2026.) | 16.7.2025. | (“machine learning” OR “deep learning” OR “artificial intelligence”) AND (“decision-making” OR “decision making” OR “decision support systems”) AND (“military operations” OR “warfare”); ; English | 148 |
| | 20.7.2026. | Same syntax with date change;<br>Index date: 2025-07-17 do 20.07.2026. | 90 |

### 2.3. Eligibility criteria

Eligibility criteria were established a priori using the PICOS framework [18], and it was embedded into Covidence software's screening checklist to ensure consistency and resolve discrepancies. In addition, exclusion reasons were added in the full-text screening phase.

Studies were eligible if they addressed AI, ML, DL, or closely related intelligent computational techniques in relation to military decision-making, decision support, command and control, operational planning, crisis management in a military context, military operations, or warfare. Studies were excluded if they had no decision-making component, were unrelated to military decision-making, were not accessible in full text, were not in a supported language, were primarily about autonomous weapons systems (AWS)[8] or unmanned systems[9] rather than human decision support, lacked sufficient methodological detail, addressed unrelated technologies such as robotics without a decision-support focus, had the wrong study design for the review objective, had any relations to medical and civilian aspect of decision-making, or they were talking in general about the AI in decision-making process.

### 2.4. Selection process

The Covidence software tool was used to manage duplication, title and abstract screening, full-text assessment, and extraction. The PRISMA flow diagram (Figure 2.1) reports 1,439 records identified from databases/registers and grey literature. After 253 duplicate references were removed, 1,186 studies were screened for Title and Abstract. Of these, 581 were excluded at screening, independently by two reviewers according to predefined PICOS criteria. Discrepancies were resolved through discussion. A total of 605 studies were sought for retrieval and assessed for eligibility. Full-text assessment excluded 412 studies, leaving 193 studies included for extraction [Appendix A].

### 2.5. Data extraction and synthesis

Data were extracted using a digital template created in the Covidence, and was used for each included study. This ensured consistency across all fields, regardless of which reviewer completed the extraction. The template included general information (study identification number, title, lead author, source, DOI, and country in which the study was conducted), characteristics of studies (aim, design, military branch or organization, operational domain (warfare), level of decision-making, AI method used, decision-making operational functions, data types, human role, operational environment, technology readiness level, performance summary, limitations, ethical considerations, legal/policy issues, uncertainties and risks covered), and overall assessment (key findings, future work recommendation, relevance and quality rating). Data extraction was divided between two reviewers. Although studies were assigned to a single reviewer for extraction, any ambiguous findings were flagged and discussed by both reviewers. The risk of bias was further mitigated during the final confirmation phase, where a reviewer reviewed the completed extractions for consistency before formally confirming the data set for analysis. The consensus

[8] AWS – autonomous weapons systems use artificial intelligence to independently search for, identify, and attack targets without human intervention.

[9] Unmanned systems are types of aerial, surface or underwater vehicles that operate without a human pilot/driver onboard (unmanned aerial vehicle - UAS, unmanned ground vehicle - UGV, unmanned surface vehicle - USV, or unmanned underwater vehicle - UUV). They can be remotely piloted or fully autonomous.

extraction file captured all extracted data. Because the included studies were heterogeneous in method, domain, system type, outcome reporting, and validation approach, a meta-analysis was not appropriate. The results were therefore synthesized narratively and with descriptive frequencies.

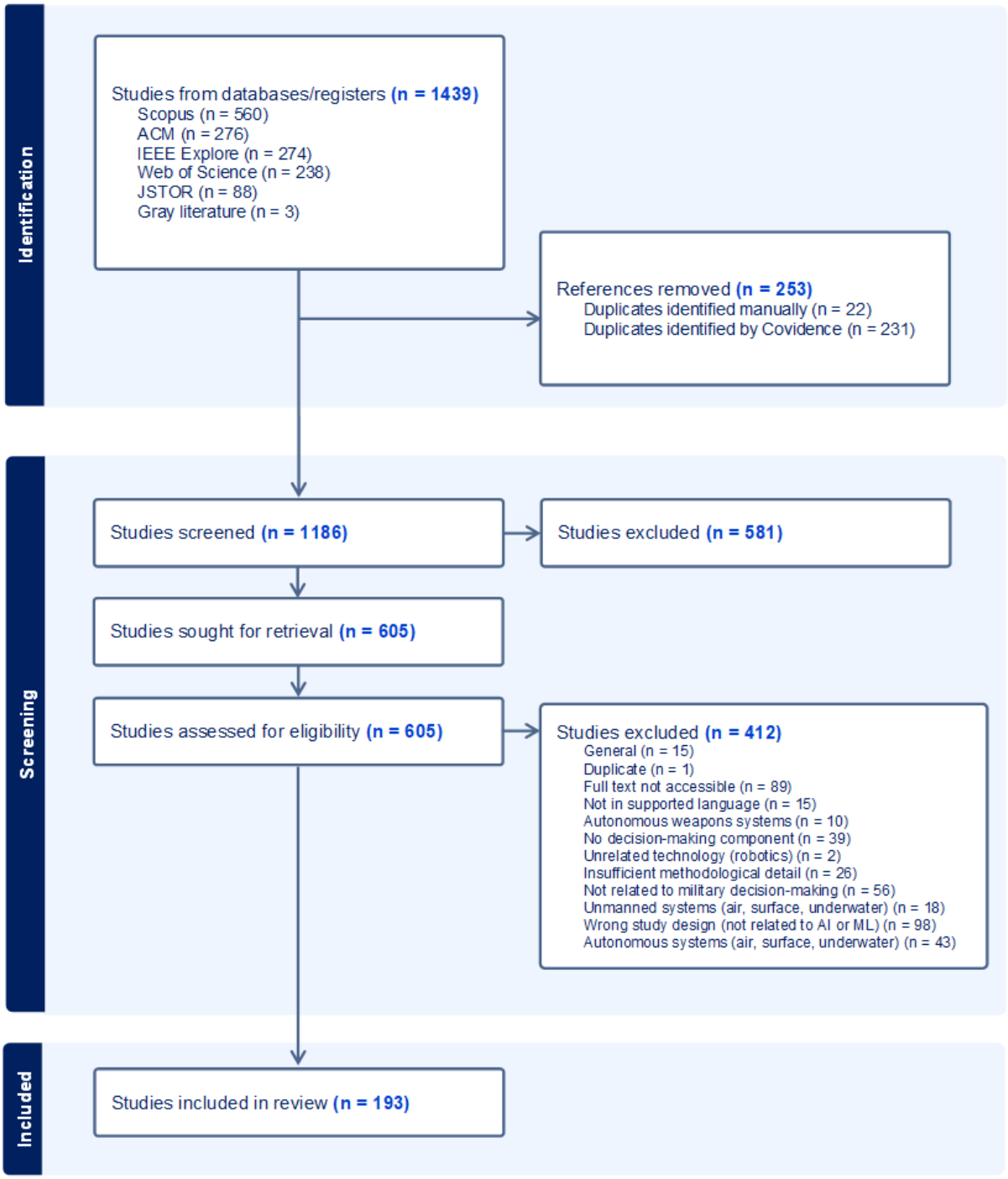


*Figure 2.1. PRISMA flow diagram [12]*

# 3. RESULTS

## 3.1. Study selection and publication profile

The review included 193 studies, listed in Appendix A. The final corpus consists of the previous 152-study set plus 41 additional studies and is given in the included-studies reference export file from Covidence. Publication years ranged from 1985 to 2026. The evidence base is notably recent: 131 of the included studies were published during 2021-2026 (with last search date on July 20th 2026), with the highest annual counts in 2025 (41 studies), 2024 (35 studies), 2023 (20 studies), and 2026 (16 studies). This indicates accelerated research interest in military AI decision support over the last several years (Figure 3.1), especially after the wider diffusion of deep learning, reinforcement learning, multi-agent systems, and generative AI methods.

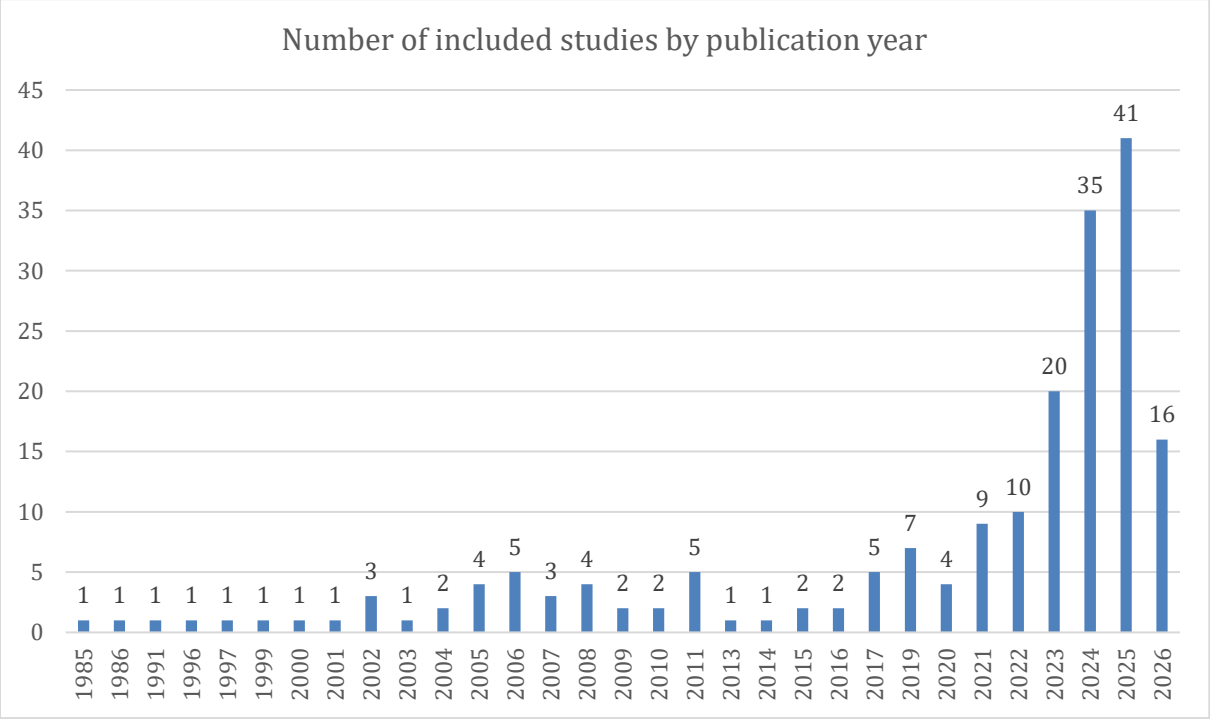


*Figure 3.1. Number of included studies by year span 1985-2026*

## 3.2. Study designs, operational environment and evidence maturity

Table 3.1 presents the list of the study design categories of included studies. Many studies contributed to more than one category (for example simulation plus empirical evaluation). As shown in Figure 3.2, simulation studies were the most frequent design category, closely followed by conceptual/theoretical articles. Empirical studies were less frequent, and methodological/model-development papers, technical reports, reviews, opinions, generic algorithm optimization and quantitative analysis made up the remainder. This pattern suggests that literature is still largely exploratory, model-oriented, and scenario-based rather than grounded in extensive operational trials.

*Table 3.1. Study design categories covered in included studies*

| Study design category | Included studies |
|---|---|
| Simulation Study | [Appendix A – 6, 11, 13, 14, 16, 20, 21, 26, 27, 28, 29, 30, 32, 33, 34, 40, 41, 43, 46, 48, 50, 51, 52, 54, 55, 58, 61, 62, 63, 64, 66, 67, 68, 70, 71, 72, 73, 74, 75, 76, 77, 78, 82, 83, 84, 87, 88, 89, 90, 92, 95, 96, 97, 98, 99, 100, 101, 102, 104, 105, 106, 108, 109, 111, 114, 115, 116, 118, 119, 120, 123, 124, 126, 127, 128, 130, 136, 138, 139, 145, 147, 148, 150, 153, 154, 155, 157, 158, 159, 160, 162, 163, 164, 165, 166, 167, 168, 169, 173, 175, 176, 177, 180, 181, 183, 184, 185, 186, 187, 188, 190, 191, 192] |
| Conceptual/Theoretical Paper | [Appendix A – 4, 5, 7, 8, 9, 10, 12, 15, 16, 18, 19, 22, 23, 25, 26, 27, 28, 29, 30, 31, 32, 34, 35, 37, 38, 41, 42, 43, 47, 53, 56, 57, 59, 60, 69, 76, 77, 78, 79, 80, 82, 85, 86, 91, 94, 101, 102, 103, 104, 105, 107, 108, 109, 110, 113, 114, 115, 116, 117, 119, 120, 125, 131, 132, 133, 134, 135, 137, 142, 143, 144, 146, 149, 151, 152, 161, 173, 174, 175, 176, 177, 178, 179, 184, 187, 189, 191, 192, 193] |
| Empirical Study | [Appendix A – 1, 2, 3, 14, 27, 28, 39, 40, 41, 42, 44, 45, 46, 51, 52, 65, 70, 84, 88, 93, 95, 107, 111, 117, 119, 120, 121, 123, 137, 140, 153, 154, 155, 157, 158, 159, 160, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 180, 181, 182, 183, 185, 186, 188, 190] |
| Methodological/model development paper | [Appendix A – 54, 122, 129, 130, 132, 133, 136, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152] |
| Technical Report/White Paper | [Appendix A – 4, 40, 41, 42, 43, 45, 94, 97, 112, 113, 114, 115, 116, 117, 125, 131, 134, 135, 172] |
| Review/Systematic Review | [Appendix A – 10, 17, 24, 26, 27, 31, 38, 49, 53, 69, 81, 91, 112, 156, 191] |
| Text and opinion | [Appendix A – 91, 156, 193] |
| Generic algorithm optimization | [Appendix A – 13] |
| Quantitative analysis | [Appendix A – 50] |

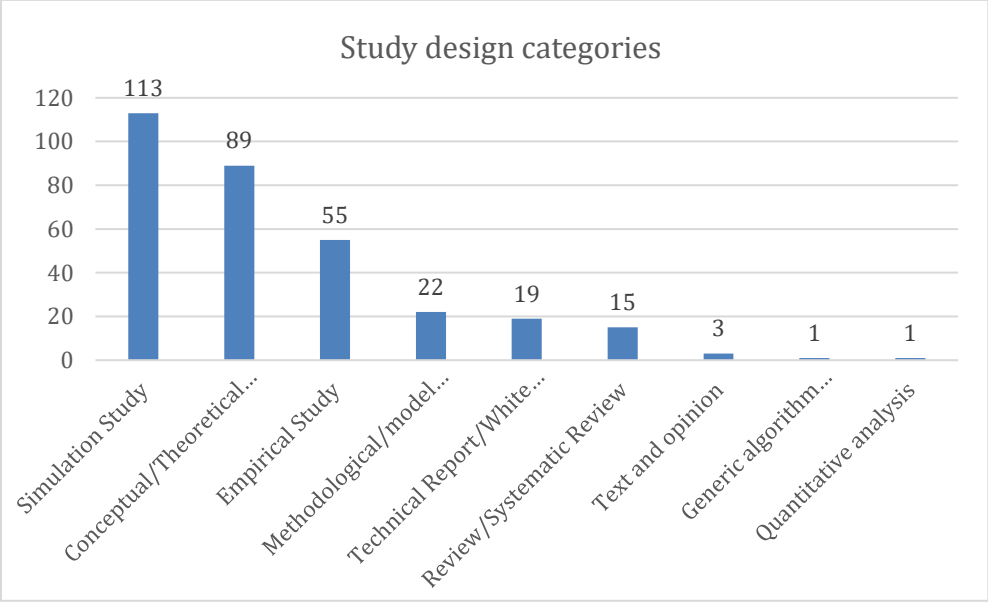


*Figure 3.2. Study design categories in included studies*

The operational environment of systems in included studies was also dominated by simulation, with laboratory and field settings appearing less often and combat settings only rarely reported. Distribution of included studies according to operational environment is presented in Table 3.2, and visual representation in Figure 3.3.

*Table 3.2. Operational environment covered in included studies*

| **Operational environment** | **Included studies** |
|---|---|
| Simulation | [Appendix A - 1, 2, 3, 4, 7, 8, 11, 13, 14, 16, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 32, 33, 34, 40, 41, 43, 44, 45, 46, 48, 49, 50, 52, 53, 54, 55, 58, 60, 61, 62, 63, 64, 65, 66, 67, 68, 70, 71, 72, 73, 74, 75, 77, 78, 81, 82, 83, 84, 85, 87, 88, 90, 92, 93, 95, 96, 97, 98, 99, 100, 101, 102, 104, 105, 106, 108, 109, 110, 112, 113, 114, 115, 116, 118, 119, 120, 123, 124, 125, 126, 127, 128, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 143, 145, 146, 147, 148, 149, 150, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 172, 173, 174, 175, 176, 177, 178, 180, 181, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193] |
| Laboratory | [Appendix A - 1, 27, 28, 30, 34, 36, 39, 40, 41, 42, 46, 51, 52, 57, 107, 111, 113, 115, 116, 121, 129, 140, 141, 151, 153, 154, 156, 157, 158, 159, 164, 166, 167, 169, 170, 171, 180, 181, 182, 183, 184, 185, 186, 187, 188, 190, 191, 192] |
| Field | [Appendix A - 6, 27, 40, 51, 112, 117, 119, 120, 122, 125, 129, 134, 135, 137, 142, 144, 163, 170, 171] |
| Combat | [Appendix A - 112, 117] |

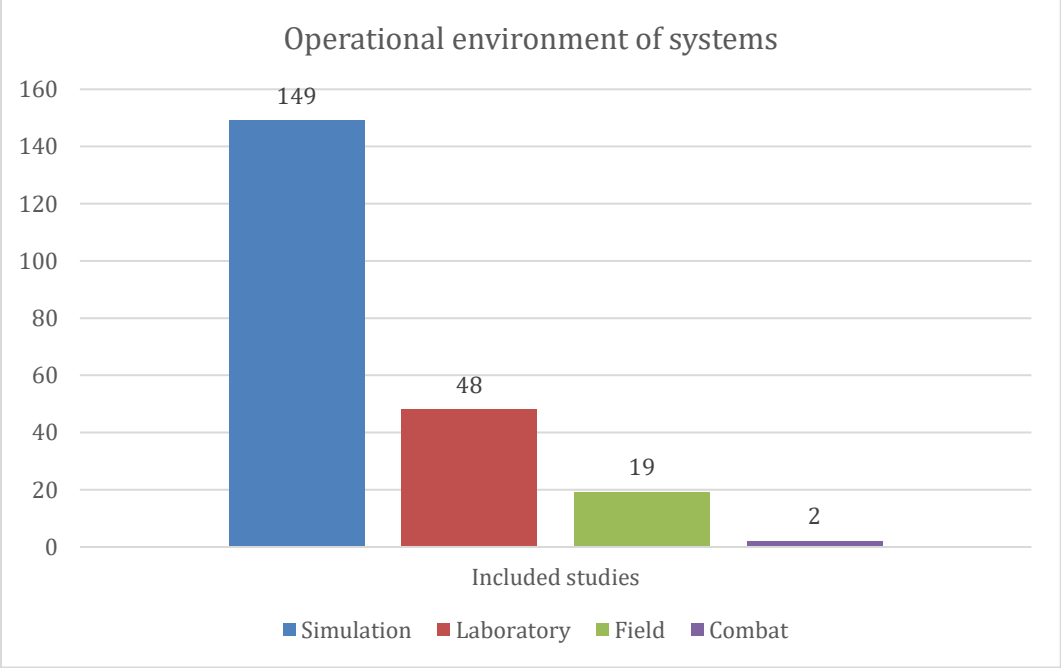


*Figure 3.3. Operational environment of systems covered in included studies*

Technology maturity was generally limited and is shown in Figure 3.4. as technology readiness level (TRL) overview. Prototype systems were by far the most frequently reported readiness level with 134 studies, followed by conceptual systems in 53 studies, while field-tested and operational/deployed systems were rare, as listed in Table 3.3. This finding is important for practitioners: although AI decision support is frequently proposed and experimentally demonstrated, the transition from laboratory or simulation environments into operational command settings remains limited in the reviewed literature.

*Table 3.3. Technology readiness level covered in included studies*

| **Technology readiness level** | **Included studies** |
|---|---|
| Prototype | [Appendix A – 1, 3, 5, 7, 14, 16, 17, 18, 20, 21, 26, 28, 29, 33, 34, 36, 37, 39, 40, 41, 42, 43, 45, 46, 48, 49, 51, 52, 54, 55, 57, 58,, 61, 62, 63, 65, 66, 67, 68, 70, 71, 72, 73, 74, 75, 77, 81, 82, 83, 84, 87, 89, 93, 97, 99,100, 101, 105, 106, 107, 108, 109, 111, 115, 116, 118, 119, 120, 121, 122, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 144, 145, 146, 147, 148, 149, 150, 151, 153, 154, 155, 156, 157, 158, 159, 160, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 190, 191, 192] |
| Conceptual | [Appendix A – 2, 4, 8, 9, 10, 12, 15, 19, 22, 23, 24, 25, 30, 31, 32, 35, 38, 44, 47, 50, 53, 56, 59, 60, 64, 69, 76, 78, 79, 80, 85, 86, 88, 90, 91, 92, 94, 95, 96, 98, 102, 103, 104, 110, 113, 114, 123, 143, 152, 161, 174, 189, 193] |
| Field-tested | [Appendix A – 6, 27] |
| Operational/Deployed | [Appendix A – 117] |
| Other: ranges from conceptual to operational-reported use | [Appendix A – 112] |
| Other: Simulation | [Appendix A – 11, 13] |

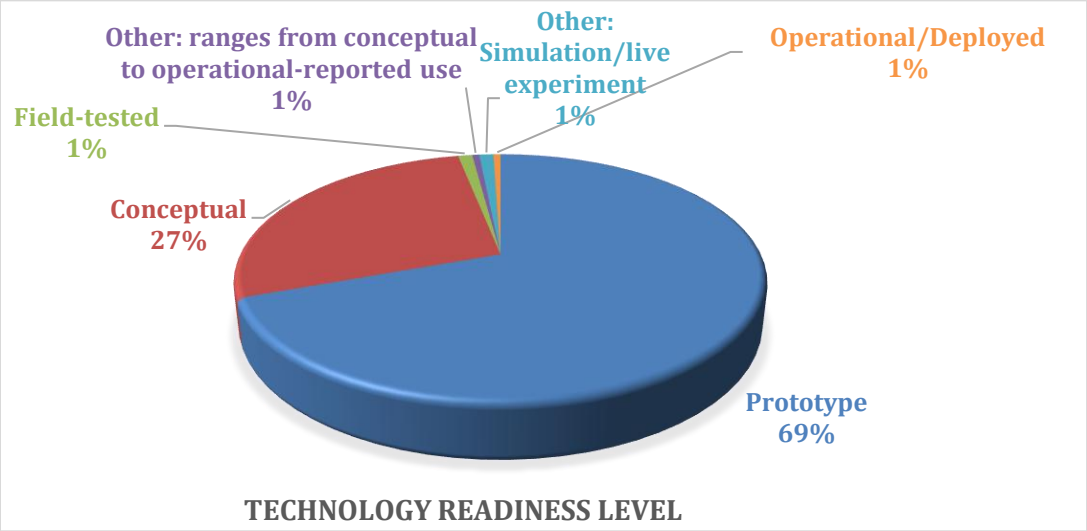


*Figure 3.4. Technological maturity of systems in included studies*

### 3.3. Military branches, domains/warfare, and decision levels

Included studies covered all military branches (component services), and the distribution is listed in Table 3.4. Some studies covered just one branch, others covered more than one branch separately or could cover any of the branches generally. The most common branches covered were Army with 41 studies, Navy with 35 studies and Air Force with 29 studies, as shown in Figure 3.5. Marine Corps were covered with 3 studies. Joint forces that include cooperation of more than one branch were represented in 21 studies. Also, findings from 77 studies could relate to any of military branches. Additional to military branches, some studies were related to units or organizations such as DARPA[10], NATO[11], or specialized units that can perform multidomain, cyber operation, electronic warfare, intelligence or security operations in military branches not specified.

*Table 3.4. Military branches covered in included studies*

| **Military branch / organization** | **Included Studies** |
|---|---|
| Army | [Appendix A – 8, 11, 14, 17, 20, 27, 36, 37, 38, 41, 45, 52, 56, 70, 73, 74, 81, 82, 89, 95, 96, 99, 101, 103, 104, 108, 109, 119, 120, 125, 127, 131, 134, 135, 137, 139, 145, 150, 180, 181] |
| Navy | [Appendix A – 2, 6, 7, 12, 13, 16, 18, 22, 25, 27, 30, 43, 48, 51, 58, 61, 65, 67, 68, 78, 81, 91, 94, 106, 107, 121, 122, 133, 146, 155, 160, 169, 171, 182, 188] |
| Air Force | [Appendix A – 1, 6, 18, 23, 25, 27, 28, 44, 49, 64, 72, 81, 83, 84, 86, 100, 115, 116, 136, 138, 147, 165, 182, 185, 186, 188, 190, 191, 192] |
| Marine Corps | [Appendix A – 78, 117, 131] |
| Joint | [Appendix A – 1, 3, 7, 8, 11, 12, 20, 25, 37, 41, 44, 57, 60, 63, 82, 83, 84, 168, 180, 188, 189] |
| Military in general | [Appendix A – 4, 5, 9, 10, 14, 19, 21, 23, 24, 26, 33, 34, 39, 53, 59, 62, 66, 69, 76, 77, 79, 80, 81, 85, 90, 93, 97, 98, 102, 105, 110, 111, 112, 113, 114, 118, 123, 124, 125, 126, 128, 129, 130, 132, 140, 141, 142, 143, 144, 148, 149, 151, 152, 153, 154, 156, 157, 158, 159, 161, 162, 163, 164, 166, 167, 172, 173, 174, 175, 176, 177, 178, 179, 183, 184, 187, 193] |
| Other | DARPA [Appendix A – 18, 69],<br>NATO [Appendix A – 15, 17, 19, 38, 41]<br>MDO [Appendix A – 3, 10, 27, 29, 33, 46, 53, 57, 71, 75]<br>Cyber [Appendix A - 31, 42, 47, 54, 55, 172]<br>EW [Appendix – 87, 88, 92, 111, 153, 263, 170]<br>Intelligence [Appendix – 80]<br>EOD [Appendix A – 24]<br>Defense and Security [Appendix A – 32, 35, 39, 40, 130, 183] |

[10] DARPA (Defense Advanced Research Projects Agency) is a research and development agency within the U.S. Department of Defense.

[11] NATO (North Atlantic Treaty Organization) is a political and military alliance of 32 member countries across North America and Europe.

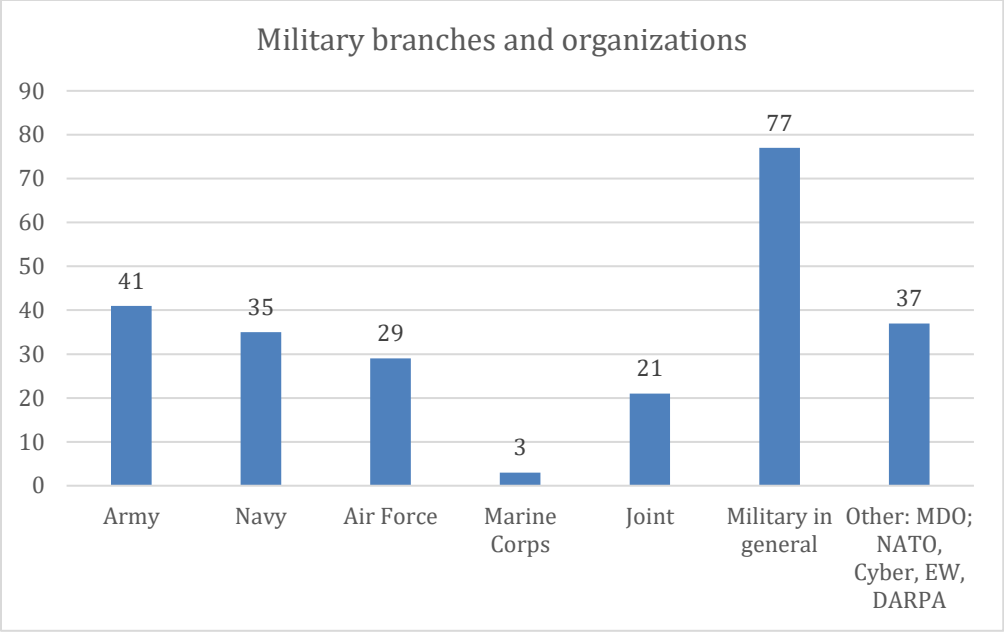


*Figure 3.5. Military branches and organizations covered in included studies*

Depending on the assigned area of responsibility (AOR) and the area of operations (AO), the armed forces conduct their operations in military operational domains. Domains have physical dimensions in battlespace and they are temporary based. By the NATO doctrine [4], there are five primary warfighting domains which represent specific military activity (warfare) within the battlespace: maritime domain, land domain, air domain, space domain, and cyberspace[12]. Some domains include more than one warfare, such as maritime domain, which includes surface warfare and underwater warfare. Modern warfare relies on multi-domain operations (MDO) where forces conduct operations across all domains simultaneously.

Operational domains (warfare) covered in included studies were diverse and are listed in Table 3.5, and visually represented in Figure 3.6, with air warfare, land warfare, air warfare, electronic warfare, and surface warfare as the most represented. Additional warfare represented were multidomain operations, cyber warfare, space warfare, information warfare, and underwater warfare. Warfare such as strike warfare, amphibious warfare, and urban warfare were also mentioned, but not in many included studies. It is important to note that the relation between military branch and operational domains is not unambiguously determined, which means that one military branch can perform different warfare in different domains. For example, Army can perform land warfare, air warfare, electronic warfare, etc., depending on what resources and capabilities specific forces have.

[12] Cyberspace includes networks of information, technology infrastructures, telecommunications, networks, computer systems and embedded processors.

*Table 3.5. Operational domains (warfare) covered in included studies*

| Operational domain | Included studies |
|---|---|
| Land Warfare | [Appendix A - 1, 3, 4, 5, 6, 8, 10, 11, 17, 20, 26, 27, 33, 36, 38, 41, 45, 46, 52, 53, 56, 57, 66, 68, 70, 73, 81, 82, 89, 90, 95, 96, 99, 101, 105, 108, 109, 113, 117, 119, 120, 125, 126, 127, 131, 134, 135, 137, 139, 140, 143, 150, 158, 161, 163, 165, 168, 180, 181, 183 ] |
| Air Warfare | [Appendix A – 1, 2, 3, 4, 7, 8, 10, 17, 18, 21, 26, 27, 28, 32, 33, 38, 39, 43, 44, 49, 53, 57, 61, 64, 65, 72, 81, 83, 84, 86, 88, 90, 100, 107, 115, 116, 124, 125, 128, 130, 131, 136, 138, 147, 148, 155, 158, 159, 161, 162, 163, 165, 166, 167, 171, 177, 182, 183, 185, 186, 187, 188, 190, 191, 192] |
| Surface Warfare | [Appendix A - 2, 3, 4, 8, 10, 12, 13, 16, 17, 22, 26, 27, 33, 38, 43, 48, 57, 58, 61, 67, 79, 81, 91, 94, 97, 122, 133, 145, 146, 155, 160, 168, 169, 188] |
| Electronic Warfare | [Appendix A - 2, 17, 26, 27, 29, 31, 42, 67, 71, 72, 81, 84, 87, 88, 92, 98, 102, 111, 114, 115, 116, 118, 124, 138, 153, 154, 156, 157, 159, 161, 162, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 186, 187, 188, 189, 190, 191, 192] |
| Multi-Domain Warfare (MDO) | [Appendix A - 3, 4, 5, 6, 9, 15, 17, 19, 23, 25, 26, 27, 35, 37, 38, 50, 53, 56, 57, 59, 60, 62, 63, 73, 103, 141, 144, 151, 162, 168, 173, 174, 175, 176, 177, 178, 179, 180, 183, 184, 185, 188, 189, 190, 191, 192] |
| Cyber Warfare | [Appendix - 8, 10, 31, 35, 37, 38, 41, 42, 47, 53, 54, 55, 56, 57, 59, 69, 76, 106, 121, 129, 132, 142, 157, 164, 172, 174, 175, 176, 177, 178, 184, 189, 193] |
| Space Warfare | [Appendix A - 8, 10, 17, 27, 38, 50, 57, 81, 172] |
| Information Warfare | [Appendix A - 74, 76, 78, 82, 85, 90, 142, 152, 184, 189, 193] |
| Underwater Warfare | [Appendix A - 7, 30, 51, 81, 91] |
| Other: Strike Warfare, Amphibious Warfare, Hybrid Warfare, ISR, CBRN, etc. | [Appendix A - 5, 11, 14, 24, 29, 32, 33, 34, 39, 40, 41, 46, 49, 50, 64, 65, 67, 68, 70, 75, 77, 80, 83, 89, 93, 97, 100, 104, 110, 112, 123, 128, 148, 149, 168] |

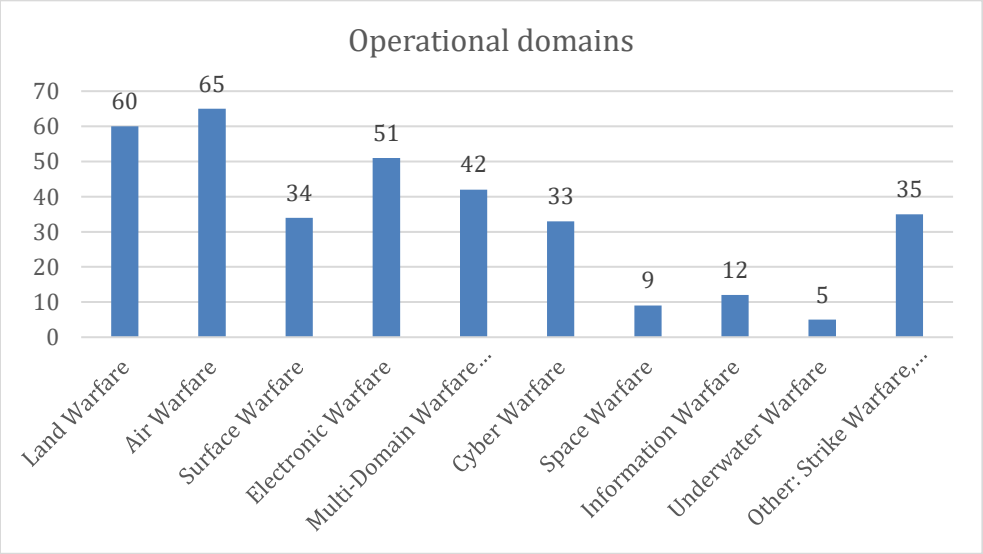


*Figure 3.6. Operational domains covered in included studies*

The results given in Table 3.6 shows that 176 studies covered tactical level of decision-making, 151 studies covered operational level, and 56 studies covered strategic level of decision-making. Since there is no strict border between these levels and many times in real life they overlap, some studies could cover more than one layer, or the findings can be used in all three levels. Results are visually presented in Figure 3.7.

*Table 3.6. Levels of decision-making in included studies*

| Level of decision-making | Included studies |
|---|---|
| Tactical | [Appendix A – 1, 2, 3, 4, 5, 6, 7, 10, 13, 14, 16, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 60, 61, 62, 64, 65, 66, 67, 68, 69, 70, 71, 72, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 185, 186, 187, 188, 189, 190, 191, 192] |
| Operational | [Appendix A – 1, 2, 3, 4, 5, 6, 11, 12, 17, 18, 19, 20, 21, 22, 23, 25, 26, 27, 28, 29, 31, 32, 33, 35, 36, 37, 38, 40, 41, 42, 43, 44, 45, 47, 48, 49, 50, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 74, 76, 77, 78, 79, 80, 81, 82, 83, 85, 86, 91, 94, 96, 98, 100, 101, 102, 103, 104, 106, 107, 108, 109, 110, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 124, 125, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 154, 155, 157, 158, 162, 163, 164, 165, 168, 169, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 183, 184, 185, 186, 188, 189, 190, 191, 192, 193 ] |
| Strategic | [Appendix A – 3, 4, 8, 9, 15, 18, 19, 20, 23, 27, 28, 31, 32, 34, 35, 37, 38, 40, 41, 44, 47, 49, 50, 53, 56, 57, 59, 60, 63, 69, 76, 81, 85, 103, 110, 112, 117, 123, 125, 129, 133, 137, 142, 146, 149, 151, 162, 168, 172, 173, 176, 179, 184, 188, 191, 193] |


*Figure 3.7. Levels of decision-making covered in included studies*

### 3.4. AI techniques used in military decision support

Included studies cover different AI methodologies, specialized learning paradigms and architectural design, depending on if models were data-driven, logic-based or if they mimic neural connection. The goal was the same - to discuss or build intelligent systems that will support the commander in making his final decision. Different mathematical structures, different statistical objectives and input/output modalities which were found in included studies are grouped into 5 categories by core techniques and subfields of AI for the purpose of this review: ML, DL, Symbolic AI, Generative AI, and Other.

According to Table 3.7, the most common technical categories were different ML algorithms (unsupervised learning, supervised learning and reinforcement learning) and DL architectures that utilize multi-layered Artificial Neural Networks (ANN) inspired by the human brain such as Convolutional Neural Networks (CNN) and Recurrent Neural Network / Long Short-Term Memory (RNN/LSTM). Generative AI (GenAI) mostly used Large Language Model (LLM). Symbolic (rule-based) AI used systems such as Expert Systems, Knowledge Graphs and Ontologies and logic systems such as Goal-Oriented Action Planning (GOAP). Other methodologies included probabilistic models (Game Theory, Bayesian Belief Network) and evolutionary algorithms (Heuristic Optimization). Different AI fields are visually presented in

Figure 3.8.

Some models represented in included studies could fit more than one category since they are not a single model, technique or architecture, but they represent fields of AI that span through multiple categories. One of those fields is Natural Language Processing (NLP) that focuses on enabling computes to interpret human language, that fits every AI category. There were 25 studies that used NLP in ML, DL, and GenAI (LLM). [Appendix A - 6, 11, 17, 18, 26, 27, 57, 81, 108, 109, 112, 113, 119, 120, 121, 123, 125, 129, 133, 142, 144, 151, 160, 184, 193]

Computer Vision is another field that fits more than one category since it focuses on enabling computers to see and interpret visual data. It can span from classic statistical models to modern neural networks. There were 14 studies that explicitly used Computer Vision as primary AI techniques, mostly in DL, but in ML as well. [Appendix A - 19, 26, 46, 57, 81, 112, 113, 125, 140, 147, 154, 156, 161, 182]

Also, there were 51 studies that used Multi-Agent Systems (MAS) that span through ML (reinforcement learning), Symbolic AI (Expert System) and Other (Game Theory, Belief-Desire-Intention (BDI) agent model). [Appendix A - 3, 5, 7, 13, 19, 21, 22, 25, 28, 33, 34, 37, 40, 41, 43, 48, 49, 62, 63, 64, 66, 68, 70, 82, 84, 88, 89, 90, 92, 95, 99, 100, 101, 108, 109, 123, 131, 138, 141, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193]

Explainable AI (XAI) also spans across multiple categories, but techniques of 12 included studies fit into ML and DL. [Appendix A - 52, 69, 93, 103, 164, 165, 174, 177, 178, 179, 183, 188]

*Table 3.7. Five categories of AI covered in included studies*

| **AI system description** | | **Included studies** |
|---|---|---|
| Machine Learning (ML) | Machine Learning (unspecified) | 35 studies - [Appendix A - 1, 5, 6, 18, 19, 25, 29, 35, 54, 56, 57, 59, 76, 78, 88, 94, 105, 112, 117, 118, 121, 122, 126, 129, 133, 136, 142, 143, 144, 145, 151, 168, 183, 184, 193] |
| | Supervised Learning | 33 studies - [Appendix A - 15, 26, 30, 40, 41, 42, 49, 50, 51, 74, 81, 91, 97, 107, 111, 113, 114, 130, 140, 154, 155, 156, 157, 159, 161, 163, 164, 165, 166, 170, 171, 182, 185] |
| | Unsupervised learning | 13 studies - [Appendix A - 15, 40, 49, 50, 81, 91, 104, 141, 157, 165, 169, 171, 186] |
| | Reinforcement Learning | 54 studies - [Appendix A - 2, 3, 9, 10, 11, 15, 17, 27, 33, 37, 48, 49, 50, 52, 53, 58, 60, 67, 71, 72, 81, 84, 90, 91, 92, 95, 97, 99, 100, 101, 102, 103, 106, 108, 109, 124, 125, 127, 128, 138, 146, 153, 156, 157, 160, 167, 173, 180, 181] |
| Deep Learning (DL) | CNN, RNN/LSTM | 72 studies - [Appendix A - 3, 5, 6, 10, 17, 26, 27, 37, 39, 40, 46, 50, 53, 58, 60, 71, 72, 75, 76, 78, 81, 87, 88, 90, 93, 96, 97, 99, 100, 103, 108, 109, 111, 112, 113, 114, 115, 116, 127, 128, 133, 138, 140, 146, 147, 148, 150, 151, 153, 154, 156, 157, 159, 160, 161, 163, 165, 166, 169, 170, 171, 180, 181, 182, 183, 184, 186, 187, 189, 190, 192, 193] |
| | Graph Neural Network (GNN) | 2 studies – [Appendix A - 99, 151] |
| Symbolic AI | Expert Systems | 42 studies - [Appendix A - 1, 4, 5, 18, 22, 31, 32, 40, 41, 43, 45, 63, 64, 65, 67, 77, 79, 80, 82, 86, 89, 110, 115, 116, 119, 120, 122, 125, 131, 132, 134, 135, 139, 156, 157, 174, 175, 176, 177, 178, 179, 191] |
| | Knowledge graphs and Ontologies | 6 studies – [Appendix A – 1, 4, 54, 64, 151, 152] |
| | Logic systems (Goal-Oriented Action Planning (GOAP)) | 2 studies – [Appendix A – 62, 68] |
| | Belief-Desire-Intention (BDI) agent model | 2 studies – [Appendix A – 7, 21] |
| | Fuzzy logic | 11 studies – [Appendix A - 20, 40, 44, 83, 89, 115, 116, 122, 136, 175, 191] |
| Generative AI | LLM | 8 studies - [Appendix A - 73, 103, 106, 123, 129, 142, 188, 193] |
| Other | Heuristic Optimization | 3 study – [Appendix A – 61, 155, 162] |
| | Game Theory | 12 studies – [Appendix A - 2, 34, 49, 55, 98, 102, 139, 146, 153, 173, 187, 191] |
| | Bayesian Belief Network | 11 studies – [Appendix A - 34, 40, 77, 110, 122, 125, 149, 153, 165, 168, 191] |

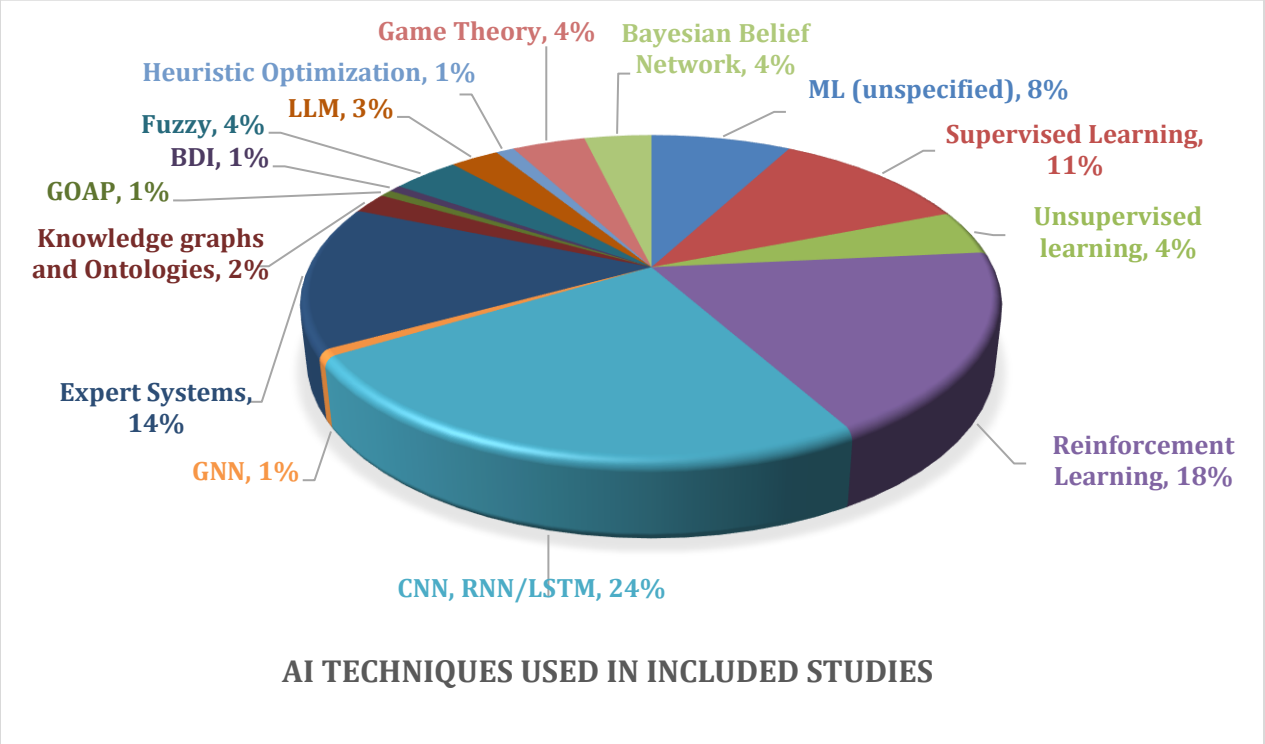


*Figure 3.8. AI techniques used in included studies*

### 3.5. Decision-making operational functions

According to Table 3.8, Command and Control and Intelligence were the most frequently extracted functions. Specifically, functions like command authority (C2) and mission planning (COA development, analysis and approval) together with situational awareness and resource allocation, map directly onto several MDMP phases. Mission analysis is supported by systems for data gathering, data analysis, intelligence processing, threat detection, target identification and overall situational awareness. COA development and COA analysis are supported by mission planning, simulation, multi-agent methods, reinforcement learning, and resource-allocation tools. The COA comparison is supported by systems that evaluate developed alternatives, forecast outcomes, and assess the risk, resulting in COA ranking and final decision that eventually becomes the commander's order. Orders production and transition are less frequently the explicit focus of the literature, although NLP and decision-support systems could plausibly support these later MDMP phases. Operational functions and activities covered in included studies are visually presented in Figure 3.9.

*Table 3.8. Military operational functions covered in included studies*

| **Operational functions** | | **Included studies** |
|---|---|---|
| Command and Control (C2) | Command and Control (C2) | [Appendix A - 15, 18, 19, 20, 22, 23, 25, 26, 27, 28, 29, 30, 32, 37, 38, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 52, 53, 54, 56, 57, 58, 59, 60, 61, 62, 69, 70, 71, 72, 73, 74, 76, 77, 78, 81, 82, 84, 86, 88, 90, 92, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 141, 142, 143, 144, 145, 146, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 167, 168, 169, 173, 174, 175, 176, 177, 178, 179, 180, 181, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193] |
| | Mission Planning (+COAs) | [Appendix A - 1, 3, 4, 5, 7, 8, 11, 14, 17, 18, 19, 20, 21, 27, 28, 29, 33, 40, 41, 43, 45, 47, 48, 52, 53, 54, 55, 56, 58, 59, 60, 62, 63, 64, 65, 66, 68, 70, 71, 72, 73, 78, 79, 81, 82, 84, 86, 89, 90, 91, 94, 96, 97, 103, 104, 105, 107, 108, 109, 110, 112, 113, 114, 115, 116, 117, 119, 120, 123, 125, 126, 127, 128, 129, 131, 132, 133, 134, 135, 136, 137, 139, 142, 143, 144, 145, 146, 149, 155, 156, 158, 160, 161, 162, 163, 165, 168, 172, 173, 175, 176, 177, 178, 179, 180, 181, 183, 185, 188, 189, 191, 192] |
| | C3, C4I, C5ISR | [Appendix A – 12, 18, 27, 37, 40, 41, 43, 80, 81, 101, 154, 155, 156, 157, 158, 160, 161, 164, 165, 166, 168, 169, 170, 171, 173, 174, 177, 178, 180, 181, 182, 183, 184, 185, 186, 188, 189, 190, 191, 192, 193] |
| | OODA loop | [Appendix A - 1, 27, 36, 38, 40, 41, 43, 44, 49, 60, 81, 108, 112, 114, 118, 125, 134, 135, 137, 146, 156, 158, 163, 165, 167, 183, 186, 187, 188, 189, 190, 191] |
| Intelligence | Intelligence in general | [Appendix A – 12, 47, 60, 77, 80] |
| | Risk Assessment | [Appendix A - 5, 14, 17, 20, 24, 48, 50, 66, 78] |
| | Situational Awareness | [Appendix A - 1, 2, 3, 4, 5, 6, 8, 16, 17, 20, 22, 23, 24, 25, 26, 27, 30, 32, 35, 36, 38, 39, 40, 41, 42, 43, 44, 45, 46, 49, 51, 52, 53, 54, 55, 56, 57, 59, 62, 63, 65, 67, 70, 75, 76, 77, 79, 80, 81, 82, 83, 86, 87, 88, 91, 93, 94, 96, 98, 99, 101, 103, 106, 107, 108, 109, 110, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 174, 177, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193] |
| | Data Analysis | [Appendix A - 1, 6, 17, 21, 26, 27, 31, 35, 39, 40, 41, 42, 44, 45, 51, 52, 53, 54, 57, 59, 64, 68, 70, 82, 85, 89, 91, 96, 97, 104, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 125, 126, 129, 131, 132, 133, 134, 135, 137, 139, 140, 141, 142, 143, 144, 147, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 163, 164, 165, 166, 167, 168, 169, 170, 172, 174, 177, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193] |
| | Data Gathering | [Appendix A - 5, 10, 11, 19, 22, 25, 26, 27, 35, 39, 40, 41, 42, 43, 51, 57, 59, 81, 82, 85, 95, 104, 112, 113, 114, 129, 154, 156, 157, 159, 161, 163, 164, 165, 166, 167, 169, 170, 171, 172, 180, 181, 182, 184, 185, 186, 187, 188, 189, 190, 191, 193] |
| | Threat Detection | [Appendix A - 4, 6, 18, 23, 35, 39, 46, 51, 55, 66, 69, 75, 76, 86, 88, 91, 93, 94, 108, 111, 114, 121, 126, 129, 140, 141, 143, 149, 166, 170, 171, 193] |
| | Target Recognition / Identification | [Appendix A - 15, 23, 46, 51, 65, 66, 71, 75, 79, 88, 94, 140, 149, 166, 170, 171, 174, 177] |

*Table 3.8. (continued)*

| **Operational functions** | | **Included studies** |
|---|---|---|
| Fires | Threat Detection | [Appendix A - 2, 3, 7, 10, 22, 26, 27, 31, 37, 40, 41, 42, 43, 45, 57, 81, 83, 92, 108, 112, 113, 115, 116, 118, 122, 125, 130, 136, 137, 142, 144, 148, 153, 154, 155, 156, 157, 158, 159, 161, 163, 164, 165, 167, 169, 173, 182, 186, 187] |
| | Target Recognition / Identification | [Appendix A - 2, 13, 16, 17, 19, 21, 22, 26, 27, 53, 70, 81, 122, 147, 154, 155, 156, 158, 159, 160, 161, 163, 178, 182, 183, 186, 191] |
| Movement and Manoeuvre | Resource and Assets Allocation | [Appendix A - 1, 2, 3, 8, 11, 13, 14, 16, 17, 19, 21, 22, 25, 27, 28, 30, 31, 33, 37, 40, 41, 43, 44, 45, 49, 50, 52, 53, 57, 58, 61, 64, 68, 70, 74, 81, 83, 90, 92, 95, 97, 98, 100, 101, 102, 103, 104, 106, 107, 109, 110, 112, 117, 118, 119, 120, 123, 124, 125, 127, 130, 131, 132, 133, 134, 136, 137, 138, 144, 147, 148, 150, 153, 154, 155, 156, 157, 158, 160, 162, 163, 165, 167, 168, 175, 180, 181, 185, 187, 188, 189, 190, 191, 192] |
| Protection | Force Protection | [Appendix A - 12, 26, 27, 40, 41, 42, 43, 81, 112, 113, 115, 116, 122, 132, 136, 142, 153, 154, 155, 156, 157, 158, 159, 161, 163, 164, 165, 167, 168, 169, 173, 176, 178, 181, 182, 183, 185, 186, 187, 190, 191, 192] |
| Sustainment | Logistics | [Appendix A - 8, 10, 81, 95, 101, 107, 119, 120, 155, 168] |

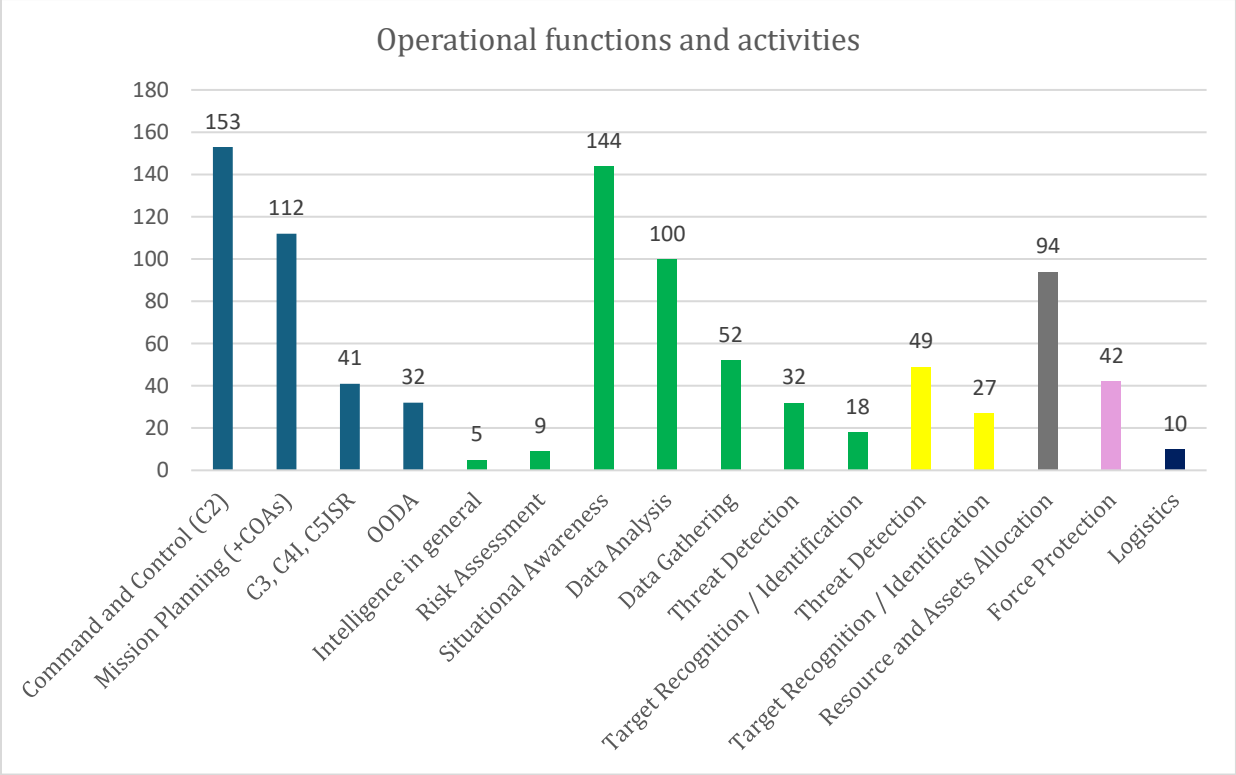


*Figure 3.9. Operational functions and activities covered in included studies*

### 3.6. Data sources, operational environment, and human role

Simulated data was the most common data type used in included studies, followed by sensor data, human input or expert annotations, geospatial data, communications, and open-source intelligence. Some studies also used data feed from weapons systems (weapons parameters, status, performance). Other data sources included different log data, cyber data, historical data or specific military databases. Most of studies used more than one data source for research. Data sources used in included studies are presented in Table 3.9, and visually presented in Figure 3.10. The dominance of simulated data is understandable given the sensitivity, scarcity, and security classification of real military operational data. However, it limits external validity.

*Table 3.9. Data sources/types in included studies*

| **Data source/type used** | **Included studies** |
|---|---|
| Simulated Data | [Appendix A - 1, 2, 3, 7, 11, 13, 14, 15, 16, 17, 18, 19, 20, 21, 26, 27, 28, 29, 31, 32, 33, 34, 40, 41, 44, 46, 48, 52, 53, 55, 58, 60, 61, 62, 63, 64, 65, 66, 70, 71, 72, 73, 74, 75, 81, 84, 85, 87, 88, 89, 90, 91, 92, 93, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 108, 109, 111, 112, 113, 114, 118, 123, 124, 126, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 141, 144, 145, 146, 147, 148, 149, 150, 152, 153, 154, 155, 156, 157, 158, 159, 160, 162, 163, 164, 165, 166, 167, 168, 169, 173, 175, 176, 177, 180, 181, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192] |
| Sensor Data (e.g. radar, sonar, satellite) | [Appendix A - 21, 22, 25, 26, 27, 32, 35, 37, 38, 39, 40, 42, 43, 45, 51, 53, 56, 57, 58, 59, 64, 67, 68, 71, 72, 73, 75, 77, 78, 79, 80, 81, 82, 83, 86, 87, 88, 89, 91, 92, 93, 100, 101, 104, 112, 113, 115, 116, 118, 122, 124, 125, 127, 128, 130, 133, 134, 135, 136, 138, 140, 141, 142, 144, 145, 146, 148, 149, 152, 153, 154, 155, 156, 157, 159, 161, 163, 165, 166, 167, 169, 170, 171, 180, 181, 182, 186, 187, 188, 190, 191, 192] |
| Human Input/Expert Annotations | [Appendix A - 1, 3, 4, 5, 7, 14, 16, 24, 25, 26, 27, 28, 30, 31, 37, 40, 41, 42, 44, 45, 70, 86, 89, 97, 103, 106, 107, 108, 109, 110, 112, 113, 114, 115, 116, 117, 119, 120, 121, 122, 123, 125, 126, 129, 130, 131, 132, 133, 134, 135, 136, 137, 139, 140, 141, 142, 143, 145, 146, 149, 150, 156, 157, 158, 160, 162, 165, 167, 168, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 186, 188, 189, 190, 191, 192, 193] |
| Geospatial Data | [Appendix A - 1, 3, 5, 13, 16, 17, 20, 22, 23, 31, 45, 52, 54, 57, 66, 68, 70, 79, 81, 104, 108, 109, 112, 113, 117, 119, 120, 125, 126, 128, 131, 134, 135, 136, 138, 139, 155, 158, 160, 161, 163, 165, 168, 169, 180, 181, 184, 185, 188, 189, 191, 192] |
| Communications | [Appendix A - 17, 18, 27, 42, 54, 71, 74, 81, 85, 93, 111, 112, 114, 117, 121, 122, 124, 125, 129, 132, 133, 134, 135, 136, 142, 153, 154, 155, 156, 157, 164, 166, 169, 170, 171, 189, 190, 191, 193] |
| Open-Source Intelligence | [Appendix A - 5, 6, 15, 17, 35, 38, 41, 45, 57, 59, 76, 81, 112, 113, 114, 129, 151, 182, 183, 184, 185, 193] |
| Other: Intelligence | [Appendix A - 53, 54, 56, 60, 77, 80, 82, 110, 142, 148, 150, 152, 184, 185] |
| Weapons data | [Appendix A - 23, 28, 58, 68, 101, 147] |
| Other: cybersecurity data, log data, historical data | [Appendix A - 10, 15, 21, 24, 29, 36, 38, 47, 53, 54, 55, 56, 66, 76, 78, 79, 82, 91, 93, 96, 103, 105, 107, 137, 142, 143, 144, 146, 168, 172, 189, 191] |

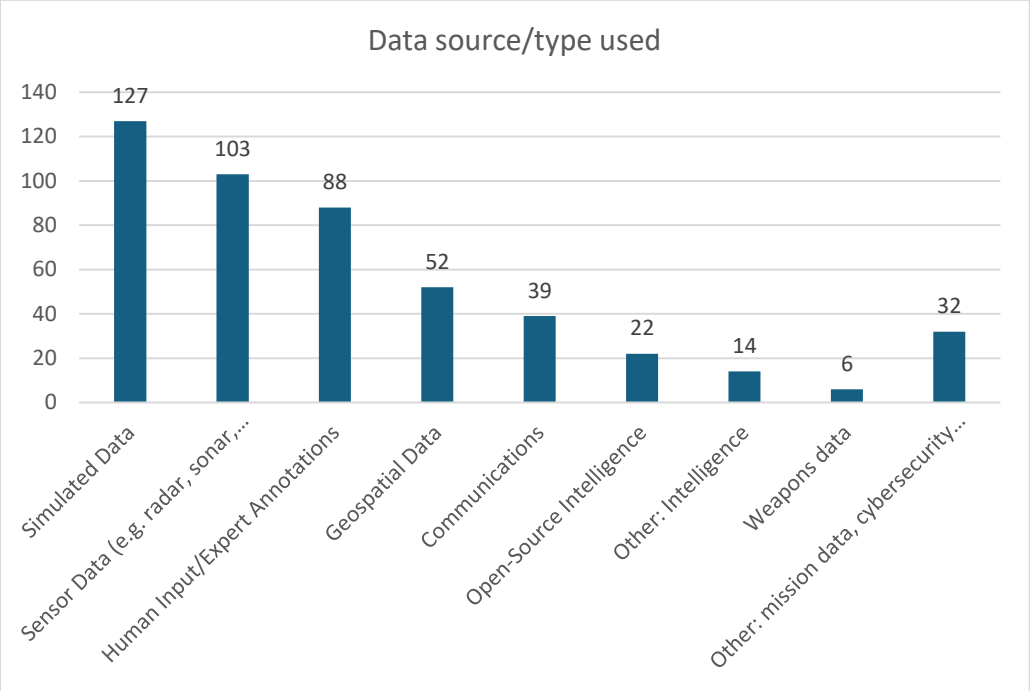


*Figure 3.10. Data source/types used in included studies*

With introducing an AI into decision-making process, it is important to realize the human involvement in the whole decision process. There are three main roles of humans when interacting with AI systems and they describe the degree of human oversight and intervention in AI systems: Human-in-the-loop (HITL), Human-on-the-loop (HOTL), and Human-out-of-the-loop (HOOTL). [19] Systems that are fully autonomous and perform tasks without human intervention or oversight (HOOTL) were not in focus of this review and studies regarding autonomous weapons systems or other autonomous systems were excluded during the review process. Study of the most interest for this review were the ones that involved humans in the process of final decision or approval (HITL). Even tough systems that operate more autonomously but human supervises the process and can intervene when needed (HOTL) could indicate autonomous decision-making, in this review it means that only a part of the process was done autonomously (usually data gathering and data processing), the final decision was still made by a human, based on provided product of autonomous activity. Table 3.10 presents how included studies were oriented regarding human involvement in decision process. Human-in-the-loop designs (137 studies) were much more common than human-on-the-loop designs (56 studies) as presented in Figure 3.11, indicating that most reviewed systems were positioned as support tools for human commanders and staff.

*Table 3.10. Human involvement in decision process*

| Human role | Included studies |
|---|---|
| Human-in-the-loop | [Appendix A - 1, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 73, 75, 76, 77, 78, 79, 80, 82, 83, 85, 86, 89, 90, 96, 103, 109, 110, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 124, 152, 155, 158, 162, 165, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 183, 188, 189, 191, 192, 193] |
| Human-on-the-loop | [Appendix A - 2, 3, 11, 25, 71, 72, 74, 81, 84, 87, 88, 91, 92, 93, 94, 95, 97, 98, 99, 100, 101, 102, 104, 105, 106, 107, 108, 111, 123, 127, 128, 138, 141, 147, 151, 153, 154, 156, 157, 159, 160, 161, 163, 164, 166, 167, 168, 169, 170, 171, 182, 184, 185, 186, 187, 190] |

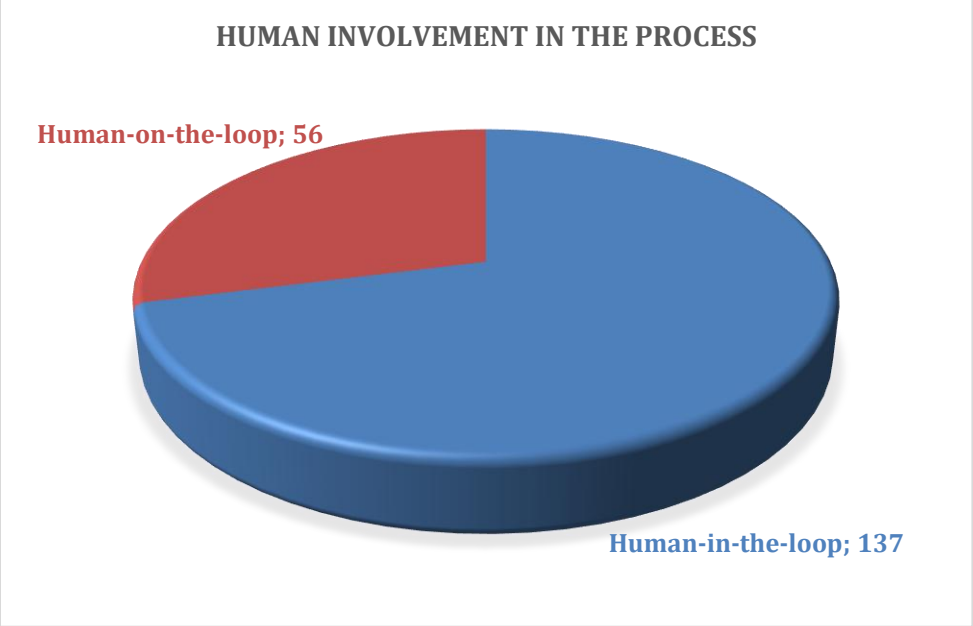


*Figure 3.11. Human involvement in the decision-making process of the included studies*

### 3.7. Performance reporting, quality of studies, and limitations

Included studies used heterogenous set of performance metrics due to diversity of methodological approaches in research. A performance summary indicated that 124 of the 193 studies mentioned some form of quantitative performance indicator, benchmark, rate, error, or metric term, while 69 were primarily qualitative or did not report conventional performance metrics. Types and comparability of metrics are presented in Table 3.11Table 3.11, and visually presented by metric groups in Figure 3.12.

The most frequently reported quantitative metrics were standard classification measures (accuracy, precision, recall, and F1-score), indicating that those studies evaluated model performance in terms of correct classification, detection, or prediction of decision-support outputs. Accuracy was the most common classification metric, while precision, recall, and F1-score were

less reported, suggesting that not all studies provided a balanced assessment of false positives and false negatives. A smaller number of studies used additional classification-related indicators, such as mean average precision, Cohen's Kappa, and probability of correct classification. Several studies included models that involved continuous prediction or estimation relied on regression and prediction error measures (R-squared - $R^2$, Mean Absolute Percentage Error - MAPE, Mean Squared Error - MSE, Root Mean Squared Error - RMSE, and Mean Absolute Error - MAE). One group of studies used probabilistic metrics (probabilistic outcomes, degree of certainty - DoC, winning probability, variance, confidence intervals, p-values, and t-scores) that expressed uncertainty, likelihood of success or statistical significance. A significant number of studies used simulation and operational performance metrics (Measures of Merit - MOM, Measures of Performance - MOP, feasibility, flexibility, robustness, and ease of use), suggesting that many studies included simulated environment rather than standard experimental benchmarks and empirical validation. Computational efficiency metrics, such as inference time, model parameters, and computational performance, were rarely reported, despite their importance for real-time military decision-making applications. Specialized metrics such as reinforcement-learning rewards (sparse and shape reward, temporal interaction gain), Image/signal-quality metrics (Structural Similarity Index Measure - SSIM, Peak Signal-to-Noise Ratio - PSNR, mutual information, VAE-based assessment), and ontology metrics were used only in a small number of studies. Also, many included studies did not report a quantitative performance benchmark, indicating that much of the literature remains conceptual, architectural, qualitative, or proof-of-concept in nature.

*Table 3.11. Performance metrics presented in included studies*

| **Performance metrics** | | **No.** | **Included studies** |
|---|---|---|---|
| Classification performance metrics | Accuracy | 22 | [Appendix A - 4, 6, 26, 37, 55, 93, 107, 121, 140, 147, 154, 157, 159, 164, 165, 166, 169, 170, 171, 182, 185, 186] |
| | Precision | 17 | [Appendix A - 4, 6, 39, 55, 93, 107, 140, 147, 157, 164, 165, 169, 170, 171, 182, 185, 186] |
| | Recall | 17 | [Appendix A - 6, 39, 55, 93, 107, 140, 147, 157, 164, 165, 169, 170, 171, 182, 184, 185, 186] |
| | F1-score | 17 | [Appendix A - 4,6, 39, 55, 93, 107, 147, 157, 159, 164, 165, 166, 170, 171, 182, 185, 186] |
| | mAP | 3 | [Appendix A - 39, 140, 182] |
| | Cohen's Kappa | 1 | [Appendix A - 6] |
| | SP index | 1 | [Appendix A - 51] |
| | Probability of correct classification (PCC) | 1 | [Appendix A - 111] |
| Regression and prediction-error metrics | $R^2$ | 3 | [Appendix A - 36, 50, 107] |
| | MAPE, MSE RMSE, MAE | 5 | [Appendix A - 130, 131, 154, 159, 163] |
| | Sum of squared errors | 1 | [Appendix A - 104] |

*Table 3.11. (Continued)*

| **Performance metrics** | | **No.** | **Included studies** |
|---|---|---|---|
| Probabilistic and decision-outcome metrics | Probabilistic output - Degree of Certainty (DoC) | 2 | [Appendix A - 1, 32] |
| | Probabilistic outcome | 9 | [Appendix A - 2, 14,17, 33, 61, 98, 102, 149, 184] |
| | p-value, t-scores, confidence interval (CI) | 5 | [Appendix A - 29, 36, 50, 168, 188] |
| | Variance | 3 | [Appendix A - 29, 121, 188] |
| Simulation and operational performance metrics | Simulation performance | 51 | [Appendix A - 13, 16, 20, 21, 28, 52, 58, 62, 65, 66, 67, 70, 71, 72, 73, 74, 83, 84, 89, 90, 92, 97, 99, 100, 108, 115, 116, 119, 120, 125, 126, 128, 132, 136, 138, 145, 148, 150, 151, 153, 155, 159, 170, 172, 177, 178, 180, 181, 183, 188, 190] |
| | Measures of Merit (MOM), Measures of Performance (MOP) | 2 | [Appendix A - 63, 88] |
| | Feasibility | 2 | [Appendix A – 26, 162] |
| | Flexibility | 3 | [Appendix A - 26, 82, 134] |
| | Robustness | 4 | [Appendix A - 26, 41, 162, 175] |
| | Ease of use | 1 | [Appendix A - 26] |
| Computational and implementation metrics | Inference Time | 1 | [Appendix A - 93] |
| | Model parameters | 1 | [Appendix A - 93] |
| | Computational performance | 8 | [Appendix A - 40, 44, 101, 105, 106, 118, 158, 191] |
| Reinforcement-learning metrics | Sparse reward, Shaped reward | 7 | [Appendix A - 3, 11, 109, 124, 167, 173, 190] |
| | Temporal sequence interaction gain ($G_0$) | 1 | [Appendix A - 2] |
| Image/signal-quality metrics | Structural Similarity Index Measure (SSIM) | 2 | [Appendix A - 46, 75] |
| | VAE-based method | 1 | [Appendix A - 87] |
| | Peak Signal-to-Noise Ratio (PSNR) | 1 | [Appendix A - 75] |
| | Mutual Information (MI) | 1 | [Appendix A - 75] |
| Ontology/system-quality metrics | OQuaRE ontology quality evaluation framework | 2 | [Appendix A – 54, 179] |
| Descriptive/statistical metrics | Mean, standard deviation, max | 4 | [Appendix A - 33, 48, 123, 160] |
| | Cronbach's Alpha | 1 | [Appendix A – 50] |
| No quantitative performance benchmark | | 69 | [Appendix A 5,7,8,9,10,12, 15, 18, 19, 22, 23, 24, 25, 27, 30, 31, 34, 35, 38, 42, 43, 45,47, 49, 53, 56, 57, 59, 60, 64, 68, 69, 76, 77, 78, 79, 80, 81, 85, 86, 91, 94, 95, 96, 103, 110, 112, 113, 114, 117, 122, 129, 133, 135, 137, 141, 142, 143, 144, 146, 152, 156, 161, 174, 176, 187, 189, 192, 193] |

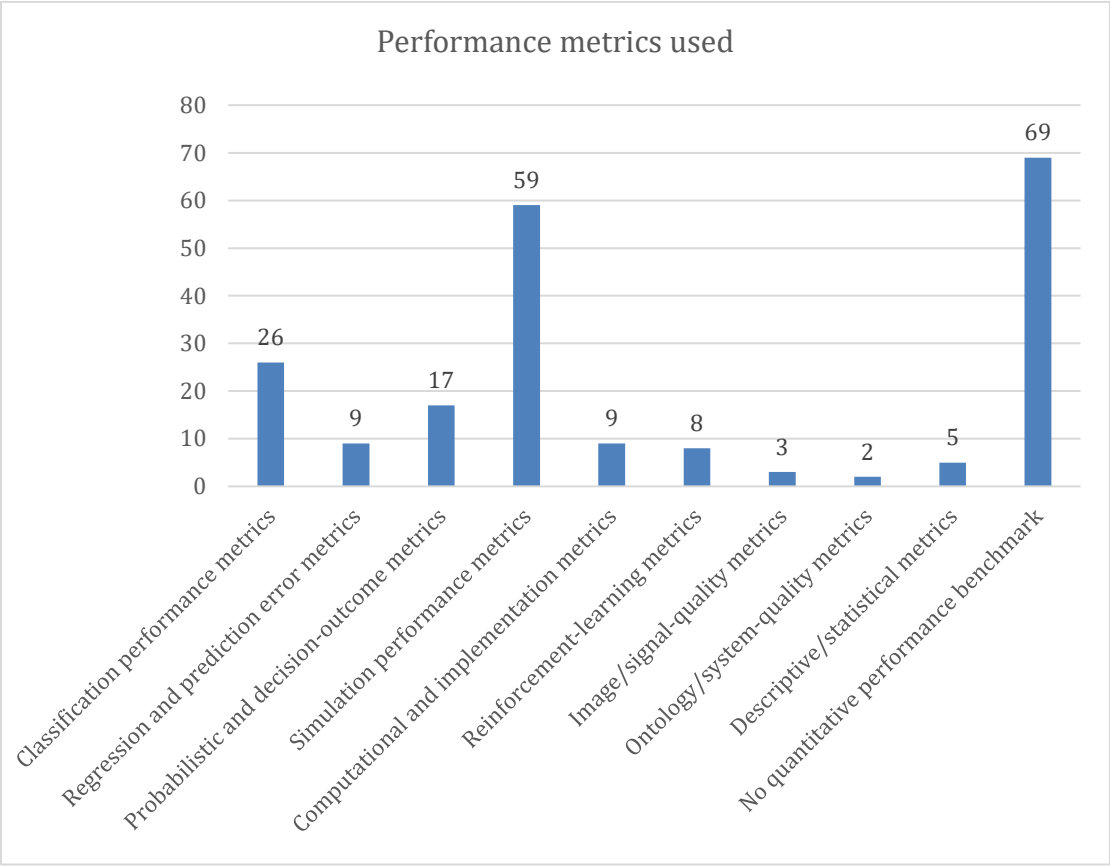


*Figure 3.12. Performance metrics presented in included studies*

To evaluate the selected studies, the reviewer assessed each article using two independent 5-point Likert-type scales. The first scale measured study relevance to the topic of military decision-making, while the second evaluated study quality regarding methodology. For both criteria, scores ranged from 1 to 5, where 1 represented the lowest possible rating (e.g., highly irrelevant or poor methodological quality) and 5 represented the highest possible rating (e.g., highly relevant or excellent methodological quality). The evaluations of the included studies are presented in Table 3.12.

Most studies were rated as highly relevant to AI in military decision-making, with ratings of 5 or 4 dominating the extraction file. Quality ratings were mostly 4, followed by 3 and 5, as presented in Figure 3.13. There were 21 studies that got both highest grade in relevance to the topic and for the quality regarding methodology [Appendix A – 3, 11, 14, 15, 17, 19, 29, 47, 48, 49, 52, 53, 60, 119, 153, 155, 160, 163, 183, 188, 190].

*Table 3.12. Relevance and quality ratings of included studies*

| **Study relevance rating** | **Included studies** |
|---|---|
| 5 | [Appendix A - 2, 3, 6, 8, 9, 11, 12, 14, 15, 17, 19, 20, 21, 25, 27, 28, 29, 31, 33, 36, 37, 38, 40, 41, 43, 45, 47, 48, 49, 50, 52, 53, 55, 56, 57, 58, 60, 61, 62, 63, 64, 65, 66, 69, 70, 71, 72, 73, 74, 78, 81, 82, 83, 84, 87, 96, 97, 100, 101, 103, 107, 108, 109, 112, 115, 116, 117, 118, 119, 120, 122, 123, 125, 130, 131, 133, 134, 135, 136, 137, 138, 142, 145, 146, 147, 148, 149, 153, 155, 157, 160, 162, 163, 164, 165, 167, 168, 174, 175, 176, 177, 178, 179, 180, 181, 183, 186, 187, 188, 189, 190, 191, 192] |
| 4 | [Appendix A - 1, 4, 5, 7, 10, 13, 16, 18, 22, 23, 24, 26, 30, 32, 34, 35, 39, 42, 44, 46, 51, 54, 59, 67, 68, 75, 76, 77, 79, 80, 85, 86, 88, 89, 90, 92, 93, 94, 95, 98, 99, 102, 104, 105, 106, 110, 113, 114, 121, 124, 126, 127, 128, 129, 132, 139, 141, 143, 144, 150, 151, 152, 154, 156, 158, 159, 161, 166, 169, 170, 171, 173, 182, 184, 185, 193] |
| 3 | [Appendix A – 91, 111, 140, 172] |
| 2 | - |
| 1 | - |
| **Study quality rating** | **Included studies** |
| 5 | [Appendix A - 3, 11, 14, 15, 17, 19, 29, 47, 48, 49, 52, 53, 60, 119, 153, 155, 159, 160, 163, 170, 171, 183, 188, 190] |
| 4 | [Appendix A - 2, 6, 7, 8, 9, 12, 16, 18, 20, 21, 24, 25, 26, 27, 28, 30, 31, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 50, 54, 55, 56, 57, 58, 59, 61, 62, 63, 64, 65, 66, 67, 69, 70, 71, 72, 73, 74, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 92, 93, 95, 96, 97, 99, 100, 101, 102, 105, 106, 107, 108, 109, 111, 112, 117, 118, 120, 121, 123, 124, 125, 128, 129, 130, 137, 138, 139, 142, 145, 146, 147, 148, 149, 154, 165, 166, 167, 174, 175, 177, 178, 180, 181, 182, 186] |
| 3 | [Appendix A - 1, 4, 5, 10, 13, 22, 23, 32, 51, 68, 75, 90, 91, 94, 98, 103, 104, 110, 114, 115, 116, 122, 126, 127, 131, 132, 133, 134, 135, 136, 140, 141, 143, 144, 152, 157, 158, 162, 164, 168, 169, 173, 176, 179, 184, 185, 187, 189, 191, 192, 193] |
| 2 | [Appendix A – 113, 156, 161, 172] |
| 1 | - |

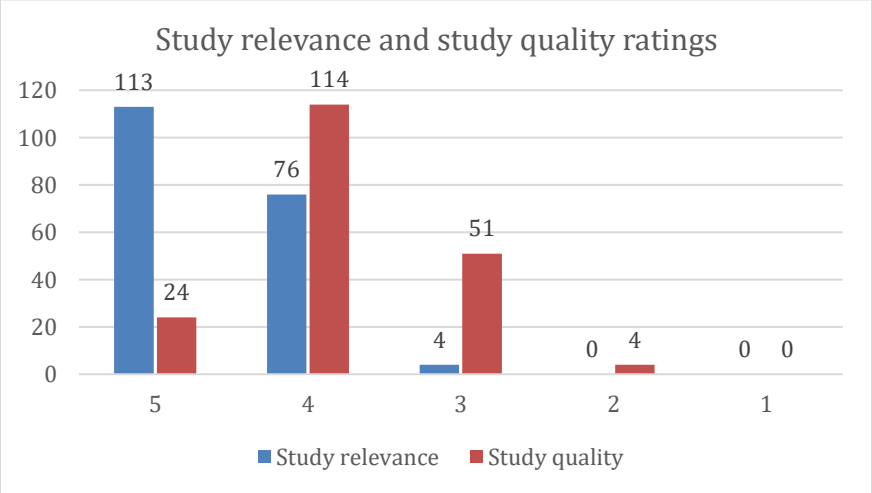


*Figure 3.13. Distribution of study relevance and study quality ratings*

The extracted limitations repeatedly concerned simplified scenarios, limited real-world validation, dependence on high-quality data, scarce or synthetic training data, model generalizability, limited explanation of model reasoning, computational constraints, and difficulty representing adversarial adaptation.

### 3.8. Ethical, legal, and policy considerations

Ethical considerations were explicitly discussed in 71 studies and not discussed in 122 studies. Legal or policy issues were raised in 56 studies and not raised in 137 studies, as listed in Table 3.13 and visually presented in Figure 3.14.

*Table 3.13. Ethical and Legal considerations raised in included studies.*

| **Ethical consideration discussed?** | **Included studies** |
|---|---|
| Yes | [Appendix A - 4, 6, 8, 9, 10, 11, 12, 14, 15, 17, 19, 21, 24, 25, 27, 28, 29, 31, 34, 35, 36, 38, 39, 41, 47, 48, 49, 50, 52, 53, 56, 57, 58, 59, 60, 65, 66, 69, 73, 76, 78, 81, 91, 103, 112, 123, 125, 129, 137, 157, 162, 164, 165, 168, 172, 173, 174, 175, 176, 177, 178, 179, 180, 182, 183, 184, 186, 188, 189, 191, 193] |
| No | [Appendix A - 1, 2, 3, 5, 7, 13, 16, 18, 20, 22, 23, 26, 30, 32, 33, 37, 40, 42, 43, 44, 45, 46, 51, 54, 55, 61, 62, 63, 64, 67, 68, 70, 71, 72, 74, 75, 77, 79, 80, 82, 83, 84, 85, 86, 87, 88, 89, 90, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 104, 105, 106, 107, 108, 109, 110, 111, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 124, 126, 127, 128, 130, 131, 132, 133, 134, 135, 136, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 153, 154, 155, 156, 158, 159, 160, 161, 163, 166, 167, 169, 170, 171, 181, 185, 187, 190, 192] |
| **Legal or policy issues raised?** | **Included studies** |
| Yes | [Appendix A - 8, 9, 10, 11, 12, 15, 17, 19, 21, 27, 28, 29, 31, 35, 36, 37, 38, 44, 47, 48, 49, 50, 53, 54, 55, 56, 57, 59, 60, 69, 76, 78, 81, 91, 103, 112, 123, 125, 129, 142, 157, 162, 168, 173, 174, 175, 176, 177, 178, 179, 183, 184, 186, 188, 189, 193] |
| No | [Appendix A - 1, 2, 3, 4, 5, 6, 7, 13, 14, 16, 18, 20, 22, 23, 24, 25, 26, 30, 32, 33, 34, 39, 40, 41, 42, 43, 45, 46, 51, 52, 58, 61, 62, 63, 64, 65, 66, 67, 68, 70, 71, 72, 73, 74, 75, 77, 79, 80, 82, 83, 84, 85, 86, 87, 88, 89, 90, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 104, 105, 106, 107, 108, 109, 110, 111, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 124, 126, 127, 128, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 153, 154, 155, 156, 158, 159, 160, 161, 163, 164, 165, 166, 167, 169, 170, 171, 172, 180, 181, 182, 185, 187, 190, 191, 192] |

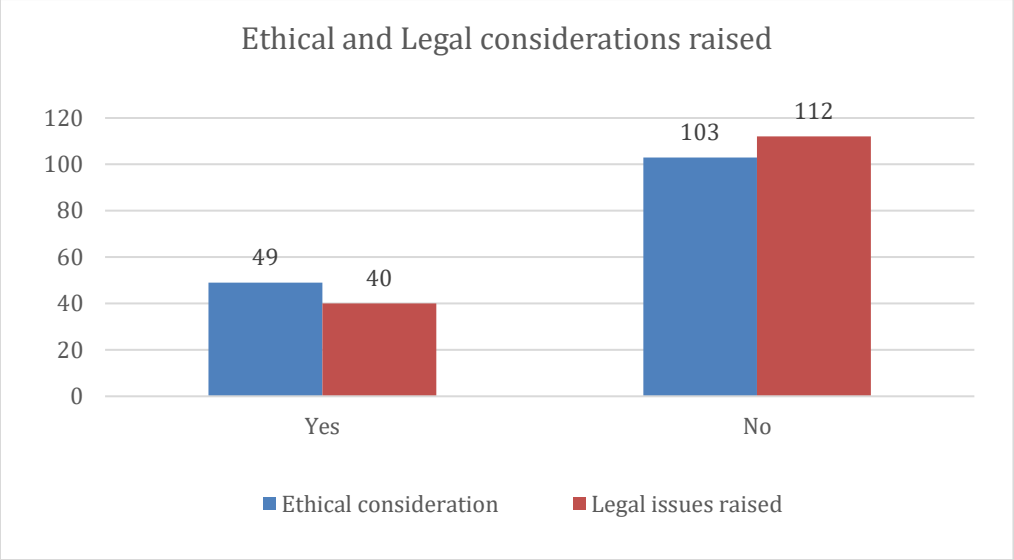


*Figure 3.14. Ethical and Legal consideration discussed in included studies*

### 3.9. Risk and uncertainty quantification

In the included studies, risk and uncertainty were addressed either explicitly (156 studies) or implicitly (37 studies) and covered through recurring categories presented in Table 3.14 and visually presented in Figure 3.15. Many uncertainties are overlapping and arise from other uncertainties, so studies usually cover many of the uncertainties listed on this list. In addition, different uncertainties can have impact on different risks. The most frequently identified category was risk to mission success (190 studies), followed by operational uncertainty (181 studies), data uncertainty (169 studies), AI model uncertainty (163 studies), and adversary-related uncertainty (154 studies). These results indicate that most studies considered uncertainty in relation to mission outcomes, operational conditions, data reliability, model behavior, and enemy adaptation. Other frequently reported categories included COA uncertainty (144 studies), system or technological uncertainty (143 studies), risk to personnel, civilians, equipment, or infrastructure (139 studies), intelligence uncertainty (138 studies), and human-related uncertainty (125 studies). Less frequently reported categories were environmental uncertainty (102 studies), sensor uncertainty (92 studies), cybersecurity, deception, spoofing, or adversarial manipulation risk (74 studies), data-selection uncertainty (72 studies), legal, ethical, escalation, or accountability risk (54 studies), and AI model-selection uncertainty (48 studies). In general, the results show that uncertainty and risk were widely represented in the extracted data, with the strongest emphasis on mission, operational, data, model, adversary, and COA-related uncertainty.

*Table 3.14. Uncertainty and risk assessment covered in included studies*

| **Uncertainty and risk assessment** | **Included studies** |
|---|---|
| Sensor uncertainty | [Appendix A - 2, 3, 4, 6, 7, 8, 9, 11, 16, 17, 18, 19, 22, 25, 27, 32, 33, 37, 39, 40, 43, 46, 49, 51, 53, 57, 58, 59, 60, 61, 62, 66, 68, 71, 72, 75, 79, 81, 84, 86, 87, 88, 90, 92, 93, 94, 96, 99, 100, 104, 108, 110, 111, 112, 113, 115, 116, 118, 122, 124, 130, 136, 140, 141, 142, 147, 148, 150, 152, 153, 154, 155, 156, 157, 159, 161, 163, 165, 166, 167, 170, 171, 181, 182, 185, 186, 187, 188, 189, 190, 191, 192] |
| Data uncertainty | [Appendix A - 1, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 22, 23, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 37, 38, 39, 40, 42, 43, 45, 46, 47, 49, 50, 51, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 96, 97, 101, 102, 103, 104, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 125, 126, 127, 129, 130, 131, 133, 134, 135, 136, 137, 139, 140, 141, 142, 143, 144, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193] |
| Data-selection uncertainty | [Appendix A - 4, 6, 17, 19, 22, 23, 25, 26, 27, 35, 38, 39, 53, 54, 55, 57, 59, 60, 64, 74, 75, 76, 77, 78, 79, 80, 81, 85, 101, 112, 113, 114, 121, 129, 133, 137, 142, 144, 151, 156, 157, 158, 159, 160, 163, 165, 166, 167, 168, 169, 170, 171, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193] |
| Intelligence uncertainty | [Appendix A - 1, 3, 4, 5, 6, 9, 10, 11, 12, 15, 16, 17, 18, 19, 20, 22, 23, 27, 28, 29, 30, 35, 36, 37, 38, 40, 42, 43, 45, 49, 50, 51, 52, 53, 54, 55, 56, 57, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 70, 71, 75, 76, 77, 79, 80, 81, 82, 83, 86, 87, 88, 89, 91, 93, 94, 96, 97, 98, 101, 103, 106, 108, 112, 113, 114, 118, 119, 120, 121, 122, 125, 126, 129, 130, 131, 133, 134, 135, 137, 139, 141, 142, 143, 144, 146, 148, 149, 150, 151, 152, 155, 156, 157, 158, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193] |
| Operational uncertainty | [Appendix A - 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 43, 44, 45, 46, 47, 48, 49, 50, 52, 53, 54, 55, 56, 57, 58, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 112, 113, 114, 115, 116, 117, 118, 119, 120, 122, 123, 124, 125, 126, 127, 128, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 142, 143, 144, 145, 146, 147, 148, 149, 150, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 190, 191, 192, 193] |
| Adversary-related uncertainty | [Appendix A - 1, 2, 3, 4, 6, 7, 8, 9, 11, 12, 13, 15, 16, 17, 19, 20, 24, 25, 26, 27, 28, 29, 31, 32, 33, 34, 35, 36, 37, 41, 42, 43, 44, 45, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 60, 61, 62, 63, 64, 66, 67, 68, 70, 71, 72, 73, 76, 77, 79, 80, 81, 83, 84, 86, 87, 88, 89, 90, 91, 92, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 105, 106, 108, 109, 110, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 125, 126, 127, 128, 129, 130, 131, 133, 134, 135, 136, 137, 138, 139, 142, 143, 144, 146, 147, 148, 149, 150, 153, 154, 155, 156, 157, 158, 160, 161, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 175, 178, 180, 181, 183, 184, 185, 186, 187, 188, 190, 191, 192, 193] |

*Table 3.14.. (Continued)*

| Uncertainty and risk assessment | Included studies |
|---|---|
| AI model-selection uncertainty | [Appendix A - 11, 12, 13, 19, 26, 39, 46, 48, 49, 53, 60, 75, 80, 81, 84, 87, 88, 108, 109, 111, 121, 123, 124, 129, 130, 133, 138, 146, 156, 157, 158, 159, 160, 163, 165, 166, 167, 180, 181, 182, 186, 187, 188, 189, 190, 191, 192, 193] |
| AI model uncertainty | [Appendix A - 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 13, 14, 15, 16, 17, 19, 21, 22, 23, 26, 27, 28, 29, 30, 31, 32, 34, 35, 36, 37, 38, 39, 40, 41, 42, 44, 46, 47, 48, 49, 50, 51, 52, 53, 55, 56, 57, 58, 59, 61, 62, 64, 67, 69, 71, 72, 73, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 90, 91, 92, 93, 94, 95, 96, 97, 99, 100, 101, 102, 103, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 133, 134, 135, 137, 138, 139, 140, 141, 142, 143, 145, 147, 148, 150, 151, 153, 154, 155, 156, 157, 158, 161, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193] |
| Course-of-action uncertainty | [Appendix A - 1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 21, 24, 25, 28, 29, 32, 33, 34, 37, 40, 41, 43, 44, 45, 47, 48, 49, 50, 52, 53, 55, 56, 58, 60, 61, 62, 63, 64, 65, 66, 67, 68, 70, 71, 72, 73, 77, 79, 80, 81, 82, 83, 84, 86, 87, 88, 89, 90, 91, 94, 95, 96, 97, 98, 100, 101, 102, 103, 104, 105, 106, 107, 109, 110, 112, 113, 115, 116, 117, 118, 119, 120, 124, 125, 126, 127, 128, 132, 133, 134, 135, 136, 137, 138, 139, 143, 144, 145, 146, 147, 149, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 167, 168, 169, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 183, 184, 185, 187, 188, 189, 190, 191, 192, 193] |
| Human-related uncertainty | [Appendix A - 1, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 23, 24, 27, 28, 29, 30, 31, 34, 35, 36, 37, 38, 40, 41, 42, 43, 44, 45, 47, 48, 49, 52, 53, 56, 60, 62, 63, 64, 65, 66, 67, 69, 70, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 86, 89, 91, 93, 94, 97, 99, 103, 108, 109, 110, 112, 113, 114, 117, 119, 120, 121, 122, 123, 125, 126, 129, 130, 131, 133, 134, 135, 136, 137, 139, 142, 143, 152, 156, 157, 158, 160, 161, 162, 164, 165, 168, 169, 170, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 188, 189, 190, 191, 193] |
| System or technological uncertainty | [Appendix A - 3, 4, 6, 7, 8, 11, 12, 14, 15, 17, 18, 19, 21, 22, 25, 27, 28, 30, 31, 33, 37, 38, 40, 42, 44, 49, 50, 53, 54, 55, 56, 57, 58, 59, 60, 61, 63, 64, 65, 69, 72, 74, 75, 76, 78, 79, 80, 81, 82, 84, 85, 86, 87, 90, 91, 92, 94, 95, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 111, 112, 113, 115, 116, 118, 119, 120, 121, 122, 123, 124, 125, 127, 128, 129, 131, 132, 133, 135, 136, 137, 138, 140, 141, 142, 144, 146, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 171, 172, 173, 174, 175, 176, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193] |
| Environmental uncertainty | [Appendix A - 1, 2, 3, 5, 6, 7, 11, 14, 16, 17, 19, 22, 26, 28, 29, 32, 33, 36, 40, 43, 45, 46, 48, 49, 50, 51, 52, 53, 56, 57, 58, 60, 61, 64, 67, 68, 74, 75, 79, 80, 81, 82, 84, 85, 87, 88, 89, 92, 93, 96, 98, 100, 102, 104, 105, 107, 108, 109, 111, 113, 115, 116, 119, 120, 124, 126, 128, 134, 138, 139, 140, 144, 145, 147, 153, 154, 156, 159, 161, 162, 163, 166, 167, 168, 170, 171, 177, 178, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193] |
| Cybersecurity, deception, spoofing, or adversarial manipulation risk | [Appendix A - 2, 8, 10, 12, 15, 17, 19, 22, 25, 27, 31, 35, 37, 38, 41, 42, 45, 47, 49, 53, 54, 55, 57, 59, 66, 69, 76, 78, 81, 85, 87, 91, 92, 98, 100, 102, 103, 106, 112, 113, 114, 117, 121, 122, 123, 129, 130, 142, 153, 154, 156, 157, 161, 164, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 184, 186, 187, 188, 189, 190, 191, 192, 193] |

*Table 3.14. (Continued)*

| Uncertainty and risk assessment | Included studies |
|---|---|
| Risk to mission success | [Appendix A - 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 142, 143, 144, 145, 146, 147, 148, 149, 150, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193] |
| Risk to personnel, civilians, equipment, or infrastructure | [Appendix A - 1, 2, 3, 8, 9, 10, 11, 12, 13, 14, 15, 17, 19, 20, 21, 22, 24, 26, 27, 28, 29, 31, 33, 36, 39, 40, 41, 42, 43, 44, 47, 48, 49, 50, 52, 53, 54, 56, 57, 58, 60, 61, 62, 63, 64, 65, 67, 68, 70, 71, 73, 75, 76, 78, 79, 80, 81, 83, 84, 85, 86, 88, 89, 90, 91, 93, 94, 95, 97, 98, 99, 100, 101, 104, 105, 106, 108, 109, 110, 112, 113, 115, 116, 119, 120, 121, 122, 123, 125, 126, 130, 132, 133, 134, 135, 136, 137, 138, 139, 142, 143, 145, 147, 148, 149, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 167, 168, 169, 170, 173, 174, 175, 176, 177, 178, 179, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193] |
| Legal, ethical, escalation, or accountability risk | [Appendix A - 4, 8, 9, 10, 12, 15, 17, 18, 19, 27, 28, 29, 31, 38, 41, 43, 47, 50, 53, 56, 57, 60, 63, 69, 76, 81, 91, 94, 109, 112, 123, 125, 137, 157, 162, 164, 168, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 188, 193] |

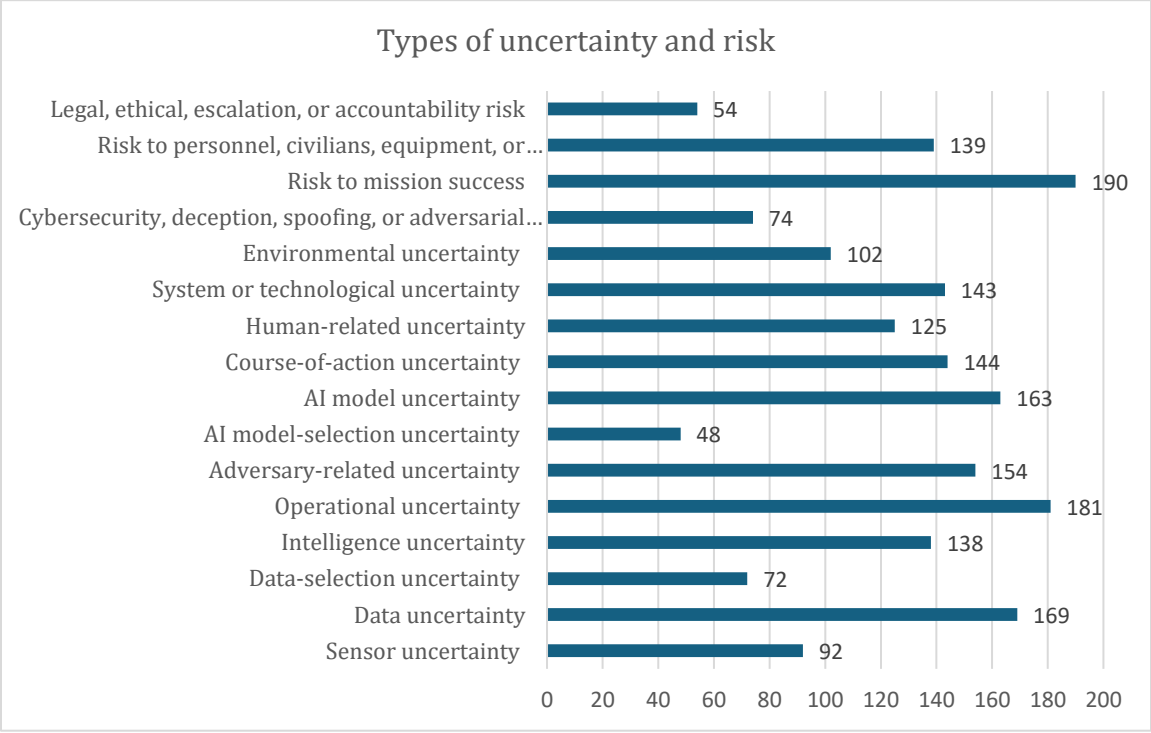


*Figure 3.15. Types of uncertainty and risk covered in included studies*

Uncertainty and risk assessment were most often first introduced during mission analysis (114 studies). Fewer studies introduced it during COA analysis/wargaming (33 studies) and COA development (12 studies) and COA comparison (2 studies). During AI model evaluation and validation there were only 4 studies, while 28 studies could not be linked to any specific MDMP step. Detailed list is given in Table 3.15 and the results are visually represented in Figure 3.16.

Table 3.15. MDMP step when uncertainty and risk are first introduced

| **MDMP step when first introduced** | **Included studies** |
|---|---|
| Receipt of Mission | - |
| Mission Analysis | [Appendix A - 1, 3, 4, 6, 7, 9, 10, 12, 15, 16, 17, 18, 20, 22, 23, 26, 27, 28, 30, 32, 35, 36, 37, 38, 39, 40, 42, 43, 45, 46, 47, 49, 50, 51, 52, 53, 54, 55, 56, 57, 60, 62, 66, 68, 69, 70, 71, 72, 75, 76, 77, 78, 79, 80, 82, 83, 85, 86, 88, 89, 91, 93, 94, 96, 101, 103, 106, 107, 110, 112, 113, 114, 115, 116, 117, 118, 121, 122, 125, 126, 129, 130, 131, 132, 133, 135, 136, 137, 141, 142, 143, 144, 145, 146, 147, 148, 150, 151, 152, 158, 161, 164, 165, 168, 169, 174, 182, 184, 185, 186, 188, 189, 190, 191] |
| COA Development | [Appendix A - 8, 61, 64, 67, 73, 97, 98, 104, 109, 160, 162, 192] |
| COA Analysis and Wargaming | [Appendix A - 2, 5, 11, 13, 29, 33, 41, 44, 48, 58, 63, 65, 90, 95, 100, 102, 105, 108, 119, 120, 123, 127, 128, 134, 138, 139, 149, 176, 177, 178, 180, 181, 183] |
| COA Comparison | [Appendix A - 124, 175] |
| COA Approval | - |
| Orders Production, Dissemination and Transition | - |
| During AI model evaluation or validation only | [Appendix A - 84, 99, 111, 140] |
| The study does not link the assessment to a specific MDMP step | [Appendix A - 14, 19, 21, 24, 25, 31, 34, 59, 74, 81, 87, 92, 153, 154, 155, 156, 157, 159, 163, 166, 167, 170, 171, 172, 173, 179, 187, 193] |

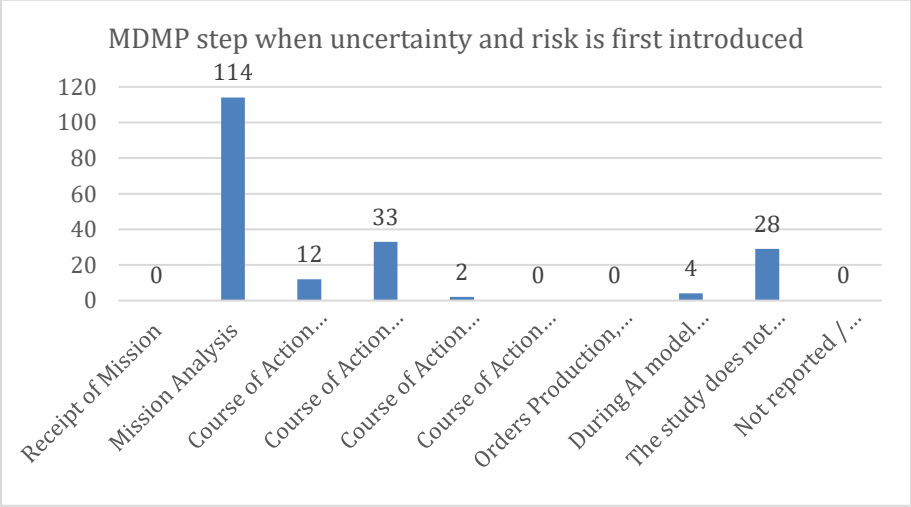


*Figure 3.16. MDMP step when uncertainty and risk are first introduced.*

# 4. DISCUSSION

## 4.1. Principal findings

This review shows that AI is being applied across a wide range of military decision-support functions, especially command and control, situational awareness, mission planning, threat detection, intelligence, target recognition, and resource allocation. Reviewed literature is broad, technically diverse, and increasingly recent. At the same time, it remains uneven. Most systems are prototypes, conceptual models, simulation-based tools, or methodological demonstrations. Far fewer studies provide operationally realistic field validation, robust human-subject evaluation with military staff, or transparent assessment of how AI recommendations affect decision quality, tempo, workload, trust, and accountability.

It is important to note that the literature used was unclassified and open source, so the results on study design and technological readiness level probably do not reflect the real situation since many military scientific projects are not publicly available. It is valid to believe that the AI methods as a decision-support systems are already field-tested and in the current use across various armed forces around the world.

The mix of different AI methodologies and techniques shows the continuity between earlier symbolic and expert-system approaches and newer data-driven approaches. Reinforcement learning with multi-agent systems was especially prominent in dynamic planning, COA development, simulation, wargaming, and resource-allocation problems. DL and particular computer vision used in CNN were more often associated with perception, target recognition, sensor interpretation, and image or signal processing. The NLP and emerging LLM approaches were linked to text analysis, report processing, intelligence synthesis, and COA drafting or summarization.

## 4.2. Mapping AI support to MDMP

The strongest alignment between the reviewed literature and MDMP occurs in mission analysis and mission planning (COA development, wargaming, and COA comparison). Mission analysis benefits from AI systems that process sensor data, geospatial, communications, intelligence, open-source and other types of data to improve situational awareness and detect and identify threats, as well as evaluate adversary strength and potential. COA development is supported by expert systems, multi-agent models, reinforcement learning, search algorithms, and generative or planning tools that propose possible options. Traditional mission planning would include the most probable and the most dangerous COA as possible options, and AI can scientifically support this phase. COA analysis and wargaming are supported by different simulation evaluations, adversarial modelling, and outcome prediction. The COA comparison is supported by decision matrices, risk assessment, optimization, and ranking. Less evidence was found for AI directly supporting receipt of mission, orders production, dissemination, and transition, although NLP and decision-support systems could be adapted to those steps.

## 4.3. Decision support for different levels of command

The results suggest that current AI support for decision process is primarily oriented toward the tactical and operational level of command rather than the strategic one. This is reasonable

because the main reason for it is the type of problems that these levels confront. Decision-making at the tactical and operational levels include short-term planning, tactical military operations, operational planning for the execution of the joint operation, and allocation of resource and assets. All these decisions are based on structured data in real time with clear physics and geometry rules.

For the tactical level those data include target detection and recognition, projectile velocity, range, rate of fire, radar detection, logistics, etc. Time dedicated to making decisions at a tactical level is short and gets even shorter in modern warfare, measuring in minutes or even in seconds. All these aspects make an ideal environment for computer vision algorithms and machine learning algorithms that are far more effective and faster in sensor data processing than humans.

The operational level is characterized by the coordination of troops and other assets, the maneuvers, and managing supplies and general logistics. AI can optimize and simulate, which is valuable support for the commander and the staff, especially if a risk assessment is integral part of the process.

Strategic decisions are highly unstructured; they rely on politics, geopolitics and military psychology where there is a lack in historical data needed for training of an AI model. Few historical data on geopolitical crises are unique and many times subjective in nature, which is aggravating factor for training of an AI model. Decisions made on the strategic level impact long-term period (months, years and even decades). At the strategic level there are too many unknowns ("Black Swans"[13]) that include political alliances, human emotions, will and moral level, and public opinion which are hard to quantify. In these situations, an AI could support decision-makes by analyzing open sources, or as an early warning system.

### 4.4. Human-machine teaming

The dominance of human-in-the-loop systems is appropriate for MDMP because command responsibility cannot be delegated to an algorithm. The most promising systems are not those that attempt to replace commanders, but those that improve staff cognition by reducing information overload, exposing assumptions, testing and comparing alternatives, making uncertainty explicit, and accelerating repetitive analytical tasks. However, human-in-the-loop design must be more than a label. Future systems should be evaluated for how commanders and staff use, question, override, or depend on recommendations. Evaluation should include workload, trust calibration, cognitive bias, explanation quality, decision speed, decision accuracy, and the risk of automation bias.

Human-on-the-loop systems are more appropriate for autonomous systems which are also emerging increasingly in recent war theaters[14], but in the context of MDMP the product of an automatization process should be used as a support for final decision made by the commander. Autonomous and unmanned systems were exclusion criteria for this systematic review, and only studies that included automatization process as a decision-support for commander's final decision were included.

[13] "Black Swans" is a term in systems theory and risk management that represent ontological uncertainties "unknown unknowns". Those are unpredictable and high-impact events that lie completely outside the realm of regular expectations and are rationalized only after they occur. [20]

[14] A "theater of war" is the entire geographic region (including land, sea, and air) that is directly involved in a conflict.

### 4.5. Data and validation challenges

Results show simulated data was the most common data type used. For unclassified studies it is hard to get real data for training AI models due to the scarcity, sensitivity and classification of real military operational data. The heavy use of simulated data can be seen as both a strength and a limitation. Simulation enables controlled experimentation and safe exploration of dangerous scenarios. It also permits repeated comparison of models and COAs. However, simulated data may not represent the ambiguity, noise, deception, missing data, tempo, degraded communications, and adversarial adaptation of real operations. In addition, it limits external validity. The transition from simulation to field or combat use requires validation with realistic operational datasets, red-team testing, adversarial robustness assessment, and continuous monitoring after deployment.

### 4.6. Ethical, legal, and policy implications

The limited discussion of ethical and legal issues is important findings of this review since it presents a significant gap. There is an imbalance between technological feasibility and human ambition for ethical and legal framework. AI decision support in military contexts can influence targeting, resource and asset allocation, force protection, and command responsibility. Even when a system is formally advisory, it can shape human judgment. The reviewed topic is inherently linked to accountability, transparency, explainability, human responsibility, proportionality, distinction, bias, data governance, escalation risk, and compliance with international humanitarian law and national policy. The relative absence of such discussion in much of the technical literature indicates a significant mismatch and imbalance between technological feasibility and ambition over ethical and legal framework. Currently, technology is evolving faster than the legal mechanisms meant to regulate its application, which impacts not only military activities, but civilian life in general. Therefore, explainability, auditability, data provenance, bias detection, accountability, legal review, and compliance with rules of engagement, law of armed conflict, international humanitarian law, and national policy should be designed into systems from the beginning. Responsible military AI should support disciplined command judgment, not obscure it.

### 4.7. Uncertainty and risk assessment implications

The findings suggest that uncertainty and risk are recognized as important elements of AI-supported military decision-making, but they are not addressed evenly through the reviewed literature. The high frequency of mission-success risk, operational uncertainty, data uncertainty, AI model uncertainty, and adversary-related uncertainty reflects the reality that military decision-making occurs in complex, dynamic, and adversarial environments where information is incomplete, models may be imperfect, and enemy behavior can change rapidly. However, the lower frequency of legal, ethical, escalation, accountability, cybersecurity, data-selection, and AI model-selection risks indicates an important gap. These risks are particularly relevant for operational use because they influence trust, accountability, compliance with rules of engagement and international law, and the commander’s ability to understand the limits of AI-generated recommendations.

Uncertainty and risk assessment were most often first introduced during mission analysis, which is generally appropriate because mission analysis is the stage where information gaps, assumptions, constraints, threats, and initial risks should first be identified. In several studies uncertainty and risk assessment appeared too late, mainly as a validation measure or performance

limitation rather than as an integral part of the decision-support process. A stronger approach would be to treat uncertainty and risk as continuous elements across the whole MDMP: first identified during mission analysis, incorporated into COA development, tested during wargaming, used as a comparison criterion during COA comparison, presented transparently to the commander during COA approval, and monitored during execution. Poorly handled uncertainty can lead to false confidence, wrong prioritization of threats, selection of unsuitable COAs, inefficient allocation of forces and resources, increased vulnerability to deception, escalation, collateral damage, or mission failure. In contrast, when uncertainty is made explicit and risk is assessed early and continuously, AI-enabled decision support can improve situational understanding, expose assumptions, support more realistic COA comparison, and increase the likelihood of mission success.

The results therefore suggest that future AI decision-support systems should not treat uncertainty only as a technical limitation or validation issue. Instead, uncertainty and risk assessment should be integrated throughout the MDMP, beginning with mission analysis and continuing through COA development, wargaming, COA comparison, approval, and execution. This would allow commanders and staff to compare courses of action not only according to predicted effectiveness, but also according to confidence, assumptions, vulnerabilities, potential consequences, and acceptable levels of operational risk.

### 4.8. Implications for practice

Based on evidence presented in this review, there are some implications which are to be considered in practice:

- AI should be introduced as decision support within MDMP, not as a substitute for commander judgment.
- Systems should be mapped explicitly to MDMP steps and staff functions before development or acquisition.
- Operational validation should include realistic time pressure, incomplete information, adversarial activities, degraded communications, and joint/multidomain and multination settings.
- Explanations should present assumptions, confidence, uncertainty, and competing COAs.
- Procurement and experimentation should require human factors evaluation, legal review, cyber and data resilience, and data governance from the outset.
- Decision-support tools should be interoperable with existing C2 (C3I, C4I, C5ISR) and planning procedures rather than isolated prototypes.
- Uncertainty and risk assessment should be integrated from the beginning of MDMP, especially during mission analysis, and carry it through COA development, wargaming, comparison, approval, and execution rather than treating it only as a final validation step.
- AI decision-support systems should be designed to show confidence levels, data-quality limits, model assumptions, adversary-deception risks, and operational consequences so commanders can use AI outputs as risk-aware support for judgment, not as deterministic recommendations.

### 4.9. Research gaps and future work

The findings show a lack of standardization in performance evaluation across the included studies, which limits direct comparison between approaches and highlights the need for more consistent reporting of model effectiveness, uncertainty, robustness, and operational applicability in future research.

Future research should move beyond proof-of-concept demonstrations toward comparative, reproducible, and operationally meaningful evaluation. Priority gaps include:

- validated datasets for military decision support;
- common evaluation metrics for COA quality and decision effectiveness;
- explainable AI tailored to commander and staff workflows;
- integration of symbolic reasoning, simulation, and data-driven learning;
- robustness against deception and adversarial manipulation;
- cross-domain and joint interoperability;
- human-machine teaming experiments with military personnel;
- systematic study of ethical, legal, and policy safeguards; and
- integration of robust uncertainty and risk assessment frameworks throughout AI-supported MDMP.

Studies should report data provenance, scenario assumptions, model limitations, uncertainty, computational requirements, and failure modes more consistently.

# 5. LIMITATIONS OF THIS REVIEW

This review depends on the search strategy, screening decisions, and extracted data provided for synthesis. Although 193 studies were included, the literature is heterogeneous in study design, technical approach, decision function, domain, validation method, and outcome reporting. For this reason, formal meta-analysis was not appropriate. Some included records may be conference papers, technical reports, or conceptual contributions rather than empirical studies. The descriptive frequencies should be interpreted as extraction-based indicators, not as measures of effect size. Finally, because the review excluded autonomous weapons systems and unmanned systems when they lacked a decision-support focus, the findings should not be generalized to autonomous targeting or autonomous platform research.

## 5.1. Other information on the review

A systematic review protocol was developed, but this systematic review was not registered in PROSPERO[15] [21] or another registry.

All supporting data files used in this systematic review (systematic review protocol, template data collection form – Covidence tool, studies included CSV file, data extraction CSV file) are available at the request to authors.

[15] PROSPERO is an international systematic review registry produced by the Centre for Reviews and Dissemination (CRD) and funded by the National Institute for Health and Care Research (NIHR).

# 6. CONCLUSION

Different AI techniques are increasingly important in research on the military decision-making process. Using AI in the MDMP enhances speed, accuracy, and operational efficiency, without replacing human commanders, as a support that scales human capability and serves as a "force multiplier". By analyzing massive datasets, AI accelerates data processing and enhance situational awareness in real-time, which can be crucial on the battlefield. Predictive analytics can forecast enemy movements and possible battle arrangements, and simulation of wargaming can identify the most probable outcomes. By reducing cognitive load, an AI can contribute to minimizing human error which can happen in stressful environments such as combat situations. By optimizing resource and assets allocation, AI algorithms can calculate the most efficient deployment of the forces and supply lines.

The evidence shows strong potential for decision support in mission analysis, situational awareness, military planning (COA development, wargaming, COA comparison), resource and assets allocation, threat detection, and intelligence analysis. At the same time, the findings show that AI-supported military decision-making is strongly shaped by uncertainty and risk. The most frequently identified risks and uncertainties were related to mission success, operational conditions, data quality, AI model performance, adversary behavior, intelligence reliability, course-of-action selection, system reliability, and possible consequences for personnel, civilians and equipment. These findings confirm that uncertainty is not only a technical issue of model accuracy, but also an operational, human, adversarial, ethical, and legal challenge that directly affects the quality of military decisions.

Nevertheless, the field remains dominated by simulations, prototypes, and conceptual models. Therefore, risk and uncertainty assessment should be incorporated more systematically into future AI-enabled MDMP. It should be introduced early in mission analysis, where information gaps, assumptions, constraints, threats, and operational risks are first identified, and then carried through COA development, wargaming, COA comparison, commander approval, and execution. If uncertainty is introduced only during model validation or final performance assessment, AI tools may create false confidence, obscure important assumptions, or lead to inappropriate COA selection. When uncertainty and risk are made explicit, AI can help commanders compare alternatives more realistically, understand the confidence and limitations of recommendations, and balance mission success against operational, human, legal, and ethical consequences.

The next stage of research should emphasize realistic validation, explainability, ethical and legal governance, data quality, and resilience under adversarial conditions (e.g. possible cyberattacks, deception, spoofing or data poisoning).

Properly designed, AI can help commanders and staff manage complexity and make faster and better-informed decisions. Poorly designed, it risks increasing opacity, automation bias, and accountability gaps. The decisive requirement is therefore not simply more AI in MDMP, but trustworthy AI that strengthens disciplined military judgment.

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# ABBREVIATIONS

| Abbreviation | Definition |
|---|---|
| ACM | Association for Computing Machinery |
| ADM | Army Design Methodology |
| AI | Artificial Intelligence |
| ANN | Artificial Neural Network |
| AO | Area of Operations |
| AOR | Area of Responsibility |
| AWS | Autonomous Weapons Systems |
| BDI | Belief–Desire–Intention |
| C2 | Command and Control |
| C3 | Command, Control, and Communications |
| C4I | Command, Control, Communications, Computers, and Intelligence |
| C5ISR | Command, Control, Communications, Computers, Cyber, Intelligence, Surveillance, and Reconnaissance |
| CBRN | Chemical, Biological, Radiological, and Nuclear |
| CCIR | Commander's Critical Information Requirements |
| CNN | Convolutional Neural Network |
| COA | Course of Action |
| COP | Common Operational Picture |
| DARPA | Defence Advanced Research Projects Agency |
| DL | Deep Learning |
| DOI | Digital Object Identifier |
| EEFI | Essential Elements of Friendly Information |
| EOD | Explosive Ordnance Disposal |
| EW | Electronic Warfare |
| F2T2EA | Find, Fix, Track, Target, Engage, Assess |
| GenAI | Generative Artificial Intelligence |
| GOAP | Goal-Oriented Action Planning |
| IEEE | Institute of Electrical and Electronics Engineers |
| ISR | Intelligence, Surveillance, and Reconnaissance |
| JPP | Joint Planning Process |
| JSTOR | Journal Storage |
| LLM | Large Language Model |
| LSTM | Long Short-Term Memory |
| MAS | Multi-Agent Systems |
| MDO | Multi-Domain Operations |

| Abbreviation | Definition |
|---|---|
| MDMP | Military Decision-Making Process |
| ML | Machine Learning |
| NATO | North Atlantic Treaty Organization |
| NLP | Natural Language Processing |
| OODA | Observe, Orient, Decide, Act |
| OPLAN | Operation Plan |
| OPORD | Operational Order |
| OPP | Operational Planning Process |
| PCC | Probability of Correct Classification |
| PICOS | Population, Intervention, Comparison, Outcome, Study Characteristics |
| PRISMA | Preferred Reporting Items for Systematic Reviews and Meta-Analyses |
| RDSP | Rapid Decision-Making and Synchronization Process |
| RL | Reinforcement Learning |
| RNN | Recurrent Neural Network |
| RQ | Research Question |
| SA | Situational Awareness |
| TLP | Troop Leading Procedures |
| TRL | Technology Readiness Level |
| UAS | Unmanned Aerial System |
| UGV | Unmanned Ground Vehicle |
| USV | Unmanned Surface Vehicle |
| UUV | Unmanned Underwater Vehicle |
| XAI | Explainable Artificial Intelligence |

## ABSTRACT

Background: Military decision-making is a process characterized by uncertainty, time pressure, information overload, adaptation of the enemy, and the need to process fragmented data into executable courses of action (COA). Artificial intelligence (AI) is increasingly examined as a support capability during a military decision-making process. New technological advancements in different AI methods facilitate this process in particular functions such as command and control, situational awareness, intelligence analysis, mission planning that include COA development, and resource and assets allocation.

Objective: This systematic review synthesizes publicly available evidence on AI applications relevant to the military decision-making process, with particular attention to how they support decision functions, decision-making levels, military domains, the commander role, the operational environment, technology maturity, methodological quality, ethical and legal considerations, and considerations of uncertainty and risk assessment.

Methods: The review was conducted according to PRISMA 2020 reporting principles using Covidence systematic review software for screening and data extraction. The search strategy was restricted exclusively to publicly available, unclassified, and open-source literature. No classified databases or restricted proprietary military networks were searched. Search strategy included Boolean string: ("machine learning" OR "deep learning" OR "artificial intelligence") AND ("decision-making" OR "decision making" OR "decision support") AND ("crisis management" OR "military operations" OR "warfare") with set up for each database. A total of 1439 records were identified from Scopus, ACM, IEEE Xplore, Web of Science, JSTOR, and grey literature. Eligibility criteria were established a priori using the PICOS framework. Title, abstracts screening was conducted independently by two reviewers according to predefined PICOS criteria which was embedded into the software's screening checklist to ensure consistency and resolve discrepancies. Discrepancies were resolved through discussion. After duplicate removal, title/abstract screening, retrieval, and full-text eligibility assessment by two reviewers collaboratively, 193 studies were included.

Results: The included literature spans from 1985 to 2026 but is strongly concentrated in recent years: 131 studies were published from 2021 to 2026. Dominate simulation studies and conceptual or methodological papers. The most common operational functions were command and control, situational awareness, mission planning (COA development), data analysis, resource and asset allocation, and intelligence. Tactical and operational decision levels were addressed more frequently than the strategic one. Most studies described prototypes as dominated technology readiness, and used simulated, sensor, geospatial, communications, or human/expert-annotated data. Human-in-the-loop approaches were the dominant model. Only a minority of studies discuss ethical, legal, or policy issues, even though these issues are central to responsible military AI use. Uncertainty and risk are predominantly introduced in mission analysis.

Conclusion: Decision-making process supported by the AI has clear potential across MDMP steps, especially mission analysis, COA development, wargaming, COA comparison, and finalizing orders. However, the current open evidence base remains more exploration than operationally validated. Future research should prioritize field validation, realistic human-machine teaming assessment, uncertainty-aware decision support, legal compliance, data governance, adversarial robustness, interoperability, and transparent performance reporting. It is important to state that this systematic review has been done on the unclassified and open literature, and the

findings presented here reflect only publicly accessible research and may not capture the full scope of active, restricted military operations or classified institutional knowledge.

Keywords: artificial intelligence; AI; military decision-making process; MDMP; decision support; command and control; risk; uncertainty; PRISMA; Covidence.

# APPENDIX A. Included studies from Covidence export

The following Table A 1 is derived from the uploaded Covidence included-studies CSV. Titles and bibliographic fields are reproduced in shortened table form for auditability.

*Table A 1. Included studies*

| Study ID | Title | Lead Author, contact details | Journal/Source | DOI/URL/ISBN |
|---|---|---|---|---|
| 1 | A Knowledge Growing System-based Decision Making-Support System Application for Forces Command and Control in Military Operations | Arwin Datumaya Wahyudi Sumari<br>Cognitive Artificial Intelligence Research Group (CAIRG)<br>Department of Electrical Engineering, State Polytechnic of Malang, Indonesia<br>Abdulrachman Air Force Base, 2nd Operation Command, Indonesia<br>Email: arwin.sumari@polinema.ac.id | 2021 International Conference on ICT for Smart Society (ICISS), IEEE | 10.1109/ICISS53185.2021.9533245 |
| 2 | A Radar Anti-Jamming Strategy Based on Game Theory With Temporal Constraints | Cheng Feng<br>Beijing Institute of Technology, Beijing, China,<br>Corresponding author: Xiongjun Fu<br>(fuxiongjun@bit.edu.cn) | IEEE Access, Volume 10, 2022 | 10.1109/ACCESS.2022.3200761 |
| 3 | A Reinforcement Learning Approach to Military Simulations in Command: Modern Operations | Adonisz Dimitriu<br>Széchenyi István University, Győr, Hungary<br>Email: dimitriu.adonisz@techtra.hu | IEEE Access, Volume 12, 2024 | 10.1109/ACCESS.2024.3406148 |
| 4 | Ability-oriented Performance Evaluation of General Intelligent Decision-making Engines Based on Knowledge Graphs | Xin Xu<br>China Electronic Products Reliability and Environmental Testing Research Institute, Guangzhou, China<br>Email: xuxin@ceprei.com | 2021 IEEE International Conference on Software Engineering and Artificial Intelligence (SEAI) | 10.1109/SEAI52285.2021.9477540 |
| 5 | Adaptive Knowledge Discovery Framework (AKDF) | Perakath Benjamin<br>Knowledge Based Systems, Inc.<br>1408 University Drive East, College Station, TX 77840, USA<br>Email: pbenjamin@kbsi.com | AAAI Spring Symposium - Technical Report | not specified |
| 6 | Advanced text and video analytics for proactive decision making | Elizabeth K. Bowman<br>U.S. Army Research Laboratory<br>Email: Elizabeth.k.bowman.civ@mail.mil<br>Phone: +1 410-278-5924 | Proceedings of SPIE, Vol. 10207 Next-Generation Analyst V (2017) | 10.1117/12.2276369 |
| 7 | Agent Oriented Modelling of Tactical Decision Making | Rick Evertsz – RMIT University, Melbourne, Australia<br>John Thangarajah – RMIT University<br>Nitin Yadav – RMIT University<br>Emails: {firstname.lastname}@rmit.edu.au | Proceedings of the 14th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2015), Istanbul, Turkey | ISBN: 978-1-4503-3413-6 |
| 8 | AI and ML in the multi-domain operations era: Vision and pitfalls | Michael A. Baker<br>U.S. Army War College<br>Email: mike.baker@asu.edu | Proceedings of SPIE, Next-Generation Analyst V (2020) | 10.1117/12.2558650 |
| 9 | AI and Warfare: A Rational Choice Approach | Atin Basuchoudhary<br>Virginia Military Institute<br>Lexington, VA 24450, USA<br>Email: basua@vmi.edu | Eastern Economic Journal (2024) | 10.1057/s41302-024-00280-7 |
| 10 | AI methodologies in upcoming modern warfare systems | Jyothi A. P.<br>Assistant Professor, Dept. of CSE<br>Ramaiah University of Applied Sciences<br>Bengaluru, Karnataka, India<br>Email: jyothiarcotprashant@gmail.com | 2022 IEEE International Conference on Current Development in Engineering and Technology (CCET) | 10.1109/CCET56606.2022.10080014 |

*Table A 1. (Continued)*

| Study ID | Title | Lead Author, contact details | Journal/Source | DOI/URL/ISBN |
|---|---|---|---|---|
| 11 | AI-Based Military Decision Support Using Natural Language | Michael Möbius<br>Airbus Defence and Space GmbH<br>Dept. Operational Analysis and Studies<br>Immenstaad, Germany<br>Email: michael.moebius@airbus.com | Proceedings of the 2022 Winter Simulation Conference (WSC 2022) | 10.1109/WSC57314.2022.10015234 |
| 12 | Artificial intelligence at the operational level of war | Steven I. Davis<br>Cyber Mission Force Pacific, U.S. Fleet Cyber Command<br>Oahu, Hawaii, USA<br>Email: steven.davis@pacom.mil | Defense & Security Analysis (2022), Vol. 38, No. 1, pp. 74–90 | 14751798.2022.2031692 |
| 13 | Artificial Life through GA in Simulation of Modern Anti-surface Warfare of Warship Fleet | Wang Bu-Yun<br>Postgraduate Team of Dalian Naval Academy<br>Dalian, China<br>Email: cloudybobo@126.com | 2009 International Conference on Intelligent Human-Machine Systems and Cybernetics (IHMSC 2009)<br>IEEE Conference Proceedings | 10.1109/IHMSC.2009.103 |
| 14 | Assessing the Impact of Alerts on the Human Supervisor's Decision-Making Performance in Multi-Robot Missions | Sarah Al-Hussaini (Corresponding Author)<br>University of Southern California, Los Angeles, CA, USA<br>Email: salhussa@usc.edu | ACM Transactions on Human-Robot Interaction<br>Vol. 14, No. 1, Article 7 (November 2024) | 10.1145/3689828 |
| 15 | Automating the OODA loop in the age of intelligent machines: reaffirming the role of humans in command-and-control decision-making in the digital age | Dr. James Johnson<br>Department of Politics and International Relations<br>University of Aberdeen, United Kingdom<br>Email: james.johnson@abdn.ac.uk | Defence Studies<br>Vol. 23, No. 1 (2023), pp. 43–67 | 10.1080/14702436.2022.2102486 |
| 16 | BOA: A Cognitive Tactical Picture Compilation Agent | Annerieke Heuvelink<br>TNO Defence, Security and Safety<br>Department of Training and Instruction<br>Soesterberg, The Netherlands<br>Email: A.Heuvelink@few.vu.nl | 2007 IEEE/WIC/ACM International Conference on Intelligent Agent Technology (IAT 2007) | 10.1109/IAT.2007.52 |
| 17 | A survey of data-centric technologies supporting decision-making before deploying military assets | Alexandra Zabala-Lopez<br>Colombian Air Force – Air and Space Operations Command – Aerospace Technology Development Centre for the Defense (CETAD), Bogotá, Colombia<br>Universidad de los Andes, Bogotá, Colombia | Defence Technology, Vol. 42 (2024), pp. 226–246 | 10.1016/j.dt.2024.07.012 |
| 18 | Challenges in applying artificial intelligence methodologies to military operations | Lloyd F. Arrowood, Oak Ridge National Laboratory<br>Oak Ridge, Tennessee, USA | Conference proceedings (late 1980s; based on references 1981–1986 citations) | 10.1145/12808.12853 |
| 19 | Characteristics of the Military Domain and their Impact on Military AI Applications | Antoine Smallegange – TNO Defence, Safety & Security, The Hague, Netherlands | 2025 International Conference on Military Communication and Information Systems (ICMCIS)<br>NATO Science and Technology Organization Symposium (IST-209-RSY)<br>Oeiras, Portugal, May 2025 | 10.1109/ICMCIS64378.2025.11047950 |
| 20 | Commander behavior and course of action selection in JWARS | Deborah Vakas,CACI Inc. – Federal, Arlington, VA, USA | Proceeding of the 2001 Winter Simulation Conference (Cat. No.01CH37304) | 10.1109/WSC.2001.977357 |
| 21 | Controlling teams of uninhabited air vehicles | Jeremy W. Baxter, QinetiQ Limited<br>Malvern Technology Centre, UK | AAMAS'05 – 4th International Joint Conference on Autonomous Agents and Multiagent Systems<br>Utrecht, Netherlands, July 2005 | 10.1145/1082473.1082800 |
| 22 | Data pedigree and strategies for dynamic level-one sensor data fusion | Marion G. Ceruti, Space and Naval Warfare Systems Center (SSC-SD), San Diego, California, USA. Email: marion.ceruti@navy.mil | Proceedings of the 9th International Conference on Information Fusion (FUSION 2006) | 10.1109/ICIF.2006.301806. |

*Table A 1. (Continued)*

| Study ID | Title | Lead Author, contact details | Journal/Source | DOI/URL/ISBN |
|---|---|---|---|---|
| 23 | Demand analysis of the application of intelligence push based on artificial intelligence in the military field | Ben Niu, Air Force Early Warning Academy, Wuhan, China | ICETIS 2022 (January 21–23, 2022), Harbin, China | - |
| 24 | Eliciting Expert Knowledge to Inform Training Design | Natalie Clewley, Centre for Electronic Warfare, Information and Cyber, Cranfield University, Defence Academy of the United Kingdom | ECCE 2019 – 31st European Conference on Cognitive Ergonomics Ulster University, Belfast, UK | 10.1145/3335082.3335091 |
| 25 | Enabling Autonomy in Command and Control via Game-Theoretic Models and Machine Learning with a Systems Perspective | Ali K. Raz, Purdue University | AIAA SciTech Forum 2019 | 10.2514/6.2019-0381 |
| 26 | Enhancing Defense Threat Assessment through Segmentation and Labelling of Synthetic Data | Agostino Bruzzone<br>Simulation Team & University of Genoa<br>Email: agostino.bruzone@simulationteam.com | 36th European Modeling & Simulation Symposium (EMSS 2024)<br>21st International Multidisciplinary Modeling & Simulation Multiconference | 10.46354/i3m.2024.emss.037 |
| 27 | Enhancing Military C4I-SR Through Integrating AI for Optimized Combat Effectiveness | Muhammad Munir<br>School of Computer Science, Nusa Putra University, Sukabumi, Indonesia<br>Email: muhammad.munir@nusaputra.ac.id | 2024 10th International Conference on Computing, Engineering and Design (ICCED)<br>IEEE Conference Proceedings | 10.1109/ICCED64257.2024.10983638 |
| 28 | Enhancing Tactical Military Mission Execution through Human-AI Collaboration: A View on Air Battle Management Systems | Sebastian Lindner<br>Institute of Flight Systems<br>Universität der Bundeswehr München<br>Neubiberg, Germany<br>Email: sebastian.lindner@unibw.de | 2024 IEEE 4th International Conference on Human-Machine Systems (ICHMS) | 10.1109/ICHMS59971.2024.10555606 |
| 29 | Exploration of Wargaming and AI Applications in Military Decision-Making | Hung-Xin Li<br>Department of Logistics Management<br>National Defense University<br>Taoyuan, Taiwan<br>Email: hungxinli@icloud.com | 2025 International Conference on Military Technologies (ICMT)<br>IEEE Conference Proceedings | 10.1109/ICMT65201.2025.11061360 |
| 30 | Flexible autonomous support to aid context and task switching | Kevin T. Durkee<br>Aptima, Inc., Fairborn, OH, USA | 2011 IEEE International Multi-Disciplinary Conference on Cognitive Methods in Situation Awareness and Decision Support (CogSIMA) | 10.1109/COGSIMA.2011.5753447 |
| 31 | Human-Centred AI in Military Cyber Operations | Clara Maathuis<br>Open University of the Netherlands<br>Heerlen, The Netherlands<br>Email: clara.maathuis@ou.nl | 19th International Conference on Cyber Warfare and Security (ICCWS 2024) | WOS:001418421600015 |
| 32 | The application of cognitive artificial intelligence within C4ISR framework for national resilience | Arwin Datumaya Wahyudi Sumari<br>Secretariat General of National Resilience Council (NRC), Indonesia + Cognitive Artificial Intelligence Research Group (CAIRG), Institut Teknologi Bandung (ITB)<br>Email: arwin.sumari@yahoo.com | 2017 Fourth Asian Conference on Defence Technology - Japan (ACDT) | 10.1109/ACDTJ.2017.8259600 |
| 33 | Intelligent Wargaming Approach to Increase Course of Action Effectiveness in Military Operations | Burak Yuksek<br>Cranfield University, UK<br>burak.yuksek@cranfield.ac.uk | AIAA SciTech Forum 2023 | 10.2514/6.2023-2531 |
| 34 | Human factors in computer decision-making | Dimitrios Antos<br>Harvard University<br>antos@fas.harvard.edu | 10th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2011) | ISBN: 0-9826571-7-X |
| 35 | Intelligence and awareness | Rubén Arcos | Routledge Handbook of the Future of Warfare (Chapter) | 10.4324/9781003299011-29 |
| 36 | Predicting Enemy Threats in Ground Operations Using Interpretable Machine Learning | Kyungyeol Bae | Military Operations Research, Vol. 29, No. 4, 2024 | 10.5711/1082598329489 |

*Table A 1. (Continued)*

| Study ID | Title | Lead Author, contact details | Journal/Source | DOI/URL/ISBN |
|---|---|---|---|---|
| 37 | Gaining Competitive Advantages in Cyberspace | Lieutenant Colonel Nathaniel D. Bastian, Ph.D.<br>United States Military Academy (West Point)<br>Army Cyber Institute | The Cyber Defense Review, 2023 | https://www.jstor.org/stable/48730572 |
| 38 | The Strategic Corporal, the Tactical General, and the Digital Coup d'oeil – Military Decision-Making and Organizational Competences in Future Military Operations | Anders Theis Bollmann<br>University of Copenhagen, DK<br>atb@ifs.ku.dk | Scandinavian Journal of Military Studies, Vol. 6, No. 1, 2023 | 10.31374/sjms.190 |
| 39 | Object Detection for Military Surveillance using YOLO Framework | Shankhanil Borthakur, Department of Electronics Engineering, Sardar Vallabhbhai National Institute of Technology, Surat, India, shankhanil974@gmail.com, | 2023 IEEE 20th India Council International Conference, INDICON 2023 | 10.1109/INDICON59947.2023.10440938 |
| 40 | Hybrid methods for multisource information fusion and decision support | Jerome J. Braun,Lincoln Laboratory, Massachusetts Institute of Technology<br>244 Wood Street, Lexington, MA 02420-91 85, USA,<br>jbraun@ll.mit.edu. | Proceedings of SPIE, Vol. 6242 Multisensor, Multisource Information Fusion: Architectures, Algorithms, and Applications 2006 | 10.1117/12.664085 |
| 41 | Strategic Engineering to support Decision Makers in Complex Systems: Innovative Models for Cognitive Warfare Simulation | Agostino Bruzzone<br>Sim4Future; University of Genoa; NATO HQ SACT collaboration<br>Email: agostino@itim.unige.it | 14th International Defense and Homeland Security Simulation Workshop (DHSS 2024),<br>21st International Multidisciplinary Modeling & Simulation Multiconference | 10.46354/i3m.2024.dhss.005 |
| 42 | Leverage intrusion detection system framework for cyber situational awareness system | Bisyron Wahyudi Masduki<br>Department of Electrical Engineering<br>Universitas Indonesia<br>Email: bisyron.wahyudi@ui.ac.id | 2017 International Conference on Smart Cities, Automation & Intelligent Computing Systems<br>IEEE Conference Proceedings | 10.1109/ICON-SONICS.2017.8267823 |
| 43 | Weapon engagement management for ship defense | Bruce A. Chalmers, Defence Research Establishment Valcartier<br>2459 Pie XI Blvd. North, Val-Bélair, Québec G3J 1X5<br>Canada, E-mail: bruce.chalmers@drev.dnd.ca | SPIE Proceedings, Vol. 3080 Multisensor, Multisource Information Fusion (1997) | 10.1117/12.277160 |
| 44 | The Fuzzy Analytic Hierarchy Process for Evaluating the Effectiveness of Manned and Unmanned Collaborative Combat | Wang Chen, China North Vehicle Research Institute, Beijing, China, 15019683511@139.com | 2024 27th International Conference on Computer Supported Cooperative Work in Design (CSCWD)<br>IEEE, 2024 | 10.1109/CSCWD61410.2024.10580208 |
| 45 | Situation/Threat Assessment Fusion System (STAFS) | Jeung Won Choi,Data Fusion Lab, Agency for Defense Development (ADD), Daejeon, Korea,<br>{jwchoi.iwioo.dlcho}@add.re.kr | ISIF (International Society of Information Fusion), 2002 | 10.1109/ICIF.2002.1020973 |
| 46 | Performance Analysis for Generative Image Restoration Algorithm for Battlefield Objects | YoungHyeon Cho<br>Division of Artificial Intelligence Engineering<br>Korea Maritime & Ocean University<br>Busan, South Korea<br>peakso_@naver.com | 2024 IEEE International Conference on Big Data and Smart Computing (BigComp) | 10.1109/BigComp60711.2024.00085 |
| 47 | Human Centered Explainable AI Framework for Military Cyber Operations | Clara Maathuis, Open University of the Netherlands, The Netherlands, clara.maathuis@ou.nl | MILCOM 2023 – Workshop on Artificial Intelligence for Cyber<br>IEEE Military Communications Conference (MILCOM 2023) | 10.1109/MILCOM58377.2023.10356338 |
| 48 | Optimizing Naval Movement Using Deep Reinforcement Learning | Joseph Coble<br>FCC CMF SOUTH<br>U.S. Navy<br>Miami, FL USA,<br>joseph.r.coble.mil@mail.mil | 2023 International Conference on Machine Learning and Applications (ICMLA) | 10.1109/ICMLA58977.2023.00062 |
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