“Enhancing organizational effectiveness through knowledge-centric distance learning: The case of military education in Lithuania”

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ENHANCING ORGANIZATIONAL EFFECTIVENESS THROUGH KNOWLEDGE-CENTRIC DISTANCE LEARNING: THE CASE OF MILITARY EDUCATION IN LITHUANIA

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Abstract

Modern defense environments demand sustainable, knowledge-driven training systems that adapt to technological, organizational, and strategic challenges. This study explores the sustainability of military distance learning in Lithuanian military education and its role in enhancing adaptability and resilience. It assesses how digital, knowledge-based systems support long-term effectiveness and flexibility. Sustainability refers to maintaining scalable, resilient education under changing conditions. Adaptability is the ability to adjust learning processes and technologies, while resilience ensures institutional stability and performance during disruptions. The study employs fuzzy logic integrated with the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method to analyze interdependencies among eight critical factors of sustainable distance learning. A structured expert survey was conducted in 2024 with 17 Lithuanian military education specialists, all holding Ph.D. degrees and possessing extensive academic and practical experience in e-learning, instructional design, and technology management. The analysis revealed that technological infrastructure, instructional design, and scalability function as primary causal drivers shaping learner engagement and institutional support. Quantitative results show that technological infrastructure exerted the highest influence weight (0.187), followed by instructional design (0.162), while psychological support acted primarily as an effect factor. These findings confirm that sustainable distance learning enhances adaptability by ensuring uninterrupted access to training, flexible pacing, and integration of emerging digital tools. In conclusion, the study demonstrates that sustainable military distance learning serves as a strategic enabler of knowledge transfer, leadership development, and organizational effectiveness, thereby strengthening both the adaptability and institutional resilience of military education systems.

Keywords effectiveness, military, distance, training, sustainability, innovation, Lithuania

JEL Classification I23, M53, O32

INTRODUCTION

The accelerating pace of geopolitical change, technological advancement, and the growing complexity of modern warfare have reshaped the demands placed on military education systems. Contemporary defense environments are characterized by hybrid threats, cyber operations, multinational missions, and rapidly evolving operational requirements (Sottilare, 2024; Presnall et al., 2025; Tornero-Aguilera et al., 2024). In this context, military personnel must acquire not only technical and tactical expertise but also broader competencies such as adaptability, critical thinking, and decision-making under uncertainty. Traditional training models, based primarily on face-to-face instruction, field exercises, and physical drills, while essential, are no longer sufficient to address the full spectrum of these challenges.

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Distance learning has emerged as a promising approach to complement and extend conventional training methods. Its scalability, flexibility, and location-independent delivery make it particularly valuable for military organizations where personnel are frequently deployed or stationed in remote environments (Rastgar & Farokhizadeh, 2021; Strielkowski et al., 2025). Digital platforms also provide access to simulations, interactive modules, and adaptive resources that enhance both professional competencies and soft skills such as communication, collaboration, and leadership (Sottilare, 2022). Despite these advantages, however, the adoption of distance learning in military contexts raises critical concerns about its long-term sustainability and organizational impact.

The scientific problem arises from the absence of a comprehensive framework to evaluate and ensure the sustainability of distance learning in military education systems. Unlike civilian higher education, where digital learning strategies are widely studied and implemented, defense institutions face unique challenges related to technological security, institutional support, learner engagement, and operational integration (Ali Alnaqbi & Yassin, 2021; Gligorea et al., 2023). Without systematic analysis, military distance learning risks remain fragmented, underutilized, or misaligned with defense objectives. This gap is particularly evident in Lithuania, where the strategic modernization of the armed forces requires innovative training models capable of reinforcing resilience, adaptability, and organizational effectiveness.

1. LITERATURE REVIEW

Sustainable distance learning (SDL) in military education has become an increasingly relevant topic in recent years as armed forces worldwide seek to modernize training systems and ensure continuous professional development. Previous research emphasizes that sustainability in distance education depends on the capacity to maintain educational quality, learner engagement, and institutional adaptability over time (Hornstra et al., 2023; Powell & Townley, 2025). However, military education presents distinct challenges compared to civilian academic settings, including the need for discipline, leadership development, operational readiness, and hands-on skills training (Retter et al., 2024; Ministry of National Defence of the Republic of Lithuania, 2022). Addressing these challenges requires a holistic approach that integrates technological, pedagogical, institutional, and psychological dimensions into a coherent framework.

Existing studies highlight that while each of these dimensions has been examined individually, few have explored their interdependencies in the specific context of military education (Khraban, 2022; Amalia et al., 2024; Gligorea et al., 2023). To develop a comprehensive understanding of sustainable distance learning, this section synthesizes previous research according to four major thematic groups: technological, pedagogical, institutional, and psychological factors, each of which contributes to the resilience and effectiveness of military distance learning systems.

A strong technological foundation is consistently identified as a prerequisite for sustainable military distance learning (Presnall et al., 2025). Robust technological infrastructure and digital accessibility ensure secure communication, stable connectivity, and user-friendly platforms that facilitate interaction between cadets and instructors. Military-specific challenges, such as remote operations and data security, demand military-grade cybersecurity systems and flexible, mobile-compatible learning environments (Amalia et al., 2024). Without such foundations, distance learning risks fragmentation and loss of continuity, undermining both quality and sustainability.

Pedagogical innovation lies at the heart of effective, sustainable distance learning. Instructional design and pedagogical effectiveness must ensure engagement, knowledge retention, and skill application through simulations, gamification, and scenario-based learning (Hornstra et al., 2023; Zemmer, 2024). Adaptive learning technologies further personalize content, making training more responsive to individual cadet needs.

Equally important is instructor readiness and digital teaching competence, as the effectiveness of online military education depends heavily on instructors' ability to navigate digital environments (Kenyon, 2020; Air University, 2024). Professional development in e-learning methods, interactive digital tools, and continuous feedback mechanisms strengthens instructional quality.

Finally, learner engagement and motivation are key determinants of success in distance education (Noble, 2017; Mun, 2022). Strategies such as gamified challenges, peer collaboration, mentorship programs, and self-paced learning models sustain motivation and foster leadership skills. Effective assessment and performance measurement further ensure competency-based outcomes through simulations, real-world projects, and AI-supported feedback systems (Lee et al., 2022; Kim et al., 2024).

Sustainability also depends on strong institutional frameworks. Institutional support and policy frameworks must guarantee funding continuity, integration of online learning into formal military curricula, and recognition of digital training for career progression (Powell & Townley, 2025). Standardized accreditation and flexible scheduling further strengthen legitimacy and accessibility.

In addition, the scalability and adaptability of distance learning programs are essential to meet evolving military demands (Gligorea et al., 2023; Volk et al., 2020). Incorporating emerging technologies such as AR, VR, and AI enables rapid program updates and specialization-based customization. Scalable and adaptive systems ensure readiness to respond to global security challenges while maintaining educational consistency.

Military personnel often face significant stress due to the demanding nature of their roles, making psychological and social support crucial for sustainable distance learning (Khraban, 2022; Bekesiene et al., 2021a, 2021b, 2024). Effective programs incorporate mental health resources, such as virtual counseling and stress management workshops, to promote well-being. Peer networks and support groups also play an essential role in creating a sense of community among cadets in virtual settings. Additionally, flexible learning structures help cadets balance their military duties, personal life, and education, preventing burnout (Nguyen, 2024). These support systems ensure that learners remain mentally resilient, motivated, and equipped to successfully complete their training.

Overall, the reviewed studies highlight that sustainable military distance learning is shaped by the dynamic interrelation of technological, pedagogical, institutional, and psychological factors. Together, these components form a complex system in which weaknesses in one area can undermine overall effectiveness. While existing research provides valuable insights, most studies examine isolated aspects of military e-learning, leaving a gap in systematic approaches that integrate these dimensions into a coherent framework.

Accordingly, the purpose of this study is to assess the sustainability of distance learning in Lithuanian military education by identifying and analyzing the interrelationships among the critical factors underlying the four principal dimensions of sustainability: technological, pedagogical, institutional, and psychological.

Therefore, the hypotheses to be tested in the study are as follows:

H1: *Technological infrastructure has a significant effect on the sustainability of military distance learning.*

H2: *Pedagogical design and instructor readiness strongly influence cadet engagement, motivation, and knowledge retention.*

H3: *Institutional support and scalability determine the long-term integration of distance learning into military education systems.*

H4: *Psychological and social support mechanisms significantly affect learner resilience and successful program completion.*

2. METHODOLOGY

Based on the literature, the sustainability of distance learning in the Lithuanian Armed Forces can be assessed by identifying and analyzing

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the key technological, pedagogical, institutional, and psychological factors that influence its effectiveness and long-term viability. As demonstrated in the literature review, these factors can be grouped into eight key criteria: technological infrastructure (C1), instructional design (C2), instructor readiness (C3), learner engagement (C4), assessment strategies (C5), institutional support (C6), scalability of distance learning programs (C7), and psychological well-being (C8). Together, these criteria form a framework for evaluating the resilience and sustainability of military e-learning systems (see Table 1).

To systematically analyze the interrelationships among these criteria, this study employs the Fuzzy DEMATEL (Decision-Making Trial and Evaluation Laboratory) method. DEMATEL was originally developed by the Battelle Institute in Geneva (Fontela & Gabus, 1976) to examine complex decision-making environments characterized by multiple interdependent factors. Unlike traditional multi-criteria decision-making methods, DEMATEL identifies both direct and indirect causal relationships, making it well-suited for modelling the dynamics of sustainable military distance learning.

This study was conducted in the sequence of seven steps:

Step 1: Selection of evaluation criteria was based on the literature review; eight criteria (C1-C8) were identified as determinants of sustainability in military distance education (Table 1).

Step 2: An expert group was formed. To ensure the validity and reliability of the fuzzy DEMATEL analysis, an expert panel was purposefully collected, consisting of 17 specialists with extensive academic and professional experience relevant to the research topic. All experts hold Ph.D. degrees and are affiliated with the General Jonas Žemaitis Military Academy of Lithuania. The selection process followed purposive selection principles, ensuring that participants possessed both disciplinary expertise and practical experience in distance learning and related domains. The experts represent a diverse set of academic backgrounds, including e-learning, educational sciences, information and communication technologies, technology management, and business management. Their average academic experience is 17 years, ranging from 10 to 22 years, which ensures a balanced representation of both senior and mid-career scholars.

Table 1. Competencies and teaching strategies that affect cadet education

Code	Key Criteria	How it affects sustainable distance education
C1	Technological Infrastructure	Ensures uninterrupted training, even in remote or deployed settings
C2	Instructional Design	Adaptive learning technologies tailor content to individual progress, ensuring personalized learning experiences
C3	Instructor Readiness	Refers to military instructors' preparedness to effectively teach in an online environment, including their proficiency in using digital tools, adapting to new instructional methods, and engaging remote learners
C4	Learner Engagement	Facilitates competency-based education, ensuring military personnel develop mission-critical skills efficiently. Promoting long-term institutional sustainability requires investment in motivation strategies to enhance learning effectiveness and produce better-trained personnel. Developing leadership-oriented engagement models helps cadets and officers perceive distance learning as a strategic career advantage rather than a mere obligation
C5	Assessment Strategies	Assessment methods should integrate real-time performance evaluations, simulations, and practical field exercises, allowing distance learning to reflect actual military challenges
C6	Institutional Support	Implementing robust administrative support systems can provide structured guidance on enrollment, scheduling flexibility, and access to digital learning tools
C7	Scalability of Distance Learning Programs	Allows for the rapid deployment of educational resources during crises or wartime scenarios
C8	Psychological Well-being	Flexible learning structures, such as asynchronous course access and individualized learning pathways, can help balance training demands and psychological well-being

Note: C1 is a technological factor; C2, C3, C4, and C5 are pedagogical factors; C6 and C7 are institutional factors; C8 is a psychological factor.

Furthermore, each expert has authored over 50 Scopus-indexed publications, reflecting a high level of research productivity and engagement with contemporary academic discourse. Importantly, all experts have first-hand experience in the design, implementation, and delivery of online and hybrid learning programs within military education settings, particularly during the COVID-19 pandemic, when distance learning became a primary instructional mode. This combination of theoretical knowledge and practical involvement in online military education guarantees that the evaluations provided are grounded in both academic rigor and operational relevance.

Step 3: A pairwise comparison questionnaire was prepared to capture the perceived influence of each criterion (C1–C8, Table 1) on the others. Before completing the survey, participants were briefed on the study's objectives and trained in how to apply fuzzy scales for consistent evaluation.

Step 4: Data collection: Each expert independently completed the pairwise influence matrix, rating the impact of one factor on another using linguistic variables later transformed into fuzzy numerical values.

Step 5: Data aggregation: Individual responses were compiled and aggregated to form the group consensus matrix, ensuring equal representation of all expert judgments.

Step 6: Application of the Fuzzy DEMATEL method:

- Conversion of linguistic terms into fuzzy numbers.
- Construction of the initial direct-relation matrix.
- Normalization of the matrix to ensure comparability.
- Calculation of the total relation matrix, incorporating both direct and indirect effects.
- Computation of prominence (D+R) and relation (D–R) values for each criterion, identifying their relative importance and causal role.

Step 7: Interpretation of results: Factors were classified into cause group (criteria exerting a strong influence) and effect group (criteria more strongly influenced by others). This analysis reveals the structural dependencies that determine the sustainability of military distance learning.

The primary data for this study consisted of the expert evaluations obtained through the pairwise comparison questionnaire (see Appendix). The eight predefined criteria (C1-C8, Table 1) were derived directly from the literature review and confirmed by consensus among the 17 experts. These data served as the input for the fuzzy DEMATEL calculations.

3. RESULTS

As was mentioned above, this research methodology is grounded in expert-based evaluation, where 17 subject-matter experts with extensive experience in military education and distance learning assessed eight essential SDL factors that represent the sustainability of distance learning in military education, encompassing technological, pedagogical, institutional, and psychological domains. The factors technological infrastructure (C1), instructional design (C2), instructor readiness (C3), learner engagement (C4), assessment strategies (C5), institutional support (C6), scalability (C7), and psychological well-being (C8) were carefully selected after literature review (see Table 1) to determine how military institutions can establish a resilient and future-proof e-learning system.

To ensure precision in handling uncertainty and subjectivity in human judgment, the study employed a linguistic evaluation scale that corresponds to positive trapezoidal fuzzy numbers (see Table A1, Appendix). This approach enables a more refined and reliable representation of expert opinions under ambiguous conditions.

The fuzzy DEMATEL methodology was applied systematically through seven key steps, ensuring a rigorous mathematical analysis of sustainable distance learning factors. First, linguistic assessments of the 17 experts were collected and averaged (Table 2). These values were then used to construct the initial direct-relation matrix and the

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Table 2. Linguistic assessment of the evaluators' opinion (average)

Code	C1	C2	C3	C4	C5	C6	C7	C8
C1	0	VH	VH	VH	H	H	VH	H
C2	L	0	M	M	M	H	H	VH
C3	VL	M	0	L	M	H	M	H
C4	M	M	VH	0	H	M	L	H
C5	VL	M	H	L	0	L	L	H
C6	M	M	M	L	L	0	M	H
C7	M	H	H	VH	M	M	0	VH
C8	VL	L	L	L	L	VL	L	0

Note: C1 – technological infrastructure, C2 – instructional design, C3 – instructor readiness, C4 – learner engagement, C5 – assessment strategies, C6 – institutional support, C7 – scalability, and C8 – psychological well-being.

normalized direct-relation matrix, which are presented in the Appendix (see Table A2 and Table A3, Appendix). Following normalization, the total-relation matrix, as illustrated in Table 3, was designed. This matrix provides a holistic view of the direct and indirect influences among the sustainable distance learning factors. The total relation matrix provides a comprehensive overview of the interconnections among the eight key sustainable distance learning factors, allowing for a structured analysis of their mutual influences. By examining the values within this matrix, it is possible to identify common relationships and determine which factors exert the most significant impact on others. To ensure a clear and precise interpretation of these relationships and to avoid misrepresentations in the influence-relations map, a threshold value was applied. This threshold value serves as a cutoff point, ensuring that only the most relevant and significant relationships are retained in the final analysis.

The threshold value was determined using the mean average of all elements in the total relation matrix, a widely accepted method for filtering out weaker or insignificant connections (Ebrahimi, 2023). In this study, the calculated threshold value is 0.166, meaning that any relationship below this value was considered too weak to be included in the final influence-relations map. By applying this filtering technique, the calculated analysis results highlighted in Table 3 reveal meaningful and impactful relationships, enabling decision-makers to focus on the most influential factors affecting the sustainability of distance learning in military education.

Following Step 6, the prominence and cause-effect relationships were then determined with the final results displayed in Table 4. These results indicate the degree of influence each factor has within the sustainable distance learning framework and whether it belongs to the cause or effect group.

Moreover, DEMATEL results allow us to make a decision on study hypotheses. First, it was proved that C1 has the highest prominence (R+C = 3.000), the highest outgoing influence (largest *Ri*), and a strongly positive causality index (R–C = 1.470). C1 exhibits significant direct and indirect influences on nearly all other criteria (all exceed or approach the threshold), including the strongest single ef-

Table 3. Defuzzied total-relation matrix into a crisp total-relation matrix

Code	C1	C2	C3	C4	C5	C6	C7	C8
C1	0.098	0.308	0.343	0.288	0.262	0.274	0.290	0.371
C2	0.098	0.105	0.193	0.160	0.160	0.210	0.203	0.308
C3	0.074	0.150	0.097	0.106	0.139	0.190	0.142	0.242
C4	0.126	0.173	0.269	0.087	0.206	0.173	0.131	0.275
C5	0.063	0.137	0.192	0.094	0.062	0.106	0.099	0.222
C6	0.116	0.152	0.166	0.111	0.110	0.082	0.145	0.240
C7	0.142	0.236	0.265	0.252	0.186	0.193	0.113	0.341
C8	0.048	0.077	0.086	0.072	0.073	0.065	0.072	0.066

Notes: This study applied the mean average as the threshold; * > 0.166.

fect on psychological well-being (C1→C8 = 0.371). So, hypothesis *H1* "Technological infrastructure (C1) is the primary driver of sustainable distance learning" was confirmed.

Second, hypothesis *H2* "Instructional design (C2) significantly influences learner engagement and competency outcomes" was partially supported. C2 is a cause (R–C = 0.099) and ranks high in prominence (R+C = 2.775), which shows it is an important driver in the system. However, the direct effect C2 → C4 is 0.160, which is slightly below the significance threshold (0.166). This indicates C2's influence on engagement is primarily indirect (via other drivers, notably C1 and C7) rather than a strong direct link in the retained map. Thus, *H2* holds at the system-level (C2 matters) but not as a dominant direct link to C4 in the filtered network.

Third, hypothesis *H3* "Institutional scalability (C7) enhances long-term resilience of DL systems" was proved: C7 is the second most prominent criterion (R+C = 2.925) and a clear net driver (R–C = 0.533). C7 exerts significant direct and indirect effects on many other criteria (C7→C2, C7→C3, C7→C4, C7→C5, C7→C6, C7→C8), indicating that scalability materially contributes to system resilience and the capacity to respond to changing conditions.

Fourth, hypothesis *H4* "Psychological and social support (C8) functions primarily as an effect factor influenced by technological, pedagogical, and institutional components" was supported. C8 has the largest negative causality index (R–C = –1.506) and the highest column sum (Ci = 2.065). C8 receives strong influences from several drivers (notably C1 and C7). In other words, psychological well-being is mainly affected by improvements (or weaknesses) in infrastructure, scalability, design, and institutional support.

The final step of the analysis involved constructing the cause-and-effect relationship diagram, which provides a visual representation of the interdependencies among key SDL factors. This diagram enables decision-makers to identify priority areas and develop targeted strategies to enhance the sustainability of distance learning in military education. The classification of assessment criteria into cause-and-effect groups plays a critical role in determining which factors require immediate intervention to drive improvements across the system.

The analysis revealed that technological infrastructure (C1), instructional design (C2), learner engagement (C4), and scalability (C7) belong to the cause group, meaning they serve as the primary drivers influencing other factors. On the other hand, instructor readiness (C3), assessment

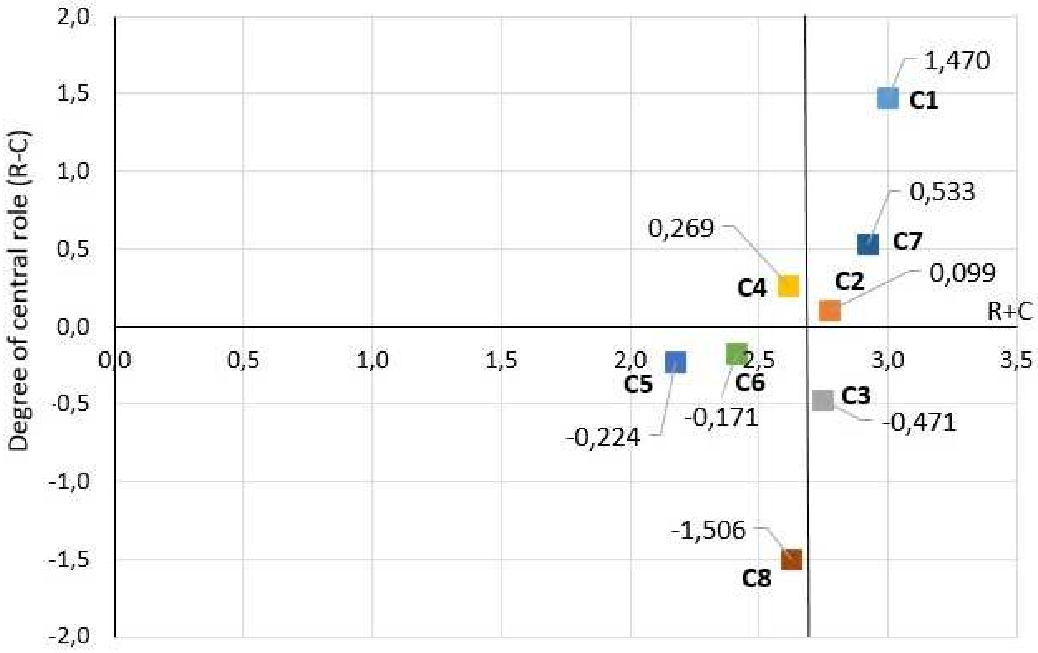

Figure 1. Cause-and-effect relationship diagram

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strategies (C5), institutional support (C6), and psychological well-being (C8) fall into the effect group, meaning they are impacted by changes in the cause group factors. Since cause factors have a direct influence on the effect group criteria, they should be prioritized in decision-making. The cause group represents the influencing criteria, while the effect group consists of the influenced criteria. Given the interdependence among these factors, improving elements within the cause group will simultaneously enhance the effect group criteria (see Figure 1).

Therefore, strengthening technological infrastructure, instructional design, learner engagement, and scalability should be the primary focus, as these improvements will lead to a ripple effect, positively impacting instructor readiness, assessment strategies, institutional support, and psychological well-being.

4. DISCUSSION

This study provides new insights into the sustainability of distance learning in military education by revealing the complex interdependencies among key factors that determine its effectiveness, adaptability, and resilience. The results of analysis demonstrate that technological infrastructure (C1), instructional design (C2), and scalability of distance learning programs (C7) serve as primary drivers that improve the efficiency and effectiveness of remote education for military personnel. Their combined impact ensures that distance learning remains adaptable, resilient, and capable of meeting the evolving demands of military training and education. These findings align with previous research on military e-learning and educational resilience, reinforcing the idea that digital transformation, adaptive instructional models, and scalable frameworks are pivotal in addressing the evolving needs of military personnel in distance education.

The importance of *Technological Infrastructure* (C1) has been consistently highlighted in previous research on military education (Slattery, 2024). Studies indicate that robust digital platforms, cybersecurity protocols, and AI-driven learning systems significantly enhance accessibility and data security in military training environments. The findings of this study reaffirm that the sustainability of distance learning heavily relies on a well-developed technological backbone, ensuring uninterrupted learning experiences and fostering operational readiness among service members.

The study's emphasis on *Instructional Design* (C2) aligns with findings by Moore and Frank (2013) and Mamites et al. (2022), which stress the necessity of interactive and scenario-based learning approaches in military training. Effective instructional design enhances knowledge retention and decision-making skills by incorporating real-time feedback, immersive simulations, and gamified learning models (Hornstra et al., 2024; Curry & Docherty, 2017). Our findings reinforce the notion that dynamic, mission-oriented instructional strategies are essential for sustaining long-term engagement and effectiveness in military distance learning.

Scalability (C7) is another key determinant of sustainable distance education, resonating with the conclusions of Sato et al. (2024), Si et al. (2018) and Çelikbilek and Adıgüzel Tüylü (2019), who highlight the necessity of modular and cloud-based learning systems. The study findings emphasize that scalability ensures cost efficiency, interoperability across military branches, and accessibility for a diverse learner base. This supports previous assertions that a scalable learning model is fundamental for military institutions to adapt to evolving training requirements and global security challenges.

The analysis identifies *Learner Engagement* (C4) as a driving factor or autonomous giver, meaning that it holds a high degree of influence over other factors in the system. In military distance learning, C4 does not directly dominate the system but significantly affects how other educational components function, ultimately shaping sustainability and effectiveness. Although *Learner Engagement* may not be the most prominent factor, its strong relational influence suggests that it acts as a silent driver in shaping learning success, program sustainability, and instructional effectiveness. In military education, where structured discipline is often emphasized, fostering engagement and motivation becomes essential for ensuring long-term knowledge retention and operational readiness in distance learning settings. This finding aligns with existing research on e-learning effectiveness, which emphasizes learner motivation, interaction, and engagement as critical components of long-term educational success (Sottilare, 2024; Mamites et al., 2022). Also, the significance of learner engagement in digital education has been widely documented in the literature. Studies by Çelikbilek and Adıgüzel Tüylü (2019) and Mehta and Sharma (2023) indicate that interactive learning environments foster higher motivation, increased retention, and improved student performance. Similarly, a study by Tang (2020) on leadership competencies in education underscores the role of engagement strategies in shaping learner behavior and long-term success. In military education, however, engagement is often ignored in favor of structured discipline and rigid instructional models. Yet, findings by Tornero-Aguilera et al. (2024) suggest that enhancing engagement through scenario-based learning, gamification, and real-time interaction significantly improves cognitive adaptability and operational readiness. The current study's results reinforce this perspective, demonstrating that while *Learner Engagement* may not be the most prominent factor, its indirect influence is substantial, impacting how other elements function within the distance learning framework.

In the context of military distance learning, three factors, *Learners' Assessment Strategies* (C5), *Institutional Support* (C6), and *Psychological Well-being* (C8), are characterized as relatively disconnected from the system and do not exert significant influence over other factors. Although these factors may not be the most influential drivers, they still play a critical role in ensuring the sustainability and effectiveness of distance learning in military education (Army University, n.d.a.; Lepinoy et al., 2021). Their independence suggests that while they may not directly shape the system, their improvement can enhance overall learning outcomes and long-term program sustainability.

The role of assessment in distance learning has been widely studied, with Çelikbilek and Adıgüzel Tüylü (2019) and Qian et al. (2024) emphasizing that traditional testing methods are often insufficient in virtual learning environments. Military distance education, which traditionally relies on standardized testing and practical performance evaluations, may face challenges in adopting adaptive assessment models that align with competency-based learning. Studies by Mehta and Sharma (2023) suggest that real-time feedback, scenario-based assessments, and AI-driven evaluation tools improve knowledge retention and engagement. The current findings support this interpretation, indicating that while *Learners' Assessment Strategies* (C5) is a low-prominence factor, enhancing assessment strategies could indirectly improve motivation (C4) and instructional effectiveness (C2).

The *Institutional Support* (C6), which represents administrative policies, funding, faculty training, and logistical resources allocated to military distance learning in previous research, has underscored the importance of institutional backing in maintaining the quality of e-learning programs. Studies by Mamites et al. (2022) and Tang (2020) highlight that funding, faculty development, and policy frameworks are crucial for sustaining online education. However, the low prominence of C6 in this study suggests that institutional support is primarily reactive rather than proactive, meaning it is influenced by technological advancements (C1) and instructional design improvements (C2) rather than being a core driver itself. Despite its limited systemic influence, insufficient institutional support could weaken engagement (C4), psychological well-being (C8), and overall program sustainability. *Psychological Well-being* (C8) encompasses mental health, stress management, and overall psychological resilience among military personnel engaged in remote learning. Psychological well-being factor was found not to be a driving force behind the system, but was influenced by factors such as Workload, Assessment Stress (C5), and Institutional Support (C6). A lack of psychological support may result in lower retention rates, reduced Learner Engagement (C4), and poor performance, indirectly affecting sustainability. The importance of mental health support in military education is widely acknowledged (Air University Public Affairs, 2022), and the newest research by Tornero-Aguilera et al. (2024) and Huynh-Cam et al. (2024) demonstrates that stress management, resilience training, and peer support networks contribute to improved performance and retention in e-learning environments.

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While C8 does not directly drive the system, its improvement can mitigate the effects of stress, isolation, and burnout among cadets (National University, 2021). The findings suggest that targeted mental health interventions, such as virtual counseling, stress reduction programs, and flexible learning structures, are essential for sustaining Learner Engagement (C4) and academic success.

Instructor Readiness (C3) factor highlighted its importance in ensuring learning effectiveness, while also being dependent on external technological, institutional, and learner-related factors. *Instructor Readiness* (C3) refers to military instructors' preparedness to effectively teach in an online environment, including their proficiency in using digital tools, adapting to new instructional methods, and engaging remote learners. High prominence means that instructor readiness directly affects learning outcomes, engagement (C4), assessment effectiveness (C5), and the overall success of military distance education. Also, the low relation indicates that C3 cannot be improved in isolation but depends on technological infrastructure (C1), instructional design (C2), and institutional support (C6). The current findings align with previous studies, confirming that instructors' ability to adapt to online environments is not only essential but also highly dependent on external conditions (Hornstra et al., 2024). Prior research consistently highlights the importance of instructor readiness in online education. Studies by Thornhill-Miller et al. (2023) and Mamites et al. (2022) emphasize that faculty preparedness in digital teaching directly impacts engagement (C4), assessment effectiveness (C5), and learner retention (Shia et al., 2021; Air University Public Affairs, 2022; Army University, n.d.b.).

Also, recent data support the argument put forward by Sottilare (2024) that effective online instruction in military settings relies on AI-driven learning systems, interactive simulations, and cloud-based platforms. Without robust technology (C1), even well-trained instructors may struggle to maintain engagement (C4) and assessment quality (C5). Furthermore, Institutional Policies (C6) play a significant role in facilitating instructor readiness. Studies by Air University (2024) suggest that military educators require structured policies that support professional development, access to digital tools, and workload management. The current findings validate this view by showing that C3 is not an isolated variable, as it is shaped by broader systemic influences.

Our findings proved that instructors need continuous training, access to appropriate digital resources, and institutional policies that support their transition to effective online teaching. By addressing identified key interdependencies, military institutions can equip instructors with the tools, confidence, and training necessary to lead effective digital education programs. This holistic approach confirms that military personnel receive high-quality, adaptable, and engaging distance learning experiences, ultimately enhancing the sustainability of military education in evolving operational environments.

While the study provides valuable insights, it has several limitations. The analysis is limited to the Lithuanian Armed Forces, which may restrict generalizability to other military institutions with different structures and technological capabilities. The study does not fully account for differences in technological adoption across military branches, which may impact the effectiveness of digital education. Additionally, the study provides a static analysis of distance learning sustainability but lacks longitudinal data on the long-term impact of implemented strategies.

CONCLUSIONS

The purpose of this study was to evaluate the sustainability of distance learning in Lithuanian military education by identifying and analyzing the interdependencies among eight critical factors. The results demonstrate that technological infrastructure (C1), instructional design (C2), and scalability of distance learning programs (C7) are the primary drivers that enhance the efficiency, adaptability, and effectiveness of remote education for military personnel. These elements form the technological and pedagogical backbone of sustainable distance learning systems, ensuring continuous access to training, flexibility in delivery, and responsiveness to evolving operational needs.

These findings highlight the need for a strategic, multi-layered approach to distance learning sustainability, emphasizing technological advancement, pedagogical innovation, and system scalability as critical enablers of resilient and future-ready military education. While instructor readiness (C3) and learner engagement (C4) function as integrative factors connecting the technological and human dimensions of learning, assessment strategies (C5), institutional support (C6), and psychological well-being (C8) operate as outcome-dependent elements. Although these latter factors do not dominate the system, their targeted enhancement can significantly reinforce sustainability by improving learner motivation, reducing stress, and strengthening institutional support structures.

Overall, the study shows that sustainable military distance learning is a systemic construct, requiring coordinated development across technological, pedagogical, organizational, and psychological dimensions. By prioritizing resources toward key driver factors while supporting secondary components through focused interventions, military education institutions can build more adaptable, resilient, and effective learning environments.

AUTHOR CONTRIBUTIONS

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APPENDIX A

Table A1. Linguistic scale to express judgment

Linguistic Term	Meaning	Fuzzy Scale Representation*
Very low influence (**VL**)	Criterion i has no influence on Criterion j	(0, 0, 0.25)
Low influence (**L**)	Criterion i has a weak influence on Criterion j	(0, 0.25, 0.5)
Medium influence (**M**)	Criterion i moderately influences Criterion j	(0.25, 0.5, 0.75)
High influence (**H**)	Criterion i strongly influences Criterion j	(0.5, 0.75, 1.0)
Very high influence (**VH**)	Criterion i has a decisive influence on Criterion j	(0.75, 1.0, 1.0)

Note: * – Fuzzy numbers are applied during the analysis stage; experts only select the linguistic term.

Table A2. Initial direct relation matrix

Code	C1	C2	C3	C4
C1	(0, 0, 0, 0)	(0.5, 0.75, 1, 1)	(0.5, 0.75, 1, 1)	(0.5, 0.75, 1, 1)
C2	(0, 0, 0.25, 0.50)	(0, 0, 0, 0)	(0, 0.25, 0.5, 0.75)	(0, 0.25, 0.5, 0.75)
C3	(0, 0, 0.25, 0.25)	(0, 0.25, 0.5, 0.75)	(0, 0, 0, 0)	(0, 0, 0.25, 0.50)
C4	(0, 0.25, 0.5, 0.75)	(0, 0.25, 0.5, 0.75)	(0.5, 0.75, 1, 1)	(0, 0, 0, 0)
C5	(0, 0, 0.25, 0.25)	(0, 0.25, 0.5, 0.75)	(0.25, 0.5, 0.75, 1)	(0, 0, 0.25, 0.50)
C6	(0, 0.25, 0.5, 0.75)	(0, 0.25, 0.5, 0.75)	(0, 0.25, 0.5, 0.75)	(0, 0, 0.25, 0.50)
C7	(0, 0.25, 0.5, 0.75)	(0.25, 0.5, 0.75, 1)	(0.25, 0.5, 0.75, 1)	(0.5, 0.75, 1, 1)
C8	(0, 0, 0.25, 0.50)	(0.5, 0.75, 1, 1)	(0.5, 0.75, 1, 1)	(0.5, 0.75, 1, 1)
Code	**C5**	**C6**	**C7**	**C8**
C1	(0.25, 0.5, 0.75, 1)	(0.25, 0.5, 0.75, 1)	(0.5, 0.75, 1, 1)	(0.25, 0.5, 0.75, 1)
C2	(0, 0.25, 0.5, 0.75)	(0.25, 0.5, 0.75, 1)	(0.25, 0.5, 0.75, 1)	(0.5, 0.75, 1, 1)
C3	(0, 0.25, 0.5, 0.75)	(0.25, 0.5, 0.75, 1)	(0, 0.25, 0.5, 0.75)	(0.25, 0.5, 0.75, 1)
C4	(0.25, 0.5, 0.75, 1)	(0, 0.25, 0.5, 0.75)	(0, 0, 0.25, 0.50)	(0.25, 0.5, 0.75, 1)
C5	(0, 0, 0, 0)	(0, 0, 0.25, 0.50)	(0, 0, 0.25, 0.50)	(0.25, 0.5, 0.75, 1)
C6	(0, 0, 0.25, 0.50)	(0, 0, 0, 0)	(0, 0.25, 0.5, 0.75)	(0.25, 0.5, 0.75, 1)
C7	(0, 0.25, 0.5, 0.75)	(0, 0.25, 0.5, 0.75)	(0, 0, 0, 0)	(0.5, 0.75, 1, 1)
C8	(0, 0, 0.25, 0.50)	(0, 0, 0.25, 0.25)	(0, 0, 0.25, 0.50)	(0, 0, 0, 0)

Table A3. Normalized fuzzy directed-relation matrix

Code	C1	C2	C3	C4
C1	(0.0,0.0,0.0,0.0)	(0.024,0.037,0.049,0.049)	(0.024,0.037,0.049,0.049)	(0.024,0.037,0.049,0.049)
C2	(0.0,0.0,0.012,0.024)	(0.0,0.0,0.0,0.0)	(0.0,0.012,0.024,0.037)	(0.0,0.012,0.024,0.037)
C3	(0.0,0.0,0.012,0.012)	(0.0,0.012,0.024,0.037)	(0.0,0.0,0.0,0.0)	(0.0,0.0,0.012,0.024)
C4	(0.0,0.012,0.024,0.037)	(0.0,0.012,0.024,0.037)	(0.024,0.037,0.049,0.049)	(0.0,0.0,0.0,0.0)
C5	(0.0,0.0,0.012,0.012)	(0.0,0.012,0.024,0.037)	(0.012,0.024,0.037,0.049)	(0.0,0.0,0.012,0.024)
C6	(0.0,0.012,0.024,0.037)	(0.0,0.012,0.024,0.037)	(0.0,0.012,0.024,0.037)	(0.0,0.0,0.012,0.024)
C7	(0.0,0.012,0.024,0.037)	(0.012,0.024,0.037,0.049)	(0.012,0.024,0.037,0.049)	(0.024,0.037,0.049,0.049)
C8	(0.0,0.0,0.012,0.024)	(0.024,0.037,0.049,0.049)	(0.024,0.037,0.049,0.049)	(0.024,0.037,0.049,0.049)
Code	**C5**	**C6**	**C7**	**C8**
C1	(0.012,0.024,0.037,0.049)	(0.012,0.024,0.037,0.049)	(0.024,0.037,0.049,0.049)	(0.012,0.024,0.037,0.049)
C2	(0.000,0.012,0.024,0.037)	(0.012,0.024,0.037,0.049)	(0.012,0.024,0.037,0.049)	(0.024,0.037,0.049,0.049)
C3	(0.000,0.012,0.024,0.037)	(0.012,0.024,0.037,0.049)	(0.000,0.012,0.024,0.037)	(0.012,0.024,0.037,0.049)
C4	(0.012,0.024,0.037,0.049)	(0.000,0.012,0.024,0.037)	(0.000,0.000,0.012,0.024)	(0.012,0.024,0.037,0.049)
C5	(0.000,0.000,0.000,0.000)	(0.000,0.000,0.012,0.024)	(0.000,0.000,0.012,0.024)	(0.012,0.024,0.037,0.049)
C6	(0.000,0.000,0.012,0.024)	(0.000,0.000,0.000,0.000)	(0.000,0.012,0.024,0.037)	(0.012,0.024,0.037,0.049)
C7	(0.000,0.012,0.024,0.037)	(0.000,0.012,0.024,0.037)	(0.000,0.000,0.000,0.000)	(0.024,0.037,0.049,0.049)
C8	(0.000,0.000,0.012,0.024)	(0.000,0.000,0.012,0.012)	(0.000,0.000,0.012,0.024)	(0.000,0.000,0.000,0.000)