Technological Aspects of the Capability Development of the Logistics Support

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ABSTRACT

The development of the capabilities of the armed forces is significantly influenced by the use of new progressive technologies. This trend is reflected not only in new approaches to the conduct of combat operations and their logistical support but also in the form of new types of conflicts, risks and threats. The paper discusses the possibilities of new emerging technologies for the development of military logistics capabilities. There are discussed potential applicability for military logistics capabilities development, in short, and long-term horizons.

1. THE IMPORTANCE OF TECHNOLOGICAL CHANGES

Societal development is very closely linked to technological change. The influence of technology has always had a significant impact on the course and conduct of armed conflict. These have always been fought using technologies and approaches that people have also commonly used for their livelihoods, whether they are agricultural or industrial societies. It is likely that this will also be the case in the current information society. For this reason, it is useful to monitor developments and approaches in the use of so-called 'Emerging' and 'Disruptive Technologies' already commonly encountered in the civilian sector. These advances are often already part of the competitive struggle in the commercial sphere. These Emerging Technologies bring significant potential to their users in the form of significant competitive advantage, whether in business or in armed conflict.

1.1 Implications of changes in the security environment

In connection with these technological changes, it is also worth mentioning that the character of armed conflicts is changing from purely symmetrical to asymmetrical. In terms of the definition of symmetry and asymmetry in military conflicts, there is no clear definition. As an initial framework for identifying military capabilities definition and possible technological consequences, it is possible to apply Samuel Huntington (Huntington, 2001) point of view, which is measured by military power in four dimensions as follows:

- *quantitative dimension:* e.g., number of soldiers, weapons, military equipment and resources;
- *technological dimension:* efficiency and level of weapons and military equipment;
- *organizational dimension:* solidarity, discipline, training and morale of the troops, the effectiveness of command-and-control links;
- *social dimension:* ability and willingness of society to effectively apply its military power.

If two military units with a different potential are confronted, it is an asymmetric operation. In the early nineties of the 20th century, some elements of symmetry still occurred, e.g., in Iraq from 1990 to 1991. Since that time, asymmetric conflicts have prevailed (Foltin, 2018). In terms of supply systems, these conflicts are more demanding, since the supported units are deployed at large distances from parental bases, thus the overall delivery times are extending, and the financial demands of the logistics chain as a whole are increasing. At the same time, there is no rear area in asymmetric conflicts which ultimately means that the probability of an attack on or disruption of the logistics chain is going up with decreasing distance from the final beneficiary of support.

1.1.1 Security Trends

Another issue for strategic consideration will be the change in technological superiority and its impact on the position of individual states and the distribution of their economic and military potentials (Lipowský, et al., 2020). In general, it can be assumed that technological development will further open the scissors between the capabilities of the so-called superpowers and the rest of the world. For the time being, it is difficult to imagine that the dominant states or alliances would agree on measures to stop or limit the development of these technologies. Technological development is also seen as an opportunity to gain a decisive advantage over a potential adversary or competitor. For this reason, it is advisable to constantly monitor trends in technological developments and to learn how best to assess their impact and implications for future developments.

In the military sphere, efforts will be made to apply innovative technologies, particularly in the context of command-and-control systems, reconnaissance equipment, electronic warfare, and the modernisation of military equipment. An important aspect in the field of technologies will be the possibility of their interconnection and interaction, which will increase the efficiency of their use. Technology development is no longer so much about individual inventors and innovators. Well-organised and well-funded systems involving a broad platform of scientific and educational institutions and production sites are playing an increasingly important role. The capacity to innovate is thus also becoming one of the international trends being pursued, nowadays, especially in the context of international investment and the potential knowledge-sharing capacity. To monitor these innovative trends, indicators of their changes are developed and maintained, such as the Global Innovation Index (WIPO), the International Innovation Index (BCG), the Innovation Index (GlobalEconomy.com) or TCdata360 (World Bank). These are indicators of technological development with the possibility of comparison between countries and sectors or monitoring the dynamics of these changes.

1.1.2 Flexibility of Response

Technology allows high flexibility to respond to reality, i.e., to current threats but also to emerging risks. And even risks that are linked to the development of technologies that potential adversaries will have at their disposal. Any significant delay in the development and use of technology will not only have economic consequences but will also affect the development of military capabilities. New analytical approaches make it possible to capture these technological and societal trends and, with the use of appropriate tools, to predict them well in advance, allowing time to prepare an adequate response. In general, this foresight is directly related to resilience and stability, which are vital not only for the further sustainable social and economic development of society but also for the development of the capabilities of the armed forces. At the same time, however, it is appropriate to perceive an increase in uncertainty as to whether some states or other entities have gained a head start in development in some important areas or even possess new disruptive technology.

1.1.3 Concentration of Necessary Capacities

During World War II, the best available US scientists were concentrated at Los Alamos to combine their efforts to develop an atomic weapon. Today, the research complexes of Silicon Valley (USA) and Shenzhen in China operate on a similar principle of concentration of scientific and development capacities. In this respect, the need to concentrate the necessary capacities and resources can therefore be seen as an important factor in achieving the expected success. Beyond this organizational measure, however, it is often much more difficult to find the necessary experts and senior project managers or to allocate sufficient financial resources for the implementation of the intended projects in the first place. Not only for the smaller countries, international cooperation, linking educational, scientific and development institutions, industry, as well as governmental and alliance entities, be it the European Defence Agency (EDA) or the NATO Science and Technology Organisation (STO), with possible overlap with individual NATO Centres of Excellence (NATO CoE), will be essential in the context of the high demands on the security of these projects. In conjunction with national grant and technology agencies, it is thus possible to fully exploit research and innovation capacities and link them appropriately at the international level.

1.1.4 Prepare for Threats and Risks

Technological advances are not just about trying to make our own defences more effective. It is also advisable to be aware of the potential impact of technological applications and to prepare well in advance for the threats and risks associated with their future arrival. However, even a good prediction of future developments does not in itself mean that we will be able to completely avert future threats. But new technologies can help us marshal the necessary resources and tailor them appropriately for an adequate response. We need to recognize today that the development of technology is not only about competitive advantage, but also about security and, in the military domain, about our very existence. There is therefore no place for any passive waiting for further threats or other incentives.

1.2 Logistics as a Key Prerequisite for the Success of the Operation

Logistics is a key driver of the success of all operations, both combat and non-combat. In spite of the significant dynamics of both real and potential changes, supply systems have always been the backbone of a well-functioning society. In the civilian sphere, intersections of supply routes represented trade centres, and often also regional centres of education. The international importance of particular centres, cities and states was based on the size of supply flows. Similarly, that was the case in the military, as is apparent from the preserved written records about the war campaigns of the Master Sun Tzu. Differences in well and badly designed supplies have directly affected the final results of war campaigns. It still applies that even the best strategist will not replace the lack of necessary resources with a clever tactic.

The importance of supplies is also obvious nowadays when the disruption of integrity and functionality of logistics chains is considered as a threat of strategic importance. Since the second half of the 20th century, when communication technologies were massively spread, the significance of information, finance and later knowledge flow has gone up. The key role has been played by communication platforms, but primarily by the possibilities brought by the internet. However, on the other hand, these strong benefits bring also new threats evolving from the constantly growing interdependence of national economies. The joint multinational effort is aimed at minimizing potential disruption of these flows, should it be caused by intentional human acts or by hardly predictable natural disasters.

1.3 Requirements for Skills Development in Relation to Technological Developments

In order to develop the capabilities of the armed forces, it is necessary to take into account new technologies, because the life cycles of military equipment are often very long. Often these cycles range from 15 to 20 years.

1.3.1 Groundbreaking Revolutionary Technologies

It is a matter of strategic importance to note Disruptive Technologies, progressive technological changes, and trends in their future development. These technologies can help to overcome some capability gaps, either by replacing limited resources, e.g. financial, material, but also human, or they can bring completely new solutions. Examples include the use of small mobile nuclear reactors and the possibility of remote power transmission while replacing internal combustion engines with electric motors. Given the fact that up to 70 % of battlefield transport capacity is for fuel, the use of these technologies can be considered "disruptive", i. e. breakthrough. Similarly, this could be the case for meeting the energy needs of supported units.

Of course, we should also expect those completely new technologies will be developed, even those that go beyond current knowledge and ideas. In this respect, we are likely to be inspired by the solutions and discoveries of artificial intelligence (AI), which is already surpassing the performance of professionals in various areas. Some of today's most disruptive technologies will include AI, quantum computing, the Internet of Things (IoT), cloud technologies, 5G networks, and 3D printing. Moreover, the interconnectivity and interaction of these technologies significantly increase the overall efficiency of the system and enable the so-called synergy effect. This effect will have an increased potential, proportionally as each technology reaches higher levels, as well as as the number of disruptive technologies expands from an ever-wider group of emerging technologies. For example, the performance of AI is dependent on computing, the most powerful form of which today is represented by quantum computers. Information is another essential element for achieving the maximum desired effect (e.g., processing analyses or performing simulations). Today, this is a large amount of data, so-called Big Data, which is processed using algorithms, usually already in the context of the use of AI, which, thanks to its ability to use machine learning, can further improve itself. Coupled with the large volumes of available data that we can store in data centers, it is only a matter of time before suitable technical applications for IoT technologies become widespread. The informational value of data derived from IoT will also lie in its timeliness. Large amounts of data at high speed are made possible by 5G networks. Moreover, the speed, capacity, or overall efficiency of the systems will play a significant, sometimes decisive role in all areas, including the military.

1.3.2 Improving Human Performance

The current development of biotechnology also gives us a glimpse of the growing potential for the possible interconnection of the human brain with the direct support of artificial intelligence systems in receiving, processing, and evaluating the information picture on the potential battlefield. If we take into account the current technological concept of so-called Industry 4.0, it is only a matter of time before there is a direct military application. In conjunction with biotechnology, not only an increase in human capabilities will be achieved, but probably also an extension of human life or augmentation of the human body. It is likely that the results of this expensive but also sensitive research and its implementation will initially find application, particularly in the defence and security structures of the most technologically advanced countries. At present, augmentation of the human body is being achieved by the exemplary use of exoskeleton structures, not only in health care or sport but also for military purposes. In this case, it is about the physical improvement of human performance. In a military environment, these systems can be used wherever we need to strengthen soldiers' abilities to lift or carry higher loads, while at the same time prolonging their endurance and durability to perform the required tasks.

An important question is what role people will play in many conflicts and how the structure and capabilities of forces will evolve with the dynamic advent of new technologies. Despite several uncertainties related to long-term development and unpredictable events, it could begin by stating that the development of the armed forces will be characterized by a decrease in infantry and, conversely, an increase in military specialists able to use the modern army. Systems, until now, we have always put man first, but his primacy will increasingly depend on his creations. Above all, much is expected of the development of artificial intelligence, which will increasingly be able to take control of the people. Its performance has already been surpassed in some areas of AI. In addition, it is not just about chess duels with the world's best chess players, but also about the involvement of artificial intelligence in military systems, including military technology. This is confirmed, for example, by information from the USA about the AI victory over a trained pilot in air combat. In addition to the above technologies (AI, quantum computing, IoT, cloud technologies, 5G networks), the use of small satellites, high-performance sensors, autonomous and automated systems, energy storage, the deployment of hypersonic weapons, the improvement of robotic devices and several other technologies are currently used. Addresses military technology trends, some of which will be introduced when it is in the interest of their owners.

2 RESEARCH GOAL, METHODS AND RESEARCH LIMITATIONS

The article aims to identify the impacts of significant emerging technologies on military logistics capabilities. From a methodological point of view, a content analysis approach was chosen to identify the expansion of the number of articles and professional papers indexed in the two most important databases of scientific papers, namely Web of Science (WoS) and Scopus. Attention is paid mainly to increasing the trend of the presented outputs, in general, and subsequently related to the field of military logistics.

The limitation of the implemented research lies in the limited applicability of the chosen methodology and the time horizon of the research, which was limited to the identification of trends in the period from 2015 to 2021.

3 PREVIEW OF EMERGING TECHNOLOGIES

Key technologies for the development of the Czech Armed Forces' capabilities will include in particular the use of artificial intelligence. Other important technologies for the development of Armed Forces and its logistics capabilities are control information systems, autonomous systems, robotic systems, Big Data including data storage, quantum technologies (e.g. for encryption, and decryption), hypersonic weapon systems (not only for their use but also for defence), systems to enhance human capabilities (augmentation - e.g. exoskeletons) or the possibility of using 3D printing of spare parts, repair of damaged military material or Smart Energy (Lipowský, et al., 2020). The use of unmanned aerial vehicles will be promising (their capabilities are also determined by the use of new sensors, control, and information systems or the use of new types and options of munitions). The future will also be influenced by the development of biotechnology.

3.1 Quantum Technologies

Technological development brings new societal challenges and opportunities. As well as supporting national economies, knowledge sharing and opportunities for cooperation, they can also bring potential risks. At the same time, their potential can also be used to address emerging risks or potential security threats. The complexity, interconnectedness, and intensity of economic and political competition in terms of its scale require attention from governments and supranational organizations, as this is the only way to accumulate the necessary resources and knowledge to achieve technological applications. Across the whole spectrum of technological innovation, the application of new knowledge in the field of quantum mechanics and its translation into future quantum computers can be considered significant.

Although the full-fledged quantum computer remains rather theoretical, there are already early computers that can work at least to a limited extent on the quantum principle. However, developments in this area are very rapid and therefore worth monitoring, especially about potential future applications. There is a growing awareness of the importance of quantum computers, which are probably already moving beyond their status as Emerging Technologies to become Disruptive Technologies. For a brief characterization of these technologies, see the article "The Impact of Emerging Technologies" in A Report 11/2020. Quantum computers exploit the properties of particles and can process large numbers of computational operations simultaneously due to their ability to operate at both 1 and 0 (instead of 1 or 0 in a conventional computer). Their massive diffusion is currently hampered by the need to use them in an environment free of electromagnetic field interference and at low temperatures close to zero. The involvement of artificial intelligence and the increasing amount of information available can be expected to help this development. Crucial new information may be revealed by investigating quantum phenomena in plants that take place under normal conditions.

The increase in speed in the processing of large amounts of data represents a technological shift that will gradually affect many areas. It is the ability to process large volumes of data in a relatively short period of time that will enable the application of new models and analytical tools, whether in healthcare, industry, or research. The potential of quantum computing will make it possible to abandon simplistic models and make greater use of the "digital twinning" approach, i.e., the digital twin of a living or non-living physical entity. In the case of military applications, this could, for example, mean creating a digital model of the armed forces as a whole, including potential testing of possible deployment scenarios against specific adversaries, with subsequent identification of potential vulnerabilities. This could lead to targeted acquisitions, capability development, and personnel preparation well in advance (see Lipowský, 2020). The reality, however, is that even a possible technologically equipped adversary could possess this capability for accurate prediction. The anticipated use of quantum computers in the military is also linked to the possibility of using new complex algorithms for encryption or decryption. Quantum algorithms can quickly solve problems in an unstructured data set. The contents of encrypted data and communications may thus become available retrospectively, which will contribute to uncovering a significant amount of intercepted but hitherto undecipherable information in the future. It will be even more necessary to prepare for the new decryption possibilities by improving the systems currently in use.

The military tactical network "Link 16" is used for the transmission of classified information by data transfer within the framework of NATO's combat activities, through which information can be transmitted within the structure of the armed forces of NATO member states. It is mainly the display of data tactical or operational images of the situation, including the guidance of combat vehicles to enemy targets, etc. "Link 16" is currently used in aircraft or ships, which in addition to encryption makes it difficult to capture this type of communication hoping). Therefore, the advantage of this network is considerable resistance to interference and already proven reliability. However, precisely in connection with the development of quantum computers and other technologies, it is necessary to start predictably preparing for the possible vulnerability of this communication system. Its further extension to other elements of NATO's armed forces is conditional on the achievement of the required interoperability and coordination between units and other elements (command posts, military equipment, etc.) of the member states' armies. Quantum computers are one of many promising technologies that can have a significant impact on the development of many other areas.

Together with other technologies, such as artificial intelligence or the Internet, they will play a significant role, especially in relatively new war domains, such as cyberspace or space. It is in these domains, that quantum computers will play a role, not only in higher information processing speeds, but also in their ability to solve comprehensively larger volumes of data in contexts, that current computers cannot or take too long to process. In conjunction with artificial intelligence, the performance of quantum computers will limit or allow its use. Many times faster, data processing will provide artificial preconditions for the more efficient performance of assigned tasks. Also in the case of quantum computers, on the one hand, it is an opportunity for much more efficient use of a new type of computer technology, but in the wrong hands, it is a threat with a significant impact.

It is clear that the development of new technologies creates new opportunities in the use of space as the last recognized military domain. We are currently witnessing considerable efforts and relocation of investments within the area. It is not just a domain for military use, but in general, it is a relatively new opportunity to expand living space. As we know from many cases in the past, the expansion of living space has often been associated with armed conflict. On the other hand, we must demand that the search for a new habitat or new deposits of scarce resources should have various causes. It was often really linked to the issue of survival, and the only solution was to migrate to more favorable areas for life or to occupy scarce resources by force. Today, it is quite clear that the development of new technologies will allow us to penetrate more and more into space, which will contribute to a new opportunity to learn about and use other resources, such as energy. For this reason, it is necessary to monitor trends in technological development and capture emerging technologies in a timely manner or new applications of existing ones.

3.2 Key Emerging Technologies for Military Logistics

In terms of overall technological development, however, it is necessary to limit the scope of further research to the identification of those emerging technologies that already have the highest application potential for military logistics, both in the short term and in the long term. For this reason, the following have been identified as technologies key to the future development of military logistics capabilities (Fridbertsson, 2022):

- artificial intelligence (AI);
- Big Data;
- Internet of Things (IoT);
- digital twinning;
- autonomous systems;
- robotics;
- exoskeleton;
- 3D printing.

Based on a search in the WoS and Scopus databases, the development of the number of publications in selected areas in the general area and the area of logistics was found (see Table 1-4, Figure 1). The WoS and Scopus databases are widely recognized scientific and research databases that contain high-level publications. The search was based on keywords. Search terms included AI (artificial intelligence), big data, IoT (Internet of Things), digital twinning, autonomous systems, robotics, exoskeleton, and 3D printing. These terms were examined individually (see Table 1-2) or under the keyword Logistics (see Table 3-4).

Table 1: Development of the number of publications in the Web of Science and Scopus databases Source: (Clarivate, 2022), (Elsevier B.V., 2022)

	Web of Science Database	2015	2016	2017	2018	2019	2020	2021
In general	AI	2 279	2 678	3 177	4 364	6 954	9 434	13 294
	Big Data	8 809	11 381	12 916	14 648	16 104	15 947	15 948
	IoT	2 356	4 461	7 154	10 278	12 641	12 959	13 099
	Digital twinning	88	89	169	352	698	1 112	1 838
	Autonomous systems	4 864	5 580	6 416	7 577	8 572	8 672	8 786
	Robotics	8 707	10 190	11 445	12 433	14 501	15 020	15 643
	Exoskeleton	612	754	1 119	1 023	1 205	1 323	1 327
	3D print	1 910	3 152	4 403	5 749	7 453	8 657	10 443

	Scopus Database	2015	2016	2017	2018	2019	2020	2021
In general	AI	4 007	4 382	5 219	7 194	11 428	15 820	22 692
	Big Data	12 921	16 994	18 902	21 674	25 844	26 184	26 774
	IoT	2 690	5 320	9 085	14 002	19 711	20 270	23 444
	Digital twinning	12	15	23	18	44	59	110
	Autonomous systems	7 410	8 205	9 429	11 493	13 699	14 111	15 375
	Robotics	14 709	16 182	18 218	22 050	24 620	24 263	24 870
	Exoskeleton	740	821	1 214	1 270	1 483	1 506	1 637
	3D print	284	468	624	796	932	1 126	1 291

Table 2: Development of the number of publications of selected areas in the Web of Science and Scopus databases in the field of logistics Source: (Clarivate, 2022), (Elsevier B.V., 2022)

	Web of Science Database	2015	2016	2017	2018	2019	2020	2021
In logistics	AI	262	293	308	424	508	599	805
	Big Data	156	239	321	401	566	722	825
	IoT	46	91	86	117	167	203	297
	Digital twinning	0	0	0	1	1	1	2
	Autonomous systems	50	60	75	90	118	126	169
	Robotics	50	56	56	82	99	116	121
	Exoskeleton	2	1	1	0	1	3	5
	3D print	0	1	3	0	2	2	3

	Scopus Database	2015	2016	2017	2018	2019	2020	2021
In logistics	AI	537	568	688	801	1 073	1 657	2 620
	Big Data	655	886	1 171	1 563	2 224	3 009	4 280
	IoT	74	119	179	305	523	768	1 255
	Digital twinning	0	0	1	1	3	2	10
	Autonomous systems	276	377	435	489	730	985	1 287
	Robotics	416	517	600	656	970	1 216	1 544
	Exoskeleton	7	7	8	11	21	15	35
	3D print	7	7	16	9	22	34	28

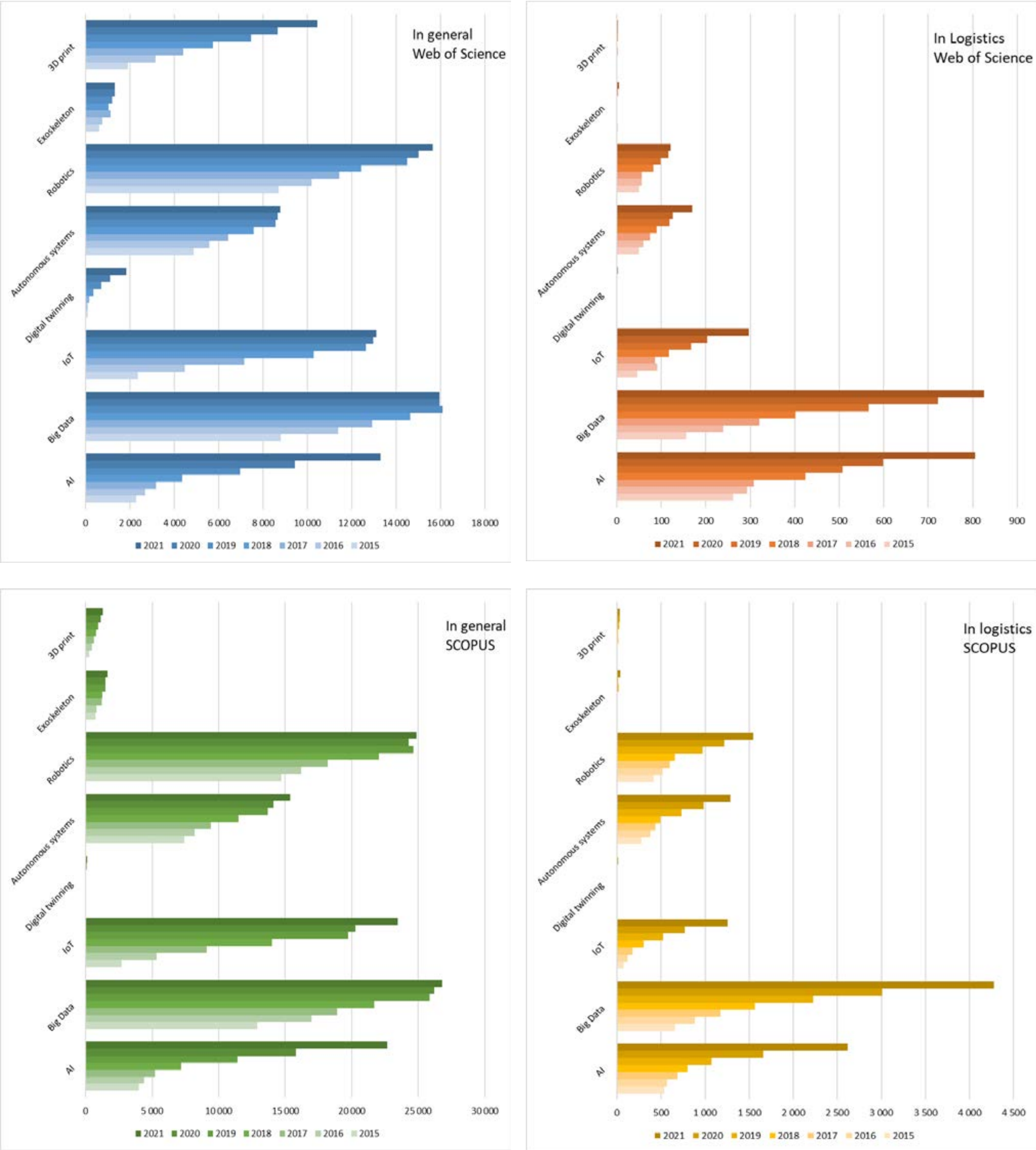

Figure 1 Development of the number of publications of selected areas in the Web of Science and SCOPUS databases in general and in the field of logistics Source: (Clarivate, 2022), (Elsevier B.V., 2022)

4.0 RESULS ADN DISCUSSION

The paper discusses the possible application of new emerging technologies with possible applications for the development of military logistics capabilities. There are discussed potential applicability for military logistics capabilities development, in short, and long-term horizon. The content analysis identified key emerging technologies, with potentially the highest degree of applicability in the conditions of military logistics, in the long term, but with a real potential for initial applicability in the short term.

The analysis of data in the WoS database, in general, shows a significant increase in research and anticipated applications in the period from 2015 to 2021, especially in digital twining (twenty-fold increase in the period), AI and IoT (six-fold increase), and 3D printing (five-fold increase). In the case of articles and published studies in the Scopus database, this is similar.

When focusing on potential applications in logistics, it is clear that digital twinning is still finding its practical application, and shortly we can expect a significant increase in the number of studies presenting research results, and in that connection increase in research projects and therefore subsequent practical applications. In the case of AI and IoT, this is a similar trend in the increase in the number of presented results as in the general application level. At the logistics application level, there are no significant differences between WoS and Scopus databases.

It is also appropriate to pay attention to the pace of increasing the number of presented results from the research. In general, the ever-increasing application potential of AI, IoT, and digital twinning is evident. On the contrary, the growth rate of the presented results in the field of robotics and autonomous systems has probably already reached its public potential, ie also the potential for solving research projects and thus also the potential in pace bring new knowledge in this area. Gradually, therefore, these application areas overlap from the categories emerging into the categorization of classical research. In terms of application "emerging" potential in the field of logistics, respectively. Military logistics, a significant increase in the number of results from research in the field of digital twinning or autonomous systems can be expected. In the field of logistics, areas of research such as robotics and big data are beginning to be saturated with applications.

5.0 CONCLUSION

The basic starting point for identifying the significance and potential impacts of emerging technologies should be to choose rational approaches to finding a place in this environment of intensive technological development. However, there are a number of technologies that make development and practical implementation cost enormous, and it is unrealistic for most countries to keep up with the leading technological powers. As with space projects, sharing research and production potential is an important prerequisite for not stopping. And this means sharing both within national capacities and international cooperation. For less affluent states, it will not really be easy to find a way to keep up. However, it should be found, because technological backwardness will have increasingly significant consequences, including on state security. For future decisions, it is necessary to monitor trends in change and related threats. In addition to being prepared to respond to these threats, it is necessary to focus on possible predictions of their further future development, including the setting of appropriate response and decision-making scenarios. Effective methods need to be adopted, which will include reducing the number of bureaucratic steps and measures required. This will not only increase the speed and accuracy of one's own decision-making but will also reduce the financial costs of individual decisions, where the resulting effect of the implemented measure should always be greater than the cost of achieving it.

The outputs of the analysis identify some areas that are generally emerging, but their potential is already declining. In the case of application to the conditions of logistics, the time shift of approximately 3-4 years behind the general application is obvious. This trend can therefore be expected in the short term, but also in the long term. From the point of view of further research, it would be appropriate to focus on other specific applications, identification of research communities, and identify their recommendations for trends, eg in the form of questionnaires and expert evaluation.

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