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THESES

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Challenges of Defence Industrial Supply Chains in Europe in the Global Security Environment of the 21st Century

Doctoral (PhD) dissertation

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Relevance and justification of the topic selection

At the beginning of the third decade of the 21st century, the global security environment has changed to an unprecedented extent. The coronavirus pandemic has triggered several crises simultaneously, each exerting a significant impact on the others, which have called into question the reliability of global supply chains. At the same time, the withdrawal of the United Kingdom from the European Union (hereinafter: EU) on 31 January 2020 – Brexit – split the economic and political structure of the western flank of Europe, reshaping the strategic routes along which goods, commodities, energy and, from the perspective of my research, defence technological assets flow. The Russo-Ukrainian conflict, which began in 2014 and escalated into a full-scale war in 2022, has highlighted that, alongside military force, logistical reserves, sustainable lines of communication and the volume of strategic stocks have by now become at least as decisive factors as the firepower of divisions.

Today, Europe is preparing for conflict in several areas at once. Hybrid threats, cyber-attacks and disinformation campaigns pose challenges that are just as serious as the need to avert the danger of conventional war. In these turbulent times, it has become clear that the outcome of combat operations is determined not only by the decisions of military commanders and the capabilities of weapon systems, but also by seamless logistic support, continuously available stocks, and the provision of food supplies and fuel. As rapidly as new units are mobilised, reserves are depleted at a similar rate if reliable sources and secure supply routes are not in place.

The old continent has now reached a strategic crossroads at which decisions may have irreversible consequences. In this situation, close cooperation with overseas partners, the strengthening of European defence autonomy, or indeed constant balancing between these two ambitions will determine how the North Atlantic Treaty Organization (hereinafter: NATO) and the EU are able to adapt to the accelerating technological competition and the pressing challenges of international sanctions. Where there is still an opportunity today to build or reshape logistic corridors, tomorrow there may remain only uncompetitive domestic factories and exhausted reserves.

In the initial phase of waging war, heavy weapons must not only be brought forward to the edge of the trenches, but the conditions for sustainable resupply must also be created in the rear. This realisation drives the rethinking of defence logistics, from uncovering the strategic vulnerabilities inherent in supply chains through to the operational solutions for protecting critical infrastructure. Redundancy in logistic networks, multi-channel sourcing, flexible mobilisation of reserves and the digital tracking of resource flows are all key elements without which modern military operations are inconceivable.

The fundamental question of this dissertation is therefore how the efficiency, flexibility, transparency and fault tolerance of these logistic systems can be raised to the highest possible level while at the same time allowing Member States' national interests and common defence objectives to be realised. The time available to Europe's defence decision-makers is limited. In my view, this is the last moment at which the current status quo can still be shaped and the strategic substantive and infrastructural foundations can be laid that are indispensable for successfully fighting the wars of the future. Alongside weapons and units, logistics is the key to military performance; recognising and applying this may offer the continent a genuine chance of long-term security.

Formulation of the scientific problem

The examination of the complex systems of defence industrial supply chains is an interdisciplinary task which simultaneously integrates the theoretical framework of supply chain management (hereinafter: SCM), the strategic considerations of the military sciences and the impact analysis of the rapidly changing international security environment. A review of the literature shows that, although well-developed civilian SCM theories are available, they can only be applied to the defence sector to a limited extent, owing to its specific requirements, namely dual (civil-military) use, national security considerations, technological sovereignty and a stringent regulatory environment.

The first dimension of the scientific problem is that research into defence industrial supply chains lacks a conceptual framework that would address logistical, industrial policy, innovation and security policy aspects simultaneously. In a changing security environment, the global nature of defence industrial value chains creates strategic vulnerabilities, since in times of crisis sanctions, export restrictions or cyber threats may interrupt critical supplier relationships. At the same time, the strategic documents of NATO and the EU do emphasise the importance of supply chain resilience, but they do not contain a quantitatively testable SCM model that would address these challenges in a unified manner.

The second problem is that analyses relating to the European Defence Technological and Industrial Base (hereinafter: EDTIB) focus primarily on existing structures, competences and competitiveness, rather than on the systematic identification of concrete manufacturing capacities, bottlenecks and vulnerabilities. There is still no publicly available capacity map covering several operational domains, meaning that defence decision-makers and researchers alike lack a unified, data-driven basis for assessing European and transatlantic production capabilities.

The third dimension is that current models do not adequately integrate the cumulative effects of global supply chain disruptions (pandemics, sanctions and trade conflicts), critical raw material dependencies, cyber security risks and technological convergence, which is particularly problematic from the perspective of EU Member States with small and medium-sized production potential. This hampers understanding of the conditions under which global and regional supply chain models can support allied force development objectives, and with what cost, time and risk profile.

The fourth problem is that the management of research, development and innovation processes related to defence-oriented SCM is not sufficiently integrated, either theoretically or practically, into the analysis of supply chains. These chains do not only ensure the flow of physical goods, but also the long-term alignment of scientific results, technologies and industrial capabilities, which appears only partially in the existing literature.

On the basis of the review of written materials available from open sources, the identified scientific problem can therefore be defined as follows: the theoretical and practical issues of defence industrial SCM have not yet been integrated into such a comprehensive conceptual framework that would be capable of addressing, within a single model, the complexity of the 21st-century security environment, technological convergence and the new dimensions of NATO-EU cooperation.

The central research question of the dissertation is therefore the following:

How can a defence industrial supply chain management model be developed in the defence sector that simultaneously ensures the development of national defence capabilities, allied interoperability and economic efficiency in the changed geopolitical and technological environment?

Research objectives

In light of the research question of the dissertation, my research objectives are as follows:

1. **Evaluation of the logistical and SCM-related requirements set out in defence strategic documents.**

My aim is to analyse, using a comparative methodology, the NATO 2030 vision and the 2022 Strategic Concept, the EU Strategic Compass, as well as Hungary’s National Security Strategy (hereinafter: HNSS) and National Military Strategy (hereinafter: HNMS), with particular regard to the expectations they formulate in relation to supply chains. I will explore how these documents define the requirements of logistical integration, the logistical dimensions of maintaining technological advantage, and the SCM aspects of protecting critical infrastructure. In the course of the research, I will identify the commonalities and differences that determine the logistical framework of allied cooperation.

2. **Collection and analysis of the defence industrial production capacities that define the European and transatlantic alliance space.**

My objective is to map and analyse comprehensively the EDTIB, with special focus on the land, air and naval defence industrial production capacities of EU and NATO Member States. I will examine in particular the production capabilities of the defence industry, their structural characteristics, and the role of initiatives such as the Hungarian Defence and Armed Forces Development Programme in European defence cooperation. In detail, I will address the quantitative and qualitative characteristics of capacities, their relationship to announced orders, and the identification of bottlenecks, and I will assess the extent to which the European defence industry is capable of responding to the challenges generated by the Russo-Ukrainian war and other current geopolitical developments. Hungary's role will be examined solely in the context of regional capacities fitting into the European industrial structure. Special attention will be paid to the time and cost requirements of replacing the Soviet legacy in defence-industrial terms, and to the challenges arising from this.

3. **Theoretical and practical analysis of global and regional supply chains.**

My aim is to carry out a comparative analysis between global and regional supply chain models along eight dimensions identified in the literature as critical, namely geographical scope, lead time, resilience, cost structure, environmental impacts, regulatory compliance, transparency and geopolitical exposure. Building the theoretical framework of my research on Douglas M. Lambert's SCM concept, but supplementing it with characteristics specific to the defence industry, I will explore the advantages and disadvantages of both models. Through practical case studies, I will analyse the possibilities for establishing regional supply chains, with particular emphasis on the feasibility of EU strategic autonomy and compatibility with NATO.

4. **Defence-oriented mapping of global supply chain disruptions and geopolitical risks.**

My objective is to analyse the effects of the coronavirus pandemic, Brexit, the Russo-Ukrainian war and geopolitical competition with China on supply chains. I will examine the risks arising from import dependence on critical raw materials and the impact of sanctions regimes on the European defence industry. I will map those vulnerabilities that stem from the complexity of global supply networks, the long development cycles of defence products and the lack of transparency in supplier chains. My research will use quantitative analysis to present the economic and security consequences of supply disruptions.

5. **Development of a defence supply chain management concept capable of supporting an integrated and coordinated defence industry.**

The ultimate aim of my research is to develop a comprehensive, SCM-focused defence industrial model that integrates the experience of Permanent Structured Cooperation (hereinafter: PESCO), the principles of smart specialisation policy and the operation of Centres of Excellence networks. The concept focuses on the integration of small and medium-sized enterprises (hereinafter: SMEs) into supply chains and on the development of dual-use technologies in order to achieve technological sovereignty. In addition, my goal is to formulate recommendations for the optimal functioning of regional clusters, the efficient allocation of coordinated defence expenditures, and the creation of a defence industrial ecosystem that is capable of responding to the security challenges of the 21st century while maintaining allied interoperability.

Hypotheses

Hypothesis 1:

The defence strategies of NATO, the EU and Hungary integrate the requirements related to supply chains and military logistics only partially and in different ways. Conceptual and emphasis-level differences can be demonstrated between the documents with regard to the criteria of logistical integration, supply chain resilience and the protection of critical infrastructures.

Hypothesis 2:

There is a significant quantitative and qualitative discrepancy between the current production capabilities of the European defence industry, the lessons of the Russo-Ukrainian war and the force development needs derived from the capability targets set out in NATO and EU strategic documents, which points to structural underfunding and a persistent imbalance between supply and demand.

Hypothesis 3:

The critical points identifiable in the supply chains of the European defence industry – from raw materials, through semi-finished to end products and the related infrastructure – conceal mutually reinforcing structural vulnerabilities which, in the event of global supply chain disruptions and geopolitical shocks, substantially endanger the functioning of the system.

Hypothesis 4:

Compared to defence industrial supply chains based on a global supplier network, the regional supply chain model delivers demonstrably better performance in most of the eight examined dimensions – in particular lead time, resilience, geopolitical exposure, regulatory compliance, supplier transparency and environmental impact – while the overall cost level does not increase significantly in the long term.

Hypothesis 5:

A coordinated regional defence supply chain management concept based on the experience of PESCO, the principles of smart specialisation, Centre of Excellence networks and regional defence clusters is capable of simultaneously reducing the supply chain risks affecting the EDTIB, increasing allied interoperability and making a substantial contribution to strengthening European strategic autonomy.

Research methods

I examine the operational military logistics aspects of supply chains using an interdisciplinary, multi-stage research methodology. The methods I apply build on one another and are designed to ensure, at every step from the theoretical framework to the practical case studies, the robustness of the data and the validity of the results.

Structured, comparative document analysis:

In the research I use a standardised, structured document analysis approach that combines elements of qualitative content analysis and quantitative comparative analysis. My aim is to carry out a systematic comparison of the logistics- and SCM-related chapters of the NATO 2030 and 2022 Strategic Concepts, the EU's 2022 Strategic Compass, and the

Hungarian strategic and force development documents. The relevant sections of these documents are examined using a unified coding system based on twelve key dimensions that define defence logistics (for example supply chain resilience, interoperability, critical infrastructure protection, digitalisation, sustainability, etc.). These dimensions were identified based on the literature and the strategic documents, ensuring comparability and coherence with the research objectives. The qualitative analysis focuses on identifying strategic objectives, priorities and risk assessments, while the quantitative assessment examines the frequency and weighting of the topics. The resulting structured comparison makes it possible to explore scientifically the convergences and divergences between national and alliance-level documents, and to assess the extent to which Hungarian defence logistics concepts align with the strategic directions of NATO and the EU.

Case study:

Instead of field visits and company interviews, data collection on domestic defence industrial clusters is based on publicly available production capacity data, company reports and press releases. I organise the data into tables and compare them with the strategic objectives using statistical indicators (e.g. annual production capacity, investment volume, R&D expenditure). Thematic comparative tables between clusters present the production profile, partner network and cooperation nodes.

Quantitative data collection and analysis:

Equipment figures from The Military Balance 2024 and defence industrial capacity data for NATO Member States from the Global Firepower database provide the basis for quantitatively underpinning the results. Using descriptive statistics and indices (e.g. capacity-to-utilisation ratio), I examine the balance between production and losses and the extent of wartime risk.

Testing the hypotheses:

The five hypotheses formulated in line with the research objectives are tested through the triangulation of the results of comparative analysis, case study work and quantitative data examination. For each hypothesis I assign specific examples and indicators, then confirm or refute them by means of document analysis and by comparing the findings of the case studies.

Construction of a conceptual model:

The “multi-dimensional SCM model” emerging from the results is represented in a diagram that comprises modules and subsystems (theoretical, strategic, cluster and risk-management modules) which are linked by two-way feedback loops and together form the optimised SCM framework.

Validation and expert consultation:

Throughout the research I maintained continuous professional consultation with my supervisors, which contributed to the refinement of the methodology and a deeper interpretation of the analyses. I published my results in scientific journals and presented them at professional conferences, where comments from researchers and practitioners working in the field of military science supported the clarification and further development of the research. Taken together, the journal peer-review processes and conference feedback served to validate scientifically both the methodology and the findings.

Temporal limitations:

The temporal frame of the research runs from September 2021 to June 2025. The main empirical results and quantitative findings of the study were finalised by March 2025. The dissertation workshop discussion took place on 4 December 2025, and the professional comments made there were implemented in the final text of the dissertation by 15 March 2026. In view of the continuously changing dynamics of the global security environment, certain data and content elements were refined after the formal end of the research in order to preserve scientific validity and topicality.

The combination of the above methods guarantees the theoretical soundness of the research, the reliability of the documents and case studies, and the scientific robustness of the strategic and practical conclusions.

Summary of the dissertation

Following the introductory part, the dissertation presents a SCM-oriented, structured document analysis of the NATO 2030 vision, NATO's 2022 Strategic Concept, the EU Strategic Compass, and Hungary's National Security and National Military Strategies. The author compares how these documents address logistical integration, supply chain resilience, the protection of critical infrastructures and the supply requirements of new defence technologies within a six-dimensional framework. The analysis demonstrates that alliance-level and national strategies only partially, and with differing emphases, integrate expectations related to supply chains, which results in conceptual and terminological differences and, at the same time, provides the analytical framework for the empirical chapters that follow.

After defining the strategic requirements, the dissertation maps the defence industrial production capacities of the European and transatlantic alliance space, with particular focus on land, air and naval weapon systems, as well as on the analysis of space and cyber capabilities. Using quantitative analysis of open-source statistics (The Military Balance, Global Firepower, etc.), the author shows that current EDTIB capacities do not meet either NATO/EU capability targets or the force development requirements justified by the experience of the Russo-Ukrainian war. The chapter highlights quantitative and qualitative shortfalls in tank, infantry fighting vehicle, artillery and helicopter fleets, and shows that, in a protracted, high-intensity conflict, existing production capacities would not be able to replace expected losses in the medium term.

Chapter 4 focuses on an SCM-based analysis of the industrial sectors that constitute and support defence industrial supply chains – the steel industry, chemical industry, semiconductor sector and industrial robotics – as well as critical raw materials (rare earth elements, cobalt, titanium, etc.). The author reveals structural vulnerabilities in several stages, from raw material extraction through semi-finished products and key components to end products and related infrastructure, with particular emphasis on the EU's dependence on China and other geopolitically risky sources. The analysis shows that the coronavirus pandemic, the Russo-Ukrainian war and other global disruptions have caused real, measurable declines in capacity and performance in supply chains, and underpins the strategic importance of the circular economy, domestic recycling and alternative sources of supply.

The final chapter of the dissertation presents a coordinated, transnational-regional hybrid defence supply chain management concept based on the experience of PESCO projects, the principles of smart specialisation, networks of centres of excellence and regional defence clusters. Within a NATO-EU Procurement Agency (hereinafter: NEPA) type joint procurement and coordination model, the author integrates EU funding instruments and NATO interoperability requirements, assigning a prominent role to the integration of small and medium-sized enterprises, dual-use infrastructure, and green and digital solutions. On the basis of case studies and quantitative estimates, the chapter demonstrates that the regional supply chain model delivers better performance than the global model in most of the dimensions examined (lead time, resilience, transparency, geopolitical exposure), while not leading to a significant increase in overall costs in the long term, and finally formulates concrete policy recommendations for gradual implementation.

Summary conclusions

I summarise the conclusions of the dissertation through the examination of the hypotheses formulated.

Hypothesis 1:

The results of the structured document analysis empirically supported the first hypothesis. The analysis of the logistical aspects of NATO 2030 and the 2022 Strategic Concept showed that the Alliance's documents place particular emphasis on supply chain resilience, military mobility, the protection of critical infrastructures and the logistical requirements of EDTs. In contrast, the EU Strategic Compass focuses more strongly on crisis management, on meeting military mobility needs through dual-use infrastructure elements, and on the institutional dimensions of strategic autonomy, but it sets out less detailed, explicit requirements regarding logistical integration.

The analysis of the HNSS and the HNMS indicated that the Hungarian documents primarily focus on directions for force development, the rebuilding of the national industrial base and alignment with allied expectations, while detailed, operationalizable requirements relating to SCM, the resilience of supplier networks and the protection of critical infrastructures are only partially present. Based on the analytical matrix used, it can be demonstrated that the five documents address logistical integration, supply chain resilience and the SCM aspects of critical infrastructures to differing degrees and with different conceptual toolsets, which confirms the conceptual and emphasis-level differences set out in the hypothesis.

The hypothesis is confirmed.

Hypothesis 2

The findings of the research empirically confirmed the second hypothesis, namely that there is a substantial gap between current European defence industrial capacities and the requirements formulated as targets or justified by the changed security environment, particularly in light of the lessons of the Russo-Ukrainian war. In the case of land forces, I demonstrated that replacing the Soviet-origin equipment – especially the 224 T-72 tanks and 1,691 BMP fighting vehicles – would require several years even if the EU's entire current armoured vehicle production capacity were mobilised (approximately 2.15 years in the former case and around 4.22 years in the latter), which in itself indicates a systemic capacity deficit. With regard to artillery ammunition, the analysis showed that the target of producing 1 million 155 mm shells per year collides with bottlenecks identified in propellant and explosives production, meaning that the declared output goals can only be achieved with significant additional investment and expansion of supplier chains.

The examination of the average age of the existing rotary-wing fleet and the platform indicators derived from the processed databases showed that roughly 42% of the European helicopter fleet has been in service for more than 30 years, while strategic documents prescribe modern capabilities with a long remaining service life. Calculations based on projected losses of tanks, artillery pieces, air defence batteries and unmanned aerial vehicles indicate that, in the event of a protracted, high-intensity European conflict, the current structure of the EDTIB would not be able to replace forecast losses in the medium term, which points to a persistent supply-demand imbalance and the cumulative impact of past underfunding.

The hypothesis is confirmed.

Hypothesis 3

The analysis of supply chains at raw material, industrial and infrastructural level confirmed the third hypothesis. Data on critical raw materials – particularly rare earth elements, cobalt and titanium – show that EU import dependence is exceptionally high in these cases. Around 98% of rare earth elements originate from China, 65% of cobalt from the Democratic Republic of the Congo, and 55% of titanium from geopolitically risky sources. Examination of the manufacturing and semiconductor sectors revealed that the European defence industry is highly dependent on East Asian supply chains for semi-finished products and key components, which led to visible supply chain disruptions during Brexit, the coronavirus pandemic, the Russio-Ukrainian war and the Red Sea crisis.

Case studies presented in the subsection analysing the infrastructure serving supply chains – including rail and road corridors with limited capacity, constrained military mobility, energy dependencies and vulnerabilities in information and communications networks – demonstrated that both physical and information logistics systems exhibit "critical point of failure" type risks in several areas. Documented cases involving the theft of Rotax engines and circumvention of sanctions, as well as cyber threats to the integrity of supplier chains, indicate that the opacity of supply chains and shortcomings in information security represent additional, mutually reinforcing layers of vulnerability. The cumulative effects of the global disruptions analysed caused real, measurable reductions in capacity and performance in the sectors examined, demonstrating that structural vulnerabilities can substantially endanger the functioning of the system.

The hypothesis is confirmed.

Hypothesis 4

The results of the eight-criteria comparative framework presented in Table 11 confirmed the fourth hypothesis. In terms of lead times, the 8-12-week maritime shipping cycles typical of the global model were contrasted, in the case studies examined, with regional solutions based on closer supplier bases, which typically enabled lead times of 72 hours, i.e. roughly 80-90% shorter completion times, providing a particularly significant advantage during periods of ramp-up in defence industrial production. As a result of reduced transport distances and changes in modes of transport, carbon dioxide emissions associated with logistics activities could be reduced by as much as 25-50% in the relations concerned.

In terms of supplier network transparency and the risk of foreign interference, in the global model most companies have accurate information only up to the second tier of suppliers, whereas in the regional configuration – owing to unified legal frameworks, fewer high-risk areas and shorter supply chains – it is possible to map meaningfully deeper (third to fifth-tier) supplier levels. Cost calculations indicate that the total cost indicator of the regional supply chain model may be 5-15% more favourable in the longer term if the financial effects of geopolitical shocks, inventory and risk management expenditures and sustainability requirements are taken into account. These results suggest that the regional model indeed delivers better performance in most of the dimensions examined, without a material increase in overall cost.

The hypothesis is confirmed.

Hypothesis 5

The coordinated, transnational-regional SCM concept developed in Chapter 5.3. and the results of the associated case studies supported the fifth hypothesis. Successful projects implemented under PESCO – particularly the MRTT-C multinational air-to-air refuelling fleet and the Eurodrone programme – showed that cooperation based on common specifications, modular, open architectures and dual OCCAR-NSPA type governance models can simultaneously enhance interoperability and the integration of SMEs (in the case of Eurodrone, around one-third of components are supplied by approximately 120 SMEs). The failed Archer project, as a counter-example, illustrated how a lack of coordination, bilateral governance and industrial conflicts of interest can lead to a deterioration of political trust and loss of capacity.

Analysis of the SAFE, EDIRPA, EDF and DEF instruments and of the proposed NEPA-like procurement agency model indicated that a combination of targeted EU funding incentives, SME quotas, transnational PPPs and a regional cluster logic can reduce supply chain risks, broaden the supplier base and harness industrial development in the service of

EU-NATO level interoperability. The integrated inclusion of S3-based smart specialisation, Centres of Excellence networks and V4 cooperation suggests that, through this concept, European strategic autonomy – particularly in the fields of critical technologies, raw materials and semiconductors – can be significantly strengthened in the medium term.

The hypothesis is confirmed.

New scientific results

The dissertation presents five main scientific results, which focus on the critical challenges affecting the supply chains of the European defence industry and on the possibilities for addressing them. The research examines the current performance and future development directions of the EDTIB in the context of 21st-century defence policy requirements and the lessons of the changed security environment. The results are based on analyses underpinned by quantitative and qualitative methods.

1st scientific product:

I developed a structured, six-dimensional, SCM-oriented document analysis framework and, through its application, demonstrated that NATO 2030, NATO's 2022 Strategic Concept, the EU Strategic Compass and Hungary's National Security and National Military Strategies integrate requirements relating to supply chains and military logistics only partially and in different ways. I identified conceptual and emphasis-level differences between alliance-level and national-level documents with regard to logistical integration, supply chain resilience and the protection of critical infrastructures.

2nd scientific product:

Using quantitative methods and the systematic analysis of capacity and equipment data from multiple sources, I demonstrated that the current production capabilities of the European defence industry – particularly in the fields of tanks, infantry fighting vehicles, artillery systems, helicopters and ammunition – do not meet either the capability targets derivable from NATO and EU strategic documents or the force development requirements justified by the experience of the Russo-Ukrainian war. I showed that this leads to quantitative and qualitative capacity deficits and to a persistent supply-demand imbalance within the EDTIB.

3rd scientific product:

By applying SCM tools and conducting a multi-stage analysis ranging from raw material supply, through semi-finished products and key components, to end products and the related transport, energy and information and communications infrastructure, I demonstrated that the supply chains of the European defence industry exhibit mutually reinforcing structural vulnerabilities. I quantified critical raw material dependencies, identified the risks arising from reliance on East Asian supply chains for semiconductors and components, and proved that the global supply chain disruptions examined (Brexit, the coronavirus pandemic, the Russo-Ukrainian war) caused actual reductions in capacity and performance in key industrial sectors.

4th scientific product:

Using a comparative framework built around eight dimensions identified in the literature as critical (geographical scope, lead time, resilience, cost structure, environmental impact, regulatory compliance, transparency, geopolitical exposure), and drawing on case studies and quantitative estimates, I demonstrated that the regional supply chain model – based on a closer, allied supplier base – delivers better performance than the global model across most of the indicators examined.

5th scientific product:

By integrating the analysis of PESCO project experience, smart specialisation strategies, Centres of Excellence networks, EU defence industrial policy instruments (EDF, EDIRPA, ASAP/SAFE, DEF) and regional defence clusters, I developed a coordinated, transnational-regional defence industrial supply chain management concept and, using qualitative and quantitative methods, demonstrated that this type of SCM-focused model is suitable for reducing EDTIB supply chain risks, strengthening allied interoperability and contributing to the gradual enhancement of European strategic autonomy in critical industries and technologies.

Applicability of the scientific results

The practical application of the scientific results of the dissertation is crucial for increasing the competitiveness and resilience of the defence industry. The combination of the theoretical framework of SCM and defence-specific characteristics in a transnational-regional hybrid model reveals strategies that simultaneously strengthen national defence capacities, interoperability within the Alliance and economic efficiency.

My research highlights that coordinated functioning of the central chain of command and regional clusters significantly improves the ability to respond rapidly to crises. For this reason, it would be expedient to establish joint logistics coordination centres in Hungary and in other Member States as well, integrating multinational NATO and EU projects.

The development of dual-use infrastructure – suitable for both civilian and military purposes – makes it possible to ensure that civilian supply does not hinder military mobilisation in a crisis. I propose the launch of an EU-funded "dual-use corridor" programme, in which several nations jointly develop specific sections of the trans-European network.

The combination of joint financing, models based on the involvement of venture capital, and military innovation investment funds guarantees long-term funding. To reinforce this, it would be appropriate to establish a "European Venture Capital Fund" initiative, in which at least ten Member States participate and jointly support SMEs' R&D projects.

The introduction of a circular economy and real-time digital monitoring systems reduces the carbon footprint and increases the transparency of supply chains. It is recommended to establish a "Green Defence Data Network" based on ENISA guidelines, in which procurement, transport and warehousing processes can be monitored in real time, optimising inventory management while reducing energy consumption.

In the dissertation, I emphasise that, in the long term, prioritising common European and Atlantic interests over national bureaucracy and defence lobbying will ensure the continent's strategic autonomy. It is important that more nations join the major projects already under way (e.g. new combat aircraft, main battle tank, naval frigate).

There is an unquestionable need to modernise existing regulations. Defence procurement directives must be updated so that they give preference to the creation of dual-use and green projects. In addition, the adoption of a "European Strategic Supply Regulation" is recommended, which would harmonise the import of critical raw materials and establish recycling quotas for all Member States.

In summary, the findings of the dissertation show that the implementation of a transnational-regional hybrid SCM model may be the answer to the security and economic challenges of the 21st century. This, however, requires the creation of new policies, better utilisation of existing programmes, the expansion of joint financing mechanisms and the relegation of narrow national interests in favour of long-term European and Atlantic security. Only in this way can the continent's defence industrial ecosystem be strengthened sustainably, guaranteeing strategic autonomy, interoperability and economic efficiency.

Recommendations and further possible directions of research

I primarily recommend the results of the dissertation to the strategic, planning and logistics leaders of the Ministry of Defence and the Hungarian Defence Forces, as well as to experts involved in NATO- and EU-level defence planning, for the development of the resilience, capacity and risk management of defence supply chains. The SCM model developed and the related case studies provide practical guidance for identifying capacity shortages, supplier dependencies and vulnerabilities of critical infrastructures, as well as for designing regional clusters and joint procurement arrangements. For the managers and development specialists of defence industrial companies – in particular SMEs – the concept offers guidance for diversifying supplier portfolios and integrating dual-use infrastructure and green and digital solutions. Finally, the results can also be used in higher education in military science and logistics, and as a starting point for further doctoral research to deepen the defence applications of SCM.

The coordinated transnational-regional hybrid SCM model constructed in my dissertation has laid the foundations for the analysis of the complex dynamics, risks and development opportunities of defence industrial supply chains, but numerous further research directions are available to deepen and extend the practical application of the results, as follows:

1. Revealing defence product supply chains using quantitative methods:
    - Detailed mapping of the supply chains of all major equipment categories (tanks, self-propelled guns, air defence systems, drone platforms, warships), highlighting resource requirements, transport routes, production and manufacturing capacities, and inventory management points.
    - Determining the percentage and absolute share of imports by country and by supplier.
    - Assessing the share of local SMEs, the supplier roles they perform, the volumes they deliver, and their value and R&D contribution ratios.

Through such quantification, the topology of critical points and dependencies becomes clearly visible, providing a basis for targeted diversification and development strategies.

2. In-depth examination of dual-use technologies:
    - Analysis of the supply chains and import and export processes of dual-use products.
    - Assessment of the impact of specific transparency, reliability and certification requirements of military applications on the structure of supplier networks.
    - Examination of the impact of the international regulatory environment on market actors' strategies and their procurement procedures.

Based on the experience of the Russo-Ukrainian war and other hybrid conflicts, it is necessary to investigate more thoroughly the production and procurement mechanisms of such products and to develop specific recommendations to reduce vulnerabilities.

3. Integrating the role of energy supply and transport infrastructure:
    - Analysis of the energy demand profile of defence industrial production and of the security of energy supply, including mapping redundancies in electricity, natural gas and hydrogen networks.
    - Examination of the vulnerabilities of critical infrastructures (power plants, storage facilities, commercial logistics centres) in crisis situations, and of the impact of the green transition (hydrogen, biomass) on the energy supply of the defence industry.
    - Analysis of the role of road, rail and inland waterway transport networks, for example by examining capacities, alternative routes and the location of strategic stockpiles.

Through such research, energy availability and freedom of movement, which constitute the "lifeblood" of defence industrial supply, can be directly integrated into SCM models.

4. Scenario planning and stress testing:
    - Using data collected in real-time digital monitoring systems to model the impact of various geopolitical, logistical and technological crisis scenarios (e.g. sanctions, hybrid attacks, natural disasters) on defence industrial chains.
    - Developing rapid post-disaster or post-conflict recovery scenarios through the optimal combination of redundancies, reserves and regional redirection mechanisms.
5. Developing joint financing schemes and policy instruments:
    - Evaluating the effectiveness of existing programmes using indicators of resource allocation, project portfolio management and risk pricing.
    - Designing and back-testing new policy instruments, incentive schemes and regional SME investment funds.
    - Harmonising the conditions of access to common funds to ease national interests and protectionism, thereby encouraging policy convergence among Member States.
6. Integrated database and information management:
    - Building a secure and interoperable, Europe-wide data platform containing supply chain parameters, procurement data, a register of critical infrastructures and risk maps.
    - Applying AI and machine learning to automate data analysis and forecasting, thereby enabling proactive chain-optimisation measures to be launched.

7. <u>Strengthening education and training, and cooperation between research and industry:</u>
   - Establishing university-defence industrial clusters in which theoretical research is developed directly in line with the needs of manufacturing and procurement companies.
   - Launching doctoral and post-doctoral programmes on dual-use technology, SCM and energy infrastructure, encouraging young researchers to participate in real industrial projects.

Further investigation of these research directions can significantly deepen the practical application of the models outlined in the dissertation and can contribute to ensuring that the European and North Atlantic defence industry is not merely a collection of fragmented clusters, but a coordinated, sustainably financed, green and digitally transparent chain capable of responding rapidly to the challenges of the 21st century, while preserving allied interoperability and strategic autonomy.

List of the author’s publications related to the topic

In English

1. Security of Global Supply Chains in view of the 2021/2022 “Chip Shortage” – National Security Review 2022/1, pp. 30-44.
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Professional curriculum vitae of the author

Captain Ferenc Hegedűs was born on 13 May 1993 in Budapest.

In 2012 he was admitted to the Faculty of Military Science and Officer Training of the National University of Public Service, to the Military Management bachelor's programme. During this period, he passed STANAG 2 and later STANAG 3 English language exams, completed his fourth semester at the University of Defence in Brno, Czech Republic, within the ERASMUS+ programme, and took part in the Ludovika Battalion's first international exercise in Hohenfels. He graduated as an economist in the Military Management BSc, specialising in logistics (military supply).

His first officer posting was in Hódmezővásárhely at the 5th "István Bocskai" Infantry Brigade, where he served in the Logistics Section of the Staff of the 3rd "Miklós Bercsényi" Infantry Battalion as a junior officer. He took part in multinational exercises in Serbia, Romania and Germany, and in 2019 served in Kosovo as Support Platoon Commander in the KFOR-20 rotation.

Between 2018 and 2020 he obtained, in part-time (correspondence) study, a Master's degree in Supply Chain Management at the Faculty of Economics and Social Sciences of Szent István University.

He was promoted to First Lieutenant in 2020, and in 2021 he was appointed Company Commander of the Logistics Company of the 3rd "Miklós Bercsényi" Infantry Battalion.

In 2021 he was admitted to the Doctoral School of Military Sciences.

In 2023 he was appointed Deputy Head of the Logistics and Finance Section of the newly established 30th "Pál Kinizsi" Armoured Infantry Brigade, where he supervised the brigade's procurement activities.

In 2024, after completing the Tactical Staff Officer Course, he was promoted to Captain and, in the same year, obtained a basic-level ARMA German language exam. He completed his doctoral studies in 2025 by obtaining the absolutorium.

On 1 May 2025 he was appointed Head of the Maintenance Section of the Logistics Branch of the brigade.

From 1 January 2026 he has been serving as an Assistant Lecturer at the Department of Operational Logistics of the Institute of Military Logistics, National University of Public Service.