Civilian-Military Integration in Ukrainian Defense Supply Chain

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ABSTRACT

This research delves into the intricacies of the Ukrainian military's supply chain during the ongoing Russian-Ukrainian war, with a specific focus on the significant role played by the civilian population in supporting the armed forces. Termed a defense supply chain, our study employs a multilevel model encompassing logistical, informational, and financial dimensions to elucidate the multifaceted levels within the defense supply chain network. Key actors identified include manufacturers, non-governmental organizations (NGOs), donors, and conscripts. The study sheds light on the vulnerabilities in the flow of goods in the defense supply chain. A resilient defense supply chain relies on efficient NGO communication and the crucial alignment of donor income growth with escalating resource prices.

Keywords

Civil-Military Integration, Defense Supply Chain, Russian-Ukrainian War, Supply Chain Network Model.

INTRODUCTION

The year 2022 marked a pivotal moment in global affairs as Russia's full-scale invasion of Ukraine reshaped the geopolitical landscape, prompting a profound reevaluation of military capabilities, strategic responses, and international alliances. Against this backdrop, our research characterizes the intricate web of dynamic civilian-military interactions within the context of the Ukrainian defense supply chain and highlights the role of information in this context.

The Russian-Ukrainian war, characterized by a full-scale invasion, unfolded as an asymmetric warfare scenario where Russia possesses substantial resources over Ukraine (International Institute for Strategic Studies, 2021). This asymmetry catalyzed a distinct military campaign heavily reliant on the self-organization of civilians. Ukrainian self-organization, which, as noted by Channel-Justice (2022), was already evident over a decade ago, as the 2013-2014 Euromaidan protests were unfolding in Ukraine.

Ukraine's two-year defensive challenges initial perceptions regarding the military power balance between Russia and Ukraine (Dalsjö et al, 2023; Ti, 2023). Increasing evidence points to the aggressor's ill-judged and overly optimistic military calculations such as Russia's poor understanding of its own forces, poor Russian training, and low standards of tactical competence. A key, yet understudied, element in Ukraine's surprising success was the role of its citizens. Indeed, Barany (2023), Hackett (2023), Hoffman (2022), and Tierney (2023) underscore the significance of the human factor in warfare, emphasizing the importance of investing in personnel, competent commanders, and comprehensive training.

Armed conflict triggers the application of the Third Geneva Convention of 1949, the First Additional Protocol of 1977, and customary rules of International Humanitarian Law (IHL). Humanitarian organizations, guided by IHL principles, maintain a clear demarcation between military and nonmilitary aid, underscoring the imperative of

principled neutrality to protect civilians and to uphold human rights (Melzer, 2019).
Ley (2022) emphasizes the fundamental role of social networks in mobilizing against insecurity, transforming individual fears into collective anger and providing a sense of security. For Ukrainian civilians, providing aid to the military is viewed as a humanitarian response, as it has helped to stave off the Russian invasion and the resulting horrific damage and suffering to the population (Dunn et al., 2023). Thus, volunteer action was overtly political, a form of resistance to Russian attacks and domination (Konrad et al., 2023; Slim, 2022).

We define the current situation in Ukraine as a full-scale invasion with a defense supply chain. By full-scale invasion we mean that one government's armed forces are defending their sovereign country against an unprovoked invasion by armed forces of another state. The term defense supply chain refers to a logistical system in which civilians are an essential and integral part for a defending nation's military success. Specifically, we study how civilians provide the Ukrainian military with ammunition, food, transport, medical supplies, warehouses, and act as the main channels for information transmission. While civilian surveillance, and participatory gathering and sharing of intelligence have a growing body of evidence, the agentic power of civilians in military logistics has not been documented. Although defense supply chain network economics has been studied (Nagurney, 2023), it has been examined in the context of behavior of defense firms, which are concerned about revenues as well as risk. Moreover, the role of information in defense supply chains has not received much attention and, yet, as we hypothesize, information plays an indispensable role in supply chain effectiveness, by providing the crucial linkages between the logistical and financial domains.

Motivated by our observations in Ukraine, our research question is: to what extent is the defense supply system in Ukraine vulnerable, and how can it be enhanced to bolster resilience?

To answer our question, we set the following three objectives:

1. To describe and visualize the structure of the defense supply chain in the Russian-Ukrainian war.
2. To analyze the roles played by key actors, including manufacturers, NGOs, donors, and conscripts, in sustaining the defense supply chain.
3. To investigate the vulnerabilities of the defense supply chain.

In what follows, we explore civil-military integration across various contexts through a literature review and we review a theoretical framework to describe the levels of the defense supply chain and the roles of key network participants. The method section outlines our approach involving participant interviews and analysis of volunteer funds. In the discussion section vulnerable points in the defense supply chain are identified, and suggestions for strengthening them are offered.

LITERATURE REVIEW

The collaboration between military and civilian entities assumes multifaceted manifestations, each driven by distinct objectives and involving a spectrum of actors, including military personnel, international organizations, local non-governmental organizations (NGOs), and governments (Franke, 2006). We navigate the terminology of Civil-Military Integration (CMI), specifically in the context of the defense supply chain in the Ukrainian case.

NATO's Civil-Military Coordination Doctrine (CIMIC) defines CIMIC as the collaboration between the NATO commander and civil actors in support of missions. Emphasizing cooperation with various organizations, CIMIC's core functions in stability operations encompass liaison, assistance to the civilian environment, and support to the military force (NATO, 2003). Distinguishing itself from Civil Affairs (CA) activities, which doctrinally differ, CIMIC prioritizes humanitarian needs and guides interactions to achieve humanitarian mission objectives, while CA centers on military needs and suggests methods to garner civilian support for military missions (Department of Defense, 2003).

Our study purposefully steers clear of delving into CA in the Russian-Ukrainian war due to the well-established civilian-military relations in Ukraine, which are marked by extensive civilian involvement in supporting and interacting with the Ukrainian military. The Ukrainian military, primarily comprised of civilians mobilized through general conscription, exemplifies CMI in conflict zones. Civilians willingly take on the partial responsibility of supplying resources for the Ukrainian military, thereby enhancing the country's military prowess. This collaborative endeavor is encapsulated by the concept of CMI, aspiring to create a unified and synergistic approach where civilian and military elements work in close tandem, sharing resources, information, and decision-making processes.

CMI emerges as a pivotal facet of collaborative endeavors between civilian and military entities, especially in the realm of global security challenges. Researchers scrutinize CMI from various angles, with one group delving into the theoretical underpinnings and evolutionary dynamics within this context. Brooks (2019) offers an overview

of the theoretical landscape. Su et al. (2020) contributes a quantitative perspective through an evolutionary game framework, and De Coning (2016) delves into the theoretical aspects, shedding light on the complexities and potential constraints in civil-military integration.

A second research perspective regarding CMI revolves around regional insights and case studies, unraveling how this collaboration unfolds in specific contexts. Lafferty et al. (2013) explore China's approach, while Welle (2010) provides an Afghanistan case study, elucidating the challenges and successes in creating a unity of command. Hønneland & Jørgensen (2018) introduce a regional dimension by examining civil-military relations on the Kola Peninsula and the delicate balance between integration and autonomy.

Vuono (2008), Lucius (2016), and Egnell (2009) shift the focus to practical aspects, offering insights into challenges and effective strategies of CMIs. Vuono (2008) addresses practical challenges in stability operations. Lucius & Rietjens (2016) explore practical approaches for cooperation in peace operations, and Egnell (2009) provides insights into navigating diverse operational environments. Berg (2020) investigates the practical implications of civil-military relations in postwar politics, specifically examining their connection to civil war recurrence.

While the existing literature delves into the theoretical underpinnings, challenges, and dynamics of civil-military integration, as well as regional perspectives and case studies, a discernible research gap persists. This gap pertains to understanding the distinct roles, contributions, and challenges of civil initiatives, in contrast to military or government initiatives within the context of CMI. Bridging this gap in the Ukrainian case assumes significance for practitioners seeking effective collaboration strategies, offering a more nuanced understanding of the diverse actors involved and their impact on the success of civil-military integration efforts. Cooperation and possible associated synergies have been modeled with a goal towards quantification in the case of humanitarian organizations by Nagurney and Qiang (2020) using a supply chain network perspective but not yet in a civilian-military defense setting.

THEORETICAL FRAMEWORK

Central to our analysis is the defense supply chain network model that provides a structured framework for understanding the defense supply chain, inspired by Nagurney et al. (2002). The authors introduced a multilevel network perspective for conceptualizing the dynamics underlying supply chains in the presence of competition. This multilevel model comprises the logistical network, the informational network, and the financial network. The authors described the behavior of the decision-makers, including manufacturers, retailers, and consumers.

In contrast, our multi-level structure of the defense supply chain involves four actors: manufacturers, NGOs, and donors. Manufacturers, NGOs, and donors are civilians. NGOs operate voluntarily within this framework. Military conscripts act as the end-users, NGOs serve as intermediaries, manufacturers produce the goods, and donors pay the price of the military product.

We examine the product flow of Unmanned Aerial Vehicles (UAVs) in the defense supply chain – a vital commodity in Ukraine's defensive strategy. The mention of drones serves as an example because even after two years of conflict, drones remain a relevant commodity. Initially, the defense supply chain redistributed goods such as food and clothing, but now there is less demand for such items, whereas drones continue to be in demand. Several studies highlight the significance of UAVs and their applications in military and humanitarian operations. For example, Jasper (2023) discusses the role of UAVs in Ukraine's military response, and Colajanni, Daniele, and Nagurney (2023) construct a three-stage stochastic optimization model focusing on three phases of disaster management integrating 5G technology and UAVs.

Manufacturers

Manufacturers are crucial in determining optimal production quantities and product pricing. Their role is pivotal in shaping supply chain dynamics, as they influence the equilibrium price for UAV products. The manufacturer's supply curve is influenced by the elasticity of production costs. An increase in the supply in UAV production results in higher production costs, affected by factors such as limited inputs (e.g., UAV components and skilled labor).

NGOs

NGOs collect information about the needs of conscripts and inform the civilian community of their needs, purchase goods from manufacturers and deliver them to the military. NGOs determine the volume of shipments based on the conscripts' needs, the manufacturer's price for the product, which they agree upon for the transactions

to take place, and the financial capacity of the community to be donors.

Conscripts

On February 24, 2022, a Presidential Decree declared a general mobilization in Ukraine summoning all military-eligible men, reservists, and conscripts capable of serving based on their health condition to join the armed forces (Presidential Decree, 2022). A part of the Armed Forces of Ukraine consists of men without prior combat experience – conscripts. We examine a scenario in which conscripts were already members of a particular NGO before the onset of Russia's invasion. Positioned as the ultimate consumers in our study, conscripts generate the demand for UAVs based on their military needs. It is important to note that 77% of all NGOs in Ukraine are currently engaged in providing assistance to the Armed Forces (ISAR Ednannia, 2023).

Donors

The process of crowdfunding donations for Ukraine involves leveraging social media platforms such as X (formally Twitter), Facebook, Instagram, and YouTube (Ye et al, 2023). Online channels, facilitated by these platforms, play a crucial role in mobilizing donors for collective action. Donors' financial capacity and relationship proximity with conscripts influence the volume of their contributions, providing an alternative source of income to government funds.

Multi-Level Structure of the Defense Supply Chain Network Model

The defense supply chain model operates on three levels: logistical, informational, and financial (Figure 1).

Logistical Network

- Manufacturers (Top Tier): Producers (m) of UAVs, determining production quantities.
- NGOs (Middle Tier): Intermediaries (n) distributing UAVs to conscripts based on their needs.
- Conscripts (Bottom Tier): End-users (o) with specific affiliations to NGOs, influencing the flow of goods.

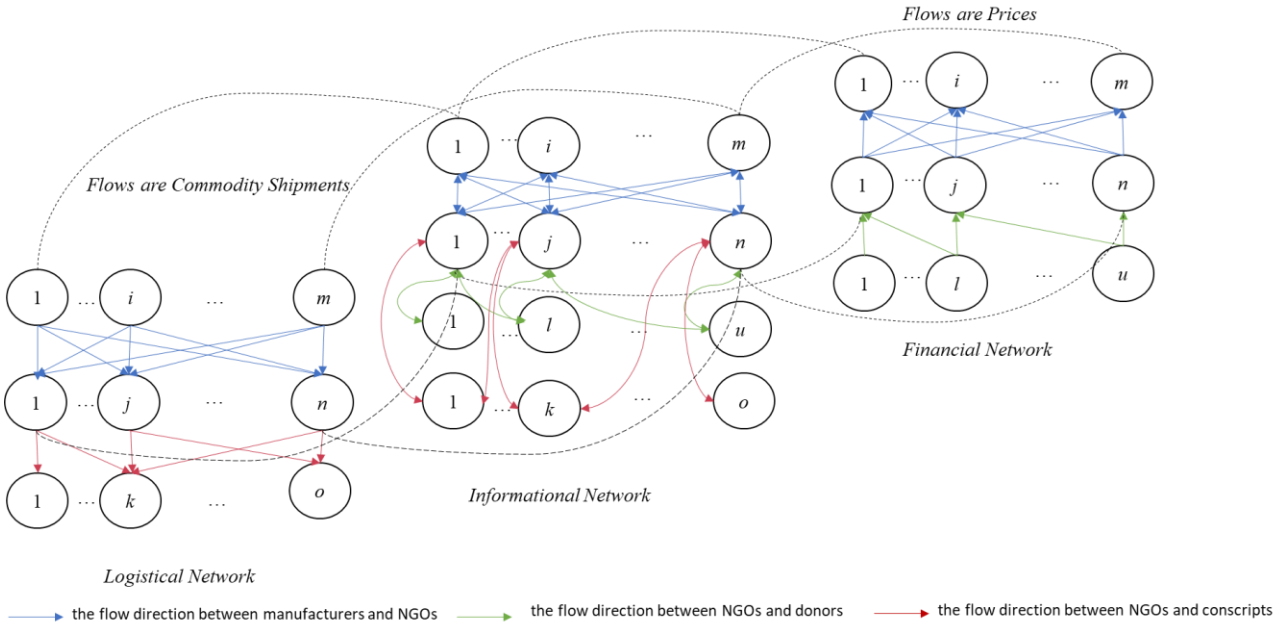

Figure 1. Multi-Level Structure of The Defense Supply Chain Network Model

The logistical network exhibits a downstream flow, starting from manufacturers down to NGOs and ultimately reaching specific conscripts. The flow is contingent on the density of ties between NGOs and conscripts, emphasizing the network's dependence on affiliations.

Informational Network

- Manufacturers (Top Tier): Provide information on prices and quantities of UAVs to NGOs.
- NGOs (Top-Middle Tier): Disseminate conscripts' needs to the civilian community, announce

crowdfunding in local network.
- Donors (Bottom-Middle Tier): Included as an additional level in the information network (u), contribute financial resources based on conscripts' needs announced by NGOs.
- Conscripts (Bottom Tier): Share information about their needs within NGOs' network.

The bidirectional movement of information involves data about commodity shipment quantities and prices, establishing transparency and connectivity within the network.

Financial Network

- Manufacturers (Top Tier): Announce price of UAVs based on costs and availability of goods.
- NGOs (Middle Tier): Facilitate financial transactions by channelling donor contributions to manufacturers.
- Donors (Bottom Tier): Drive purchases by contributing financial resources based on their financial capacity. Donors' income is generated from different sources usually outside the conduct of military operations. The part of income Ukrainian civilians donate regularly for support of an army. A change in income affects the movement of the demand curve.

The upward flow in the financial network reflects a scenario where civilian donors influence purchases through their willingness to contribute, thus driving the financial aspects of the supply chain.

METHOD

To analyze the roles played by key actors and vulnerabilities of the defense supply chain, we use analysed NGO reports and conducted interviews. Quantitative data are obtained from reports issued by the two foremost civilian funds in Ukraine which actively support the Ukrainian military and uphold a commitment to transparent reporting practices – the Serhiy Prytula Foundation, and the "Come Back Alive" Foundation. Concurrently, qualitative insights are garnered through thorough interviews conducted with pivotal stakeholders, encompassing representatives from manufacturing entities, NGOs, and military personnel. These interviews yield nuanced perspectives on decision-making processes, information flow, resource allocation mechanisms, and crucially, the challenges encountered within the defense supply chains.

The methods employed in the research present several limitations that could impact the result. In the context of an ongoing war, the exchange of sensitive information exposes the involved parties to security risks. The interviews were conducted during the summer of 2023. While this timeframe provides valuable insights into the dynamics of the defense supply chain at a specific point in time, it may not reflect changes or developments that occurred before or after the interviews. The ongoing nature of the conflict and the evolving geopolitical situation could influence the effectiveness of the supply chain over time.

The data obtained from reports issued by civilian funds provide valuable information about the flow of goods within the defense supply chain. The "Come Back Alive" Foundation and the Serhiy Prytula Foundation received approximately $286 million USD and $16 million USD respectively in donations between February 2022 and December 2023. However, the scope of these reports may be limited, and they may not capture all relevant aspects of supply chain dynamics.

Despite the limitations outlined in the study, we consider its results valuable. Particularly significant is the portrayal of the ongoing war situation, which can serve as a crucial checkpoint for assessing the broader landscape and dynamics of the conflict. Direct engagement with respondents enabled the establishment of trust and dialogue, enhancing the depth of the findings. Moreover, by using participatory research practices we deem the information valid (Cornwall et al., 1995). One author is in Ukraine, and able to observe the described situation firsthand.

Interviews

To identify connections among actors in the defense supply chain, we conducted interviews. Nine military personnel, three NGO representatives, and one manufacturer were interviewed to gather diverse perspectives on the interactions within the defense network.

The participants included a Ukrainian manufacturer specializing in UAV production. The NGOs selected represented different scales of operation: a nationwide organization, and two local organizations from Lviv and Lutsk (cities in Western Ukraine). These organizations varied in terms of size, annual budget, and the number of members and volunteers in their networks. It is worth noting that all the organizations involved in this study were established prior to 2022, and their primary activities are distinctly different from humanitarian or military operations. Rather, their primary focus is in areas such as education and cultural youth activities (Table 1).

The interviews delved into the methods used by these organizations to disseminate information about the needs of their members, their fundraising strategies, and timelines for collecting and fulfilling those needs.

In addition to inquiring about organizational characteristics and information dissemination strategies, the research methodology encompassed detailed investigations into the types of goods handled by the organizations and the frequency of both receiving and distributing these goods to the military.

Table 1. Characteristics of NGOs Interviewed

	Primary activities	Members	Annual Turnover	Conscripts Supported	Categories of Goods	Source of Funding
Nationwide organization	Education	100-250	Medium (8-40M EUR)	10-50	UAVs, Vehicles, Clothes	International donations, Members' donations
Local NGO (Lviv)	Human Rights	50-100	Small (less 8M EURO)	Less 10	UAVs, Vehicles, Medical supplies	Members' donations
Local NGO (Lutsk)	Youth	less 50	Micro (less 700K EURO)	Less 10	UAVs, Vehicles	Charity Events

Questions addressed organizational membership, categories of goods handled, frequency of transactions, funding sources, storage facilities utilization, duration of processes from need identification to fulfillment, and collaborative partnerships.

The analysis involved synthesizing data from reports with qualitative insights gathered from interviews to understand the interconnectedness and dynamics of the defense supply chain. Findings from both report analyses and interviews were used to draw conclusions and develop recommendations regarding the optimization of the defense supply chain in Ukraine.

FINDINGS

Product Analysis in Defense Supply Chain

In Ukraine, three platforms play a crucial role in supporting the Ukrainian military: the state platform UNITED24, the Serhiy Prytula Foundation, and the "Come Back Alive" Foundation. Notably, UNITED24 serves as a fundraising platform rather than a foundation, channeling contributions directly to relevant ministries, including the Ministry of Defense. The platform has raised $504 million USD in donations from the onset of the conflict until December 2023 (UNITED24, 2023).

The "Come Back Alive" Foundation, operational since 2014, focuses on enhancing the effectiveness of the Ukrainian Defense Forces by procuring equipment such as thermal optics, drones, vehicles, and surveillance systems. The "Come Back Alive" Foundation, received 2,898,936 contributions from February 2022 to December 2023, averaging $100 USD each, with 96% of donations by count and 35% by total amount below $1,000 USD (Come Back Alive, 2023).

The Serhiy Pritula Foundation, established in 2020 in Kyiv, garnered over $16 million USD in donations since the onset of the war, with an average individual contribution of $10 USD. 75% of donations fall within the $1,000 USD range (Serhiy Prytula Foundation, 2023)

Each foundation exhibits unique characteristics in its operations. The "Come Back Alive" Foundation is authorized to allocate funds for weaponry (constituting 20% of its acquisitions) and collaborates with the Ministry of Defense to determine military needs. Additionally, it engages in analytical research that influences nationwide defense decisions and implements projects focused on veteran rehabilitation.

To request assistance for a military unit from the Sergiy Prytula Foundation, an official request must be submitted on the website prytulafoundation.org with the commander's signature and stamp. The foundation then goes through the bureaucratic process, checking for the presence of the stamp and verifying whether individuals are genuinely part of the specified unit. The main challenge arises from the overwhelming number of requests, exceeding the foundation's capacity to fulfill physically (44%). Prioritization becomes necessary based on the unit's location, the tasks it performs, checks on whether aid has been received from other foundations.

Despite variations in reporting practices, our attempt to compare the categories of goods procured by these foundations from January to November 2023 reveals some trends (Figure 2). One notable observation in the foundation reports is the presence of two distinct categories – quadcopters and Unmanned Aerial Vehicles (UAVs), although theoretically, a quadcopter is a type of UAV. Typical quadcopters include the Autel Drone EVO Nano+ and the DJI Mavic 3 Enterprise. UAVs procured by the foundations encompass models such as Leleki, Furii, Valkyrii, among others, each serving diverse military purposes.

Of noteworthy interest, 53% of all acquisitions from the Serhiy Prytula Foundation are comprised of purchases of UAVs and quadcopters (22% and 37% respectively of total acquisitions). In contrast, only 14% of "Come Back Alive" Foundation's acquisitions were UAVs and quadcopters (2% and 12% respectively.

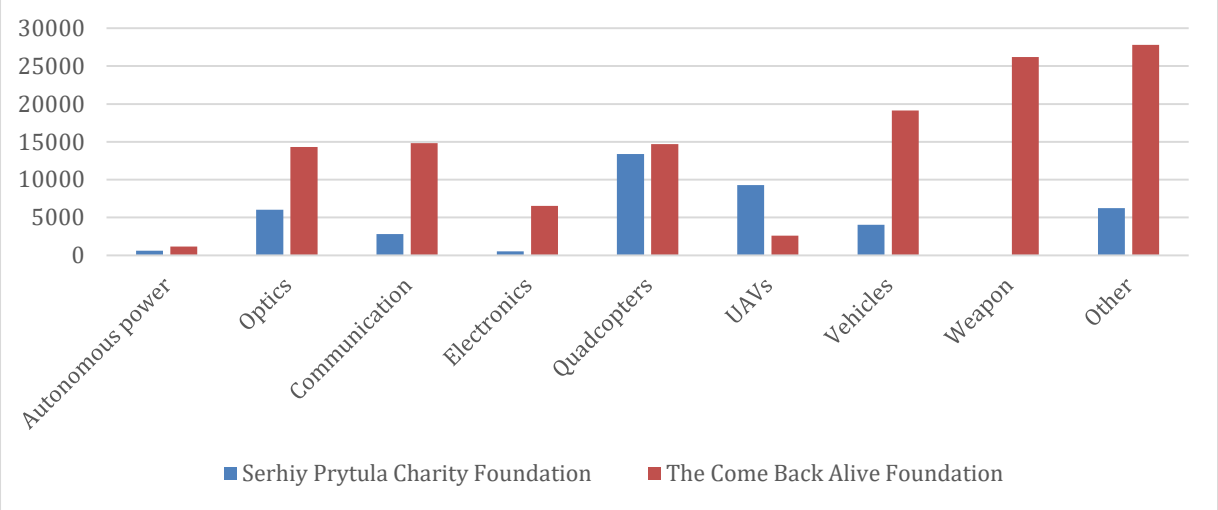

Figure 2. Procurements by Ukrainian foundations during January to November 2023, in thousands of USD

All three organizations interviewed engaged in the collection of funds for UAVs. In addition, one organization also participated in the distribution of medical supplies and another in the distribution of military clothing.

In interviews with military personnel, an additional layer of complexity was uncovered within the defense supply chain. It was revealed that the distribution of needs among military units was not uniform, and this uneven distribution was closely tied to the affiliation of unit members with various civilian networks. The research identified a distinctive pattern wherein the preferences and necessities of military units were intricately linked to their connections within different civilian networks.

An interesting observation emerged: there was a lack of expressed need for food among the military personnel interviewed. Instead, a consistent trend was identified – each individual, regardless of their specific military function, demonstrated a shared experience in expressing the need for fundraising in support of drones and transportation.

Furthermore, military personnel, upon identifying a need, would often use personal savings to fulfill that need before publicly announcing a fundraising campaign within their network of donors. This practice aimed to expedite the satisfaction of requirements by leveraging personal resources before engaging external support networks.

The study also revealed a distinct temporal aspect to the process, with the timeframe for closing requests identified needs ranging from one to three months. This finding shed light on the urgency and efficiency of the defense supply chain in responding to the evolving needs of military units. The dynamic nature of these timelines highlights the adaptability of both the military and the civilian support networks in navigating the challenges posed by the ongoing conflict.

This understanding of the non-uniform distribution of needs, coupled with the intricacies of timing and self-reliance within the military units, contributes valuable insights into the internal dynamics of the defense supply chain and further informs the overarching analysis of the defense supply network. Both report analyses and interviews revealed that UAVs were the most requested item within the defense supply chain; thus, we ground our analyses and discussion around this significant product.

DISCUSSION

Examining the intricacies of the defense supply chain model, we identify key vulnerabilities: network structure vulnerabilities, logistics gap vulnerabilities and financial vulnerability.

Network Structure Vulnerabilities

Non-All-to-All Connections. The defense supply chain operates with a multi-level structure, featuring manufacturers, NGOs, donors, and conscripts. However, the network structure is not an all-to-all connection. This creates challenges in the efficient distribution of information and resources, resulting in a leaky network where gaps in communication and coordination can emerge. Among NGOs, 16,8% continuously involve other NGOs in cooperation after the large-scale invasion and 42,4% in situational project partnerships (ISAR Ednannia, 2023).

Difficulty in Information Flow. The non-all-to-all connection structure makes it challenging to distribute information effectively. This difficulty arises from the fact that a single NGO can assist multiple members, and a recipient can receive aid from various public organizations. The lack of direct connections between all actors hinders seamless information flow, potentially leading to delays and inefficiencies in the supply chain.

Intermediaries as Necessity. To address these challenges, intermediaries become crucial to connect NGOs with one another. Establishing efficient communication and reinforcing networks require that these intermediaries facilitate the exchange of information and resources. Identifying and leveraging influential actors becomes essential for enhancing connectivity within the network.

Logistics Gap Vulnerabilities

Under-Responsiveness. The defense supply chain is vulnerable to under-responsiveness, especially in scenarios where the logistics network fails to provide the right mix of resources at the right place and time. This under-responsiveness results in a gap between the available and required logistic resources, impacting the effectiveness of combat operations.

Cumulative Shortfalls. Shortfalls in resource availability accumulate over time, leading to a widening logistics gap. If under-responsiveness persists, this gap can reach a critical point known as the logistic culmination point. Beyond this point, combat operations cannot be executed as planned, and the effectiveness of military endeavors decreases significantly.

Financial Vulnerability

Funding is essential to NGOs engaged in humanitarian operations and, for many such organizations, securing financial donations is critical to their very sustainability (cf. Toyasaki and Wakolbinger (2014), Nagurney et al. (2018), Nagurney, Salarpour, and Daniele (2019)).

The financial vulnerability of the supply chain is intricately linked to the absolute inelastic demand for military goods, particularly for UAVs. With a price elasticity of zero, changes in the product price do not influence the quantity demanded. The demand function, dependent on conscript needs and donors' income, shapes the dynamics. Conscript needs, influenced by attrition and battlefield consumption, are crucial determinants.

The financial vulnerability arises when the demand surpasses the available supply, triggering an increase in price and production volume. However, internal constraints also exist, demanding a simultaneous growth in donor incomes. If donor incomes stagnate while needs rise, a temporary surge in demand occurs, escalating prices and reducing donor incomes even further. Similarly, if needs outpace declining donor incomes, sustained demand necessitates even higher donor income growth, highlighting the delicate financial equilibrium within the civilian-military supply chain.

Resilience in the Defense Supply Chain

The vulnerabilities in the defense supply chain are rooted in the network structure's complexity, the financial vulnerability, and the potential for under-responsiveness, leading to a logistics gap. Addressing these vulnerabilities requires a focus on strengthening connections, leveraging intermediaries, supporting income growth for donors, and ensuring the adaptability of the logistics system to maintain a responsive and resilient supply chain (Figure 3).

Communication line for NGOs. Efficient communication and network reinforcement require intermediaries to connect NGOs with one another. Identifying influential actors helps to pinpoint organizations that can serve as

effective mediators in the network.

Donor Income Growth. In the realm of financial vulnerability, resilience hinges on the crucial alignment of donor income growth with the escalating prices for resources and demand. The financial network highlights the pivotal connection between donor income and the demand functions, emphasizing the need for a symbiotic relationship where increased demand and prices stimulate growth in donor incomes.

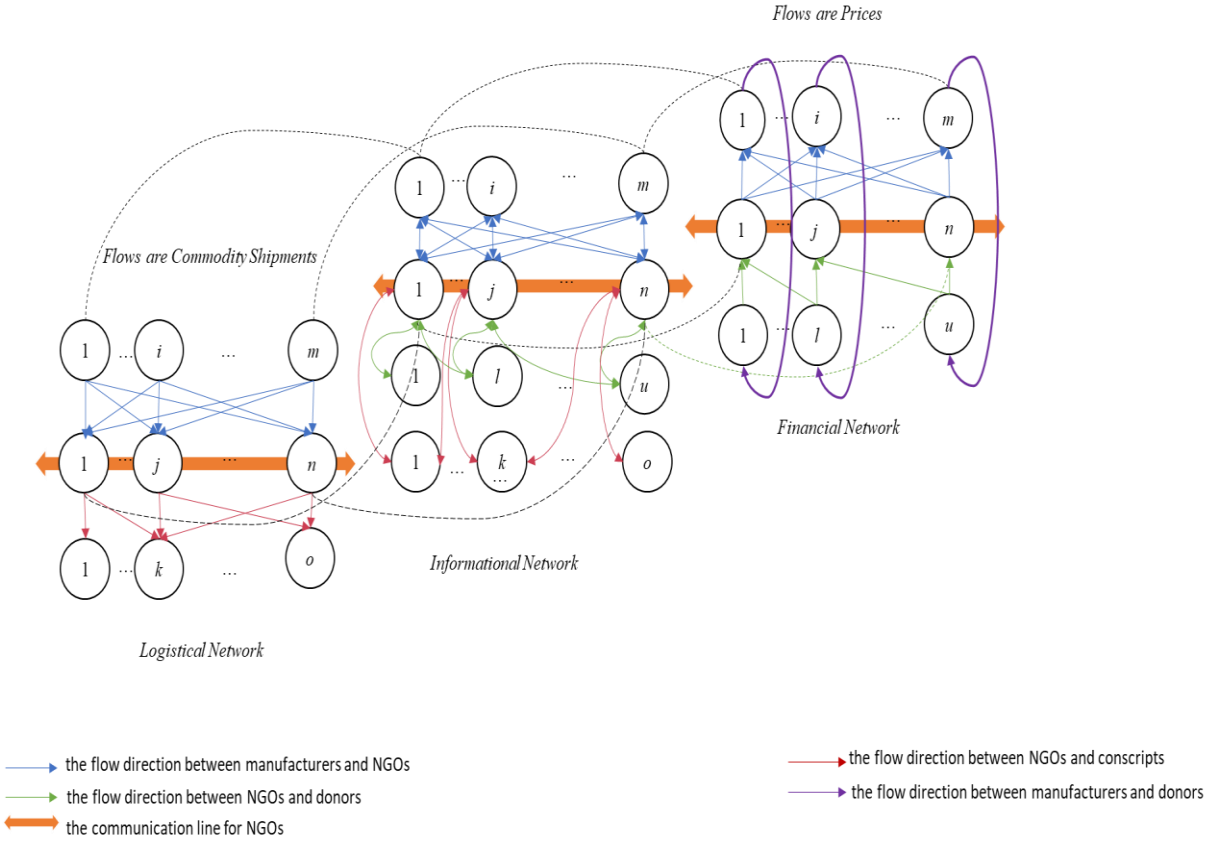

Figure 3. Resilient Defense Supply Chain Model

A noteworthy facet of resiliency involves donors working with the same manufacturers that produce the needed goods, such as UAVs. Procurements by Ukrainian foundations during the war are noteworthy for their sources of origin. For instance, UAVs Leleki, Furii, and Valkyrii are manufactured by Ukrainian companies, while quadcopters Autel and Mavic are of Chinese origin. It is important to mention that in Ukraine, approximately 200 drone manufacturers produce various types of drones, but, these manufacturers often rely on components from Chinese production (Balashova & Melnyk, 2023). In this dynamic, when donors obtain income from external sources, they contribute an amount equivalent to what is accessible as donations. However, as prices rise, their donations decrease, creating a delicate equilibrium between sustaining demand, prices, and donor incomes. The resilient defense supply chain underscores the imperative of directing financial resources towards Ukraine's military-industrial complex. This strategic allocation ensures stability through consistent salaries for the Ukrainian population.

CONCLUSION

We set out to answer the question: To what extent is the defense supply system in Ukraine vulnerable, and how can it be enhanced to bolster resilience? To answer this question, we used three objectives. Beginning with Objective 1 we described and visualized the structure of the defense supply chain in the Russian-Ukrainian war (Figure 3). The multilevel defense supply chain developed provided insight regarding key actors and illuminated their interactions within the supply chain, spanning logistical, informational, and financial dimensions (Objective 2). Our analysis revealed the pivotal roles played by manufacturers, NGOs, donors, and conscripts in sustaining the defense supply chain. By employing both quantitative data from reputable civilian funds and qualitative insights from interviews with key stakeholders, we gained an understanding of the dynamics at play. Finally in our third objective, we sought to investigate the vulnerabilities of a defines supply chain. Our investigation

identified several vulnerabilities including network structure complexities, logistics gaps, and financial fragilities. These vulnerabilities underscore the need for strategic interventions aimed at strengthening connections, leveraging civilian intermediaries, and ensuring the adaptability of the logistics system.

Importantly, our study emphasizes the importance of civilian-military integration in bolstering a nation's military capabilities. By recognizing civilians as active contributors to the defense supply chain, rather than mere recipients of aid, we advocate for a more unified approach that maximizes resources and enhances overall effectiveness.

Moving forward, addressing the identified vulnerabilities will be crucial for enhancing Ukraine's defense resilience. By channeling financial resources into the military-industrial complex and promoting collaboration between civilian and military entities, Ukraine can build a more robust defense supply system capable of effectively responding to evolving challenges and safeguarding its sovereignty.

As further work, we aim to expand our focus to encompass the development of an information network for interaction initiatives within the defense supply chain, represented by NGOs. By examining the interdependence between the flow of goods and the density of connections among NGOs, we seek to identify opportunities for enhancing efficiency, mitigating risks, and improving coordination within the defense supply chain. By undertaking these additional research efforts, we aim to deepen our understanding and identify practical measures to address vulnerabilities and enhance the resilience of the supply chain.

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