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Institute of Logistics
Faculty of Security, Logistics and Management
Military University of Technology
in Warsaw

Civil-military cooperation in the field of additive manufacturing technologies in military logistics

Współpraca cywilno-wojskowa w zakresie technologii addytywnych w logistyce wojskowej

Malgorzata Dymyt
malgorzata.dymyt@awl.edu.pl, ORCID: 0000-0002-8238-6917
Logistics Department, General Tadeusz Kościuszko Military University of Land Forces, Poland

Marta Wincewicz-Bosy
marta.wincewicz-bosy@awl.edu.pl, ORCID: 0000-0002-3844-2678
Logistics Department, General Tadeusz Kościuszko Military University of Land Forces, Poland

Abstract. Technological progress opens up opportunities for the development of many areas, including military activities. The key question becomes: how is it possible to directly incorporate modern (innovative, disruptive) technologies from the civilian system into the military sphere? The thesis statement is the assumption that the created and used the latest technologies cannot be uncritically and directly incorporated into military systems, and therefore require appropriate adaptation, taking into account the specific determinants of the functioning of the armed forces. Due to the identified research niche in the area of civil-military cooperation in the field of additive manufacturing technology (AMT), it was assumed that the main goal of the research would be to identify the challenges and directions of development of military logistics and presenting the essence and role of AMT, and to define the key factors of civil-military cooperation in the field of implementing AMT in the military logistics system. To solve the research problem, a qualitative research approach was used. Analysis allows to create a proposal of a conceptual model of cooperation between military and civilian systems in the field of implementation and development of AMT in the field of military logistics. The key conclusion from the research is that the use of AMT in the military system requires the creation of a systemic solution both at the international and individual country levels, taking into account the needs, requirements and capabilities of all stakeholders (international organizations, military, business).
Keywords: military logistics, additive manufacturing, 3D printing, civil-military cooperation, logistics development

Abstrakt. Postęp technologiczny otwiera możliwości rozwoju wielu dziedzin, w tym działań militarnych. Kluczowym pytaniem staje się: jak można bezpośrednio przenieść nowoczesne (innowacyjne, przełomowe) technologie z systemu cywilnego do sfery wojskowej? Główną tezą artykułu jest założenie, że tworzone i stosowane najnowsze technologie nie mogą być bezkrytycznie i bezpośrednio włączane do systemów wojskowych, a zatem wymagają odpowiedniej adaptacji, uwzględniającej specyficzne determinanty funkcjonowania sił zbrojnych. Ze względu na zidentyfikowaną niszę badawczą w obszarze współpracy cywilno-wojskowej w zakresie technologii wytwarzania przyrostowego (AMT) założono, że głównym celem badań będzie identyfikacja wyzwań i kierunków rozwoju logistyki wojskowej i przedstawienie istoty i roli AMT oraz określenie kluczowych czynników współpracy cywilno-wojskowej w zakresie wdrożenia AMT w wojskowym systemie logistycznym. W celu rozwiązania problemu badawczego zastosowano jakościowe podejście badawcze. Analiza pozwoliła na opracowanie propozycji koncepcyjnego modelu współpracy systemów wojskowych i cywilnych w zakresie wdrażania i rozwoju AMT w obszarze logistyki wojskowej. Kluczowym wnioskiem z badań jest stwierdzenie, że zastosowanie AMT w systemie wojskowym wymaga stworzenia rozwiązania systemowego zarówno na poziomie międzynarodowym, jak i poszczególnych krajów, uwzględniającego potrzeby, wymagania i możliwości wszystkich interesariuszy (organizacji międzynarodowych, wojskowych, biznesu).
Słowa kluczowe: logistyka wojskowa, produkcja przyrostowa, druk 3D, współpraca cywilno-wojskowa, rozwój logistyki

Introduction

The armed forces face challenges that require an innovative, comprehensive approach to capacity building and readiness to act in times of peace, crisis and war. Political, social, economic, technological and environmental changes generate a number of factors that become driving forces of opportunities and threats. The effective implementation of tasks by the armed forces requires continuous development and proactive innovation management. Industry 4.0 develops technologies that are used in military activities.

The changing environment of conducting combat or humanitarian operations means that in order to maintain combat strength, armies will have to fundamentally improve the logistic models used in the previous period and carry out extensive logistic planning (Hurley, Coleman, 2018). Due to the cooperation of the armed forces in the international and allied dimension, the development and implementation of innovations should be conducted in a way that ensures interoperability. NATO defines interoperability as the ability of Allies to act together, coherently, effectively and efficiently to achieve tactical, operational and strategic objectives, which enables forces, units and/or systems to operate together, allowing them to communicate and share common doctrines and procedures, together with mutual infrastructure and bases. This means the need to strengthen relations with the defence and security industry (NATO, 2023). Ensuring interoperability requires multi-stakeholder and multifaceted cooperation. The multitude of entities involved in the development of technological innovations useful for the military requires coordination and integration so that the potential of the created networks ensures efficient development and implementation of modern solutions.

This article focuses on issues related to civil-military cooperation in the field of adapting additive manufacturing technologies (AMT, 3D printing) to military logistics.

The thesis statement, that the authors attempted to confirm in the article is the assumption that the created modern technological solutions and the latest technologies cannot be uncritically and directly incorporated (copied) into the functioning military system, and therefore require appropriate adaptation, taking into account the specific determinants of the functioning of the armed forces. The following research questions were formulated with regard to the main issues:

1. What are the directions of development of the armed forces in the area of new technologies (AMT)?
2. What role do AMT play in military logistics?
3. What are the conditions and requirements necessary to implement AMT in the military logistics system?
4. How to shape civil-military cooperation to use the potential of AMT in military logistics?

Therefore, the purpose of this paper is twofold. Firstly, to identify the challenges and directions of development of military logistics and presenting the essence and role of AMT, and secondly, to define the key factors of civil-military cooperation in the field of implementing AMT in the military logistics system. In addition, the study examines the scope of using of AMT in modern military logistics. The review focuses on two main conceptual aspects - the essence and dimensions of civil-military cooperation and how digital technologies can support the potential, readiness, resilience, and flexibility of military logistics in times of peace, crisis and war. To solve the research problem, a qualitative research approach was used, referring to the relevant literature on military logistics and AMT. Additionally, participant observation was a complementary method.

The structure of the article corresponds to the scope of the considerations undertaken. The first part describes the research approach and procedure. Then, based on the literature review, the issues of the essence and directions of development of military logistics were characterized. Subsequently, the focus was on the issue of AMT technologies and the possibility of their use in military logistics. The next part includes the proposal of a model of cooperation between military and civilian systems in the field of implementation and development of AMT in the field of military logistics. The final part of the article includes obtained results, a discussion and conclusions.

Research methodology

In order to verify the research problem, the following research methods were used: analysis and criticism of literature, synthesis, comparison and generalizations. The detailed research methodology used in this article is based on a qualitative approach in which the literature and document review technique is used to collect data. The selection of literature was subordinated to the conceptual scope of key words such as: military logistics, additive manufacturing technologies, civil-military cooperation. The research material included domestic and foreign publications, articles in journals, reports, doctrines, and legal acts.

On the basis of the analysis of literature and documents, the theoretical part of the article was developed relating to specific objectives such as: identification and description of the directions of military logistics development, the essence of AMT and the conditions of civil-military cooperation in the field of implementing 3D printing for military logistics. In the next stage, a conceptual model was developed in a descriptive and graphic form.

An important research method supporting desk research was participant observation, which allowed for the verification of theoretical analyses. Participant observation was carried out as part of AM Village 2023. Additive Manufacturing Village 2023 (AM Village 2023) took place on June 12 – 16, 2023. The organizers of the event were the European Defense Agency (EDA), the Multinational Logistics Coordination Centre (MLCC) and the Netherland's Armed Forces. The AM Village 2023 was the first European Military Additive Manufacturing (AM) capability development workshop bringing together military units, military AM experts, industrial AM capabilities, and Universities. The AM Village 2023 aims was to define military use cases – focusing on deployed military missions - and to identify appropriate AMT which can potentially provide logistic advantages to deployed armed forces (EDA, 2023). The event was composed of military and industry demonstrations and academic workshops, aimed at fostering cooperation amongst various stakeholders working towards interoperability for AMT applications for military purposes. The AM Village 2023 was an undertaking accompanying the Additive Manufacturing for Logistic Support (AMLS) project implemented within the EDA (European Defence Agency), in which 12 countries are involved: Austria, Belgium, Czech Republic, Finland, France, Germany, the Netherlands, Norway, Poland, Portugal, Slovenia and Sweden.

Challenges and directions of military logistics development

The conditions of the activities of the modern armed forces both in times of peace, crisis and war require efficient logistics, integrating the activities of many

entities of the defence system and the civil sphere, including in the international space. The main challenges for the armed forces and defence capabilities are the need for cooperation and coordination of actions, efficiency, speed and flexibility of reaction, relocation and reconfiguration of resources. In this context military logistics is becoming a critical area of operations for the armed forces.

According to NATO doctrinal documents, logistics means "the science of planning and carrying out the movement and maintenance of forces. In its most comprehensive sense, the aspects of military operations which deal with: a) design and development, acquisition, storage, movement, distribution, maintenance, evacuation and disposition of materiel; b) transport of personnel; c) acquisition, construction, maintenance, operation and disposition of facilities; d) acquisition or furnishing of services; and e) medical and health service support" (NATO STANDARD AJP-4, 2018).

This definition defines in detail the scope of activities of logistic services, which is very wide and requires combining management, technical, medical, communication and other competencies. Military logistics is a multidimensional and complex whole, which is one of the most important and essential elements of warfare, in particular defined as: "a discipline that encompasses the resources that are needed to keep the means of the military process (operation) going in order to achieve its desired outputs (objectives). Logistics includes planning, managing, treating and controlling these resources" (Kress, 2002, p. 2, 7). Management activity is particularly important in the context of the need to integrate and coordinate activities carried out during operations. Military Logistic is a complex process, which involves collaboration and coordination between organizations and companies that are geographically distributed and are in charge of supply and transport activities (Kaddoussi et al., 2011, p. 63).

Successful logistics must provide effective support to operations and efficient management of limited resources, therefore it should be characterized by five main features, such as anticipation, integration, continuity, responsiveness and improvisation (Walden, 2006, pp. 216-2018).

The essence of logistic support is expressed in the implementation of a number of projects in the field of: preparation, rational use and maintaining readiness for use of properly planned and located in the field logistic potential and resources of the field logistic infrastructure, necessary for military units and subunits to perform their basic tasks (Nowak, 2000, pp. 41-42). As part of the logistic support, the processes of supplying supplies and providing services necessary for training and operations are carried out by units (mobile and stationary) and logistic devices in times of peace, crisis and war (Chrobak, Smyk, Kaźmierczak, 2012, p. 54).

In recent decades, significant technological progress has been observed in the field of logistics infrastructure, caused by the development of Industry 4.0 and Logistics 4.0. Therefore, the technical and technological conditions of logistics

activities in civil as well as military systems are changing. The impact of technological innovations on logistics is significant.

Military logistics is therefore facing new challenges, one of the significant accelerators of which is technological progress. This has consequences for management activities and the need to develop a new approach to the concept of logistics management, also in the context of military supply chain management.

The future challenge for military logistics is to develop the ability to provide immediate response support in a new dimension of warfare, given that the organization of war is dynamic, needs change, and force structures are dispersed (Serrano et al., 2023, p. 21).

In this context, the concept of logistics management should be oriented towards such issues as: flexible control of flows taking into account the dimension of time, multi-level and multi-directional integration of flows, thinking in terms of process dependencies and structural links within all six subsystems (management, technical, material, transport and traffic troops, military infrastructure, medical) and two functional areas (support by the host country, mobilization of the economy and strategic reserves) of the military logistics system (Jałowiec, 2021, p. 46).

The development of military logistics requires taking into account contemporary global challenges and trends and should be focused on coherent cooperation within NATO as well as the European Union and at the level of national defence systems. The issue of the development of innovations, including technological innovations, is one of the key strategic directions of the armed forces. In 2021, „"Foster and Protect: NATO's Coherent Implementation Strategy on Emerging and Disruptive Technologies" was approved as NATO's overarching strategy to guide its relationship with EDT (emerging and disruptive technologies), which identifies two main areas: supporting a coherent approach to development and adopting dual-use technologies.

As a future challenge the European Union in the strategic dimension points to the need to build military mobility. In accordance with the Action plan on military mobility 2.0, the European Union has started the next stage of work on military mobility for 2022-2026. The new Action Plan indicates that the strategic approach focuses on the need to create a well-connected military mobility network (European Commission, 2022, pp. 2-3).

The technological development of the potential of the armed forces is also one of the key directions of national scientific and defence strategies. In accordance with the assumptions of the Ministry of Science and Education set out in the document „State Science Policy", the goal of scientific activity is to increase the potential of Polish scientific and industrial entities and to strive for technological independence by creating Polish „know-how" in the field of critical technologies in the field of defence and state security (MEiN, 2022, p. 50). One of the areas subject to coordination, planning and implementation of scientific research in the Ministry of National

Defence is the development of technologies, including disruptive technologies, the development and application of which may significantly change the image of the future battlefield (MON, 2022). Gaining an advantage over the enemy, both on the conventional battlefield and in cyberspace, as well as the initial space, is available based on intelligent and military skills, but also the ability to provide logistic support and security of the state's basic infrastructure. In this context, for the implementation of logistics processes, important are quick repair and battle damaged repair technologies, for which 3D printing technology has been indicated in the "Priority directions of scientific research in the Ministry of National Defence in 2021-2035" (MON 2023, p. 3-4, 15, 27), as one of the main areas of development.

The potential of Additive Manufacturing in military logistics

In the area of logistics activities, including technical and material security, additive manufacturing is of particular interest. Additive Manufacturing (AM), also known as 3D printing, Rapid Prototyping (RP), Rapid Tooling (RT), Rapid Manufacturing (RM) or (Direct) Digital Manufacturing, is a unique technology distinguished by the fact that the material is added layer by layer (Verboeket, Krikke, 2019, p. 2). What distinguishes these methods of production from the traditional methods used so far is the incremental approach, consisting in adding layers. To make this possible, it is necessary to properly plan and design the manufactured objects. AMT includes two main aspects of physical and virtual items, where the physical aspect covers all the concrete AM elements: printers, facilities, raw materials and real end products, and the virtual aspect includes intangible elements such as design data, intellectual property rights and software (Valtonen et al., 2022, p. 1043). Thanks to digital technology, production is made to order and is individualized according to needs. It is a complex production system with a breakthrough character due to the wide spectrum of benefits. AM benefits relate to the technical and economic aspects (Daduna, 2019, p. 2721). The benefits of a technical nature imply benefits in the economic dimension, through a change in the approach to the organization of production. The specific features of AM will have a radical impact on the make-or-buy decision, and thus on the selected management structure of this form of production (Rehnberg, Ponte, 2018, p. 59). In addition, this specific approach and coherent organization of production is beneficial for the environment and becomes attractive in the context of sustainable development. Benefits in the field of sustainable development are also indicated, in particular, such as (Ford, Despeisse 2016, p. 1573):

- improved resource efficiency: improvements can be made both in production and in use,

- extended product lifetime: achieved through technical approaches such as repair, refurbishment and renovation, closer relationship between producers and consumers,
- reconfigured value chains: shorter and simpler supply chains, more localized manufacturing, innovative distribution models and new collaborations.

The significant changes brought about by AMT need to be viewed broadly as they affect not only the manufacturer but the entire supply chain. Broadly speaking, AM could have the following seven potential impacts on supply chains: reducing the complexity of the supply chain, flexible logistics and inventory management, mass customization, decentralization of production, design freedom and rapid prototyping, resource efficiency and sustainability, discussions on regulation (Araújo, Pacheco, Costa, 2021, pp. 6-7).

The strong development of 3D printing technology creates opportunities for more and more extensive use in various industries, not only in the manufacturing industry, but also in many different areas such as the defence, medical and even food sectors. AM is an enabling technology that can facilitate the rapid production of components of modern weapon systems, in particular drones, missiles and rocket engines (Nelson, 2020, p. 29). AM is emerging as a promising solution for armed forces on military and humanitarian missions overseas as it can improve spare parts availability in terms of speed, location (near deployment points or locations) and lifecycle, increase speed, reliability and material handling, and enables using general equipment production of custom parts and materials that can be for highly specific, high-tech components with unequal demand (den Boer, Lambrechts, Krikke, 2020, p. 19). AM is a potentially game-changing technology that can maximize multi--domain integration (land, air, sea, space, and cyberspace), which provides great flexibility to enable rapid and cost-effective design and production of single or multiple prototypes to meet a range of mission needs, including instant part repair and field replacement (Schrand, 2016, p. 75). An important feature of AMT is that it is a method that supports the mobility of operations, due to the flexibility in terms of mobility of production machines and base material, which is a key criterion when assessing the possibility of adding an element of spare parts production to the armed forces (Valtonen, Rautio, Lehtonen, 2023, p. 1).

In military systems, potential applications of 3D printing include: concept modelling and prototyping, complex low-volume parts such as rocket engines, spare parts (obsolete), designs using lightweight, high-strength materials, mixed materials and incorporation of additively manufactured electronics directly in/on parts, repair parts on the battlefield, aboard a ship or in space, large structures directly on site, avoiding transport vehicle size restrictions, manufacturing innovative designs or using unique materials, large structures such as buildings (using local materials) or weapons systems (such as a ship) and bio-materials such as replacement tissues, organs and body parts (NATO, 2020, p. 107).

AMT provides many benefits; however, it is also an organizational, investment, technical, IT and legal challenge. Among the most important threats arising from the use of 3D printing, there are: lack of qualified staff and need to organize training, costs related to the purchase of printers and materials, low efficiency for large and mass production, need to start reprint if a problem is found, need for processing of the object after the printing process, relatively long print time, need to organize an additional work station, legal problems, and controversies regarding intellectual property, product liability and data security (Budzik, Woźniak, Przeszłowski, 2022, p. 68).

It is indicated that significant barriers to the use of AMT on a large scale in the armed forces are too high costs of raw materials, as well as insufficient training of deployed personnel in the use of equipment (Lockman, 2018, p. 5). In addition, the barriers can include the unsatisfactory quality of the manufactured objects and a limited range of materials.

Model of civil-military cooperation in the field of using 3D printing in military logistics

The analysis of the essence and role of military logistics and the possibility of using AMT led to the creation of a conceptual model of cooperation between the military and civilian spheres in the development and implementation of 3D printing for the military logistics system. The basis for developing the model was the identification of conditions and requirements necessary to implement AMT in the military logistics system.

Based on practical experience, it should be emphasized that the availability of AMT in the civilian environment and the benefits associated with its use influence its dynamic development. However, the practical application of this technology in the military environment encounters many difficulties resulting from the specific conditions and possible applications.

This requires the military sphere, first of all, to define the objectives of the intended use of AMT. Nowadays, replacing the mass production system with 3D printing is not justified in the context of quality, economic, technological and time requirements.

Currently, it seems that its proper area of application is repair systems. A specific area of use is the creation/reproduction of parts/elements for military equipment and ordnance that remains in the army's inventory and whose production has been discontinued. This is the area that raises the least controversy, especially in the context of intellectual property protection.

Carrying out quick repairs on the battlefield (during operations), even with the current state of technology, is not an appropriate area for using AMT. It requires the creation of appropriate technical conditions (including access to software for printing devices) and environmental conditions for the printing process, the provision of appropriate materials and appropriate data (scans, technical documentation), which may not be possible in operational conditions (on the battlefield/on theatre of operations). In addition, it should be taken into account the time needed for printing and post-processing.

Repairs carried out on the rear front line can successfully use AMT, provided that conditions are created for the mobility of printing itself and post-processing (mobile containers with AMT equipment and post-processing equipment), as well as the use of effective and safe methods of delivering the printed element to the battlefield (e.g. using drones) or to the place where the need arises/is reported (repair point) (e.g. using autonomous or unmanned vehicles). There are also great prospects for the use of AMT in the repair and maintenance system as a component of logistic support for troops.

As practical experience shows, the quality of 3D printing in combat conditions is significantly different from the quality of the original elements. Moreover, the printing time extends the repair process compared to having spare parts in stock. It is also difficult to predict the durability of printed components, taking into account the realities of operations in combat conditions, including the specificity of the supplied printing material (filament). Also, important issue is that AMT is based on the use of gases in the printing process, which are dangerous components (explosive and flammable) and 3D printing require significant amounts of energy.

One of the most sensitive elements of the system is access to the database/library with technical documentation. Placing it in the cloud during hostilities may result in the inability to use it (no access to the network). On the civilian market, leading AMT equipment suppliers offer the use of libraries/databases they have created. However, this may affect the sovereignty of the decision. It is also important to properly secure technical documentation when purchasing new equipment used by a given army. There is also the problem of interoperability - when national armies use a library/database from another company, and it is necessary to obtain consent to share the data.

Another factor is the qualifications and skills needed to operate equipment and technical documentation as well as post-processing. This requires properly trained staff and the creation of an appropriate educational system. Both officers and soldiers, especially from the logistics and engineering corps, should have appropriate competences, which requires changes in the education profile.

From a logistics point of view, an extremely important component is ensuring a system for servicing and repairing equipment used for 3D printing and post-processing, as well as providing appropriate filaments (printing materials), including ensuring continuity of supplies. The shelf-life conditions of the components used

as well as the requirements regarding their storage and expiration dates are also important. Moreover, the issue of using substitutes is also important.

There is also the aspect of responsibility for the quality, strength and durability of printed elements, as well as possible damage resulting from the use of the printed part.

Identification of the essence, conditions and directions of development of military logistics is the starting point for formulating the framework of a model defining the role of AMT. This model reflects the goals and scope of multilateral cooperation from a systemic perspective.

The model was developed based on the following assumption: the implementation of disruptive innovations to the military system requires close cooperation in planning, designing, implementing and developing new technologies, products and solutions and creating specific social and technological networks.

The elements of the conceptual model concern such issues as entitles, goals and responsibility and expected benefits. A detailed description of the model elements is provided in Table 1.

Table 1. AMT civil-military cooperation model

MODEL ELEMENTS	CHARACTERISTICS OF THE ELEMENTS		
	International institutions	Military sector	Civil sector
Entitles	NATO, Defence Innovation Accelerator for the North Atlantic (DIANA), NATO Science and Technology Organization, European Defence Agency, European Defence Fund	Ministry of Defence, government agencies, military universities, state defence sector, military units.	Universities scientific and research entities technology owners, equipment suppliers raw material suppliers
Goals and Responsibility	Initiating, coordinating and supporting scientific and technological research, introduce AMT, identification military capabilities enabler in terms of using AMT, maintaining and developing interoperability, multi-domain integration. Creating the conditions for international cooperation.	Developing of the security and defence system. Ensuring the sovereignty and autonomy of the state and reliability, stability and resilience of the military system. Creation and development system innovation, staff competences. Development international cooperation. Building an integrated AMT system.	Creating and developing new and disruptive technologies. Competing on domestic and international markets. Searching for new solutions/applications and ensuring appropriate quality. Building cooperative networks and flexible supply chains. Creating an educational and development offer.

cd. tab. 1

Expected benefits	A leading role in decision-making and regulation. Development of international cooperation and maintaining the leading role of international organizations in creating organizing conditions. Standardization and unification. Impact on national systems.	Efficiency and effectiveness of operation. Creating a modern army. Development of organizational and technological potential. Access to technology.	Innovation leadership. Competitive advantage based on new technologies. Long-term development prospects. Cooperation and network benefits. Protection of ownership rights.

Source: Own study

The proposed model establishes a generalized concept of cooperation between the main actors involved in the development and implementation of AMT in the military system. The analysis of the model allows for the identification of areas of cooperation and divergence of interests, which should be taken into account when creating system solutions for the use of AMT in the field of military logistics.

Discussion

Undoubtedly, the development of AMT creates many application possibilities for modern armies. However, it requires focused development and the creation of an implementation framework. To enhance operational capabilities, military logistics must interoperate with available new technologies and resources to reduce the maintenance cost and logistics footprint of developing operations in all domains (sea, land, air, space and cyberspace) (Serrano et al., 2023, p. 21). Moreover, to achieve interoperability, standardization is key. AMT is a highly specialized field of technology that requires standardization of methods, skills, training, 3D printing and other manufacturing machinery and technical requirements for parts in the context of military use (Valtonen et al., 2022, p. 1046).

Of particular importance is the pursuit of consensus between the materials research and development community and operational military personnel, the assistance of the research and development community in understanding the capability needs on the defence side, and education focused on the effectiveness and availability of the technology for military users (Ficzere, 2022, p. 74).

Successful implementation of AM in the supply chain of the armed forces requires redefinition of existing supply chains. This means placing the AM system in

closely spaced units, moving away from the transport of finished products towards raw materials and digital projects, and reducing inventory levels of slow-moving spare parts, the amount of warehouse waste will decrease (den Boer, Lambrechts, Krikke, 2020, p. 21).

The multitude of participants representing different interests requires the creation of a framework for cooperation. Retter et al. (2021, p. 44) have formulated basic good practices for effective defence public-private partnerships with large commercial entities to provide mobility-related resources and services, addressing the main risks: unequal relationship, with contracts, formal or informal, in favour of one partner, resulting in mistrust and misunderstanding. These good practices include the following recommendations: requirements definition (identification of service strategies, goals and outcomes, continuous improvement of performance, processes and people); selection of a partner with knowledge and adoption of best practices in tenders; communication and information exchange between partners; trust and openness and ending the partnership (transition management) (Retter et al., 2021, p. 44).

In conclusion, it should be stated that the issues of ATM discussed in the article indicates the topicality and importance of the research. The development of a conceptual model of civil-military cooperation in the area of ATM and the adaptation of achievements from the civilian sphere to the military sphere is an innovative approach. As a result, the identification of factors, goals, responsibilities and expected benefits of ATM beneficiaries allowed for a contribution to science and practice in the theoretical, cognitive and research dimensions.

Conclusions

The use of AMT in the military system is necessary if one wants to build an effective and modern army. This is indicated by the strategic plans of international and national institutions that emphasize the need to develop AMT for military needs. However, it requires, above all, the creation of a systemic solution both at the international level and within individual countries. The introduction of AMT must be consistent with the applicable security and defence policy, consistent with the conditions of sovereignty and autonomy of individual countries.

The answers to the adopted research questions allowed for the formulation of conclusions regarding the determinants of ATM implementation. The solutions created should take into account the requirements of both the strategic, operational and tactical levels, in particular regarding:

1. environmental requirements,
2. technical requirements,
3. equipment and materials requirements,

4. information requirements,
5. placement and movement, transportation and mobility requirements,
6. flexibility and resilience of supply chain requirements,
7. allied operations requirements (HNS, standardization, unification, interoperability),
8. general/selected requirements for equipment and personnel.

Taking into account the identified conditions, it should be emphasized that close, integrated cooperation is necessary within the network of entities from the civilian and military sectors and the institutional sphere at the international and national levels. This means creating supply chains that take into account the specific needs and conditions of stakeholders in the state-military-business triad, also bearing in mind the need for standardization and interoperability at the allied level.

The considerations carried out confirm the adopted thesis, that modern technological solutions cannot be uncritically and directly incorporated (copied) into the functioning military system, and therefore require appropriate adaptation, taking into account the specific determinants of the functioning of the armed forces.

Nevertheless, this problem requires in-depth research. Considering the above conclusions, it can be concluded that further research directions should be focused on identifying the needs and requirements of partners and defining forms of cooperation in the field of data exchange and the use of technology.

Undoubtedly, AMT has great potential to support the logistics system of military operations. The issues discussed in the article are an attempt to organize theoretical and practical knowledge and may be the basis for further research.

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