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Characterizing the defense industry for risk management: a systems approach

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Abstract

Purpose – Management and risk techniques within industries have been studied from various disciplines in nondefense-affiliated industries. Given the assumption that these techniques, strategies and mitigations used in one industry apply to other similar industries, this paper examines the defense industry for risk assessment. We characterize interactions for onward application to risk identification in the defense industry.

Design/methodology/approach – This research employs a systems theory approach to the characterization of industry interactions, using three dimensions including environment, boundaries and relationships. It develops a framework for identifying relationship types within system-of-systems (SoS) environments by analyzing the features of interactions that occur in such environments.

Findings – The study's findings show that different systems environments within the defense industry SoS exhibit different interaction characteristics and hence display different relationship patterns, which can indicate potential vulnerabilities.

Research limitations/implications – By employing interaction as a means for evaluating potential risks, this research emphasizes the role played by relationship factors in reducing perceived risks and simultaneously increasing trust.

Originality/value – This paper intends to develop an initial snapshot of the relationship status of the Swedish defense industry in light of the global consolidation in this industry, which is a relevant contextual contribution.

Keywords Risk management, Supply chain systems, Interaction, Relationship, Defense industry characteristics, System-of-systems (SoS)

Paper type Research paper

1. Introduction

Risk management techniques in supply chain management have been studied from a variety of disciplines in the non-defense industries (Chapman *et al.*, 2002; Harland *et al.*, 2003; Hauser, 2003; Svensson, 2003; Christopher and Peck, 2004; Jüttner, 2005; Peck, 2005; Ho *et al.*, 2015). The general notion within literature has been that, given the similarities in the activities of these industries (e.g. manufacturing, services, trading), risk management and mitigation techniques applied in one industry apply to other industries with which it shares similar characteristics. Within contemporary supply chain management research, this view remains dominant with minor exceptions, as evidenced by the fact that there is sparse material dealing with risk mitigation techniques developed specifically for critical and distinctive industries such as the defense industry. The practice of generalizing risk mitigation

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strategies in non-defense industries has been further extended to the defense industry. This is because industry supply chains are thought to be similar, and as such should be treated equally regarding risk and mitigation, as argued by Jarret (1998).

The "defense sector" includes the defense industry as well as the agencies, institutions and organizations with responsibilities related to national defense. Karabag *et al.* (2016) define the defense industry as "... public organizations and private firms involved in research, development, production, and service of military materiel, equipment, and facilities". Supplies such as fuel, medical supplies and food are not included in the defense industry, although the defense sector buys and uses these types of goods and services. The defense industry manufactures, for example, weapon systems, ammunition for military use and encryption and communications equipment. However, the consolidation of the global defense industry over the last twenty years has accelerated the shift in ownership from publicly managed entities to privately held companies (e.g. Ikegami, 2013 for the Swedish case). Today, only a few defense industry organizations around the world can truly be described as national. In this paper, we focus on the defense industry represented by the collection of organizations located, registered and undertaking defense industry activities within Swedish borders. While this implies that defense supply chains become more "similar" to supply chains of firms in other manufacturing sectors, we argue that the industry and its relationships with host nation armed forces and governments are unique and present distinctive challenges to risk management and the performance of its supply chains. Furthermore, because Swedish defense had always been pro-Swedish as preferred customers based on trust and commitment (e.g. Glas, 2017), gradual changes in ownership over the last two decades have also brought changes to the conditions of engagement, on both sides of the aisle and the future of the Swedish defense industry (e.g. Lundmark, 2019). The manufacturing and trade of defense equipment are governed by an extensive national and international regulatory framework that influences how the parties in the supply chain may interact with each other (Hellberg, 2023).

In light of the challenges inherent in the contemporary business environment, there exists a renewed imperative to comprehend the impact of continuously evolving industry structures on the sector. This necessitates a focused examination of the industry's present operational methodologies, its intricate network of interactions and relationships with the prevailing external environment, its customer base encompassing the Swedish clientele and the prospective risks inherent in the supply chains that serve the industry.

The purpose of this article is to examine the current and evolving features of the Swedish defense industry, taking into account the impact on risk perception within the sector since the business was deregulated approximately 20 years ago. The article is based on the systems perspective and applies data from the industry in this regard for risk assessment. Few papers have sought to investigate the specific emerging realities within the Swedish defense industry in light of its gradual but focused privatization over the years, using industry data. This focus on temporal differences is useful and can reveal differences in supply chain relations, structure, operations and consequently risks. This research makes three major contributions. First, it provides a view into the emerging structure of the Swedish defense industry, in light of the global changes over the last two decades. Second, it analyses defense supply chain systems by identifying and characterizing interactions along the defense supply chains, which is valuable for identifying relationship types and potential areas of vulnerability. Third, it uses empirical data to demonstrate ongoing challenges in areas such as sourcing, design and maintenance.

The paper is structured into five main sections. The next section presents and discusses the method and the data collection process for this research. Section 3 presents supply chain risk analyses from a systems and system-of-systems (SoS) perspective. Section 4 presents findings from semi-structured interviews with prominent actors within the Swedish defense industry. Section 5 briefly discusses the findings and conclusions are drawn.

2. Method and data collection

This study investigates the prevailing characteristics of the Swedish defense industry for a better understanding of risk within this industry. Risk and risk management in defense supply chains are considered from a systems perspective, where customers and suppliers along the supply chain constitute a system, which in turn consists of several influencing subsystems. The study is divided into two parts. The first part is based on the results of interviews undertaken across participating firms and used to develop insight into the broader features of the evolving industry. Features are operationalized via the structure of the industry, processes and procedures, product development, regulation and maintenance. The second part draws on the systems interaction theory (SINT) (Alter, 2018) for a closer analysis of relations, communication and integration between systems, thus arguing for the need to go beyond the analysis of systems in isolation. Alter (2018) defines interaction as specific occurrences, impacts, or influences through which one entity affects another, or where two or more entities affect one another. The former is a one-way interaction, while the latter is a two-way or multi-directional interaction. Results are also presented along these method lines.

The literature on SoS motivates this analysis of the defense industry. SINT is adopted in this study because it is particularly suited to the analysis of risk due to complex, SoS interface issues. The analysis views the defense industry as interacting systems of "a market" and it's supporting "supply chain". This leads to a framework for the characterization of risk in defense industry relationships focused on four dimensions: structure, processes and procedures, product type and regulation. A fundamental characteristic of the defense industry is its impervious nature, where many processes are classified or obscured. The typologies of SINT are useful in analyzing data from literature and interviews in this setting where there is limited specific knowledge about the processes within subsystems and relationships between subsystems.

The risk characterization framework is supported by data from 20 semi-structured interviews with individuals from 4 firms. The interviews, conducted in 2022, ranged from 60–90 min and were part of a larger research project for the Swedish defense industry. Given their responsibility areas, participants possessed extensive knowledge of their organizations and their relationships with stakeholders. We asked interviewees questions concerning their companies' business and operations and the status of their firm's business relationships with industry stakeholders including customers. These questions focus on current risks experienced in the industry. All interviews were performed in person and recorded. Responses from the interviews were interpreted with an emphasis on understanding and sense-making, as opposed to explanation (Given, 2008; Gummesson, 2003).

3. Risk: a system-of-systems perspective

3.1 Risk in supply chain systems

Risk is generally described as the probability of an undesirable event occurring or the probability of variance in an expected outcome (Spekman and Davis, 2004). Christopher and Peck (2004) define risk as the likelihood of damage or loss to the supply chain. Based on this definition, Christopher and Peck (2004) identify three sources of risk to supply chains.

First, internal risk sources refer to, for example: inaccurate forecasting, the invisibility of ownership and misapplication of the just-in-time (JIT) strategy (Chapman *et al.*, 2002). Second, external risk sources concern demand and supply risks (e.g. Zsidisin *et al.*, 2000; Svensson, 2002). Lastly, environmental risk sources include political situations and social unrest (e.g. Jüttner, 2005). Also, identifying three sources of supply chain risk as environmental, network and organizational, Jüttner *et al.* (2003) define supply chain risk as "... the variations in the distribution of possible supply chain outcomes, their likelihood and their subjective values". In this regard, Jüttner (2005) also describes risk as "... any variable which cannot be predicted with a certainty and from which disruptions can emerge".

Supply chain literature often emphasizes the description of supply chains as a single entity, i.e. as single extended enterprises from the sourcing of raw materials to the ultimate end customer (e.g. Spekman and Davis, 2004). Systems analysis presents a methodology for condensing the complexity of a supply chain into a more manageable hierarchical form for risk analysis.

Systems literature, however, addresses risk from two main perspectives. For example, Schweizer (2021) distinguishes between two main risk approaches from a systems perspective. Conventional risks, also known as complicated risks, are risks that can be contained in time and space, following a linear cause-effect relationship and can be dealt with by making effective and targeted interventions into the cause-and-effect chain. Systemic risks, also known as complex risks, are characterized by their high complexity, transboundary effects, stochastic relationships, nonlinear cause-effect patterns and tipping points. Thus, complicated systems allow for the identification of cause-effect relationships between objects or parts of the system in advance of the risk event occurrence. Complications arising from intricate risks entail a discernible relationship between cause and effect that becomes apparent only after the occurrence of the risk event (Snowden and Boone, 2007).

3.2 A system-of-systems perspective

In analyzing industries for business performance, two broad systems perspectives may be considered. The first perspective is embodied within the general system theory (GST) (von Bertalanffy, 1968). From a GST perspective, systems are characterized by the interactions of their components and the nonlinearity of those interactions. Von Bertalanffy (1968) proposes that systems share some basic organizing principles irrespective of their purpose and that these principles may be modeled mathematically. It presents a way of looking at the world, one in which objects are essentially interconnected, to construct universally applicable concepts, hypotheses, principles and derived propositions (Whitchurch and Constantine, 2009). As such, the underlying interest of GST is in the structure, make-up and inter-relationship between elements of the system, including its subsystems. Discussing its applications to supply chain management, Yourdon (1989) identified four general systems theory principles as follows: (1) As systems become more specialized or complex, they become less adaptable to changing environments. (2) As systems grow larger, more resources are required to support that system, including its nonlinear increase. (3) Systems often contain other systems and are themselves components of larger systems. (4) Systems grow, creating observable implications for principle 2, i.e. more resources and support to the system.

A second viewpoint is an approach to systems analysis in which systems primarily function as a set of interacting elements that form an integrated whole to perform some function or generate some outcome (e.g. Bailey, 1983, 1994; Skyttner, 1996, 2001). The systemic approach is more interested in the results that the collection of system interaction produces, rather than the identification of the detailed nature of relationships among components within the GST. Thus, while both approaches to systems analysis remain complementary, by their definition, they also act as standalone concepts given their focus on different aspects of systems.

Systems theory allows for a model of the extended system known as the supply chain that contains diverse subsystems that enable the functions of the entire system. Thus, according to this theory, supply chain management cannot be understood in isolation from its constituent subsystems or its greater environment (e.g. Ackoff, 1994; Checkland, 1999). According to Alter (2018), system interactions are crucial for the functioning of organizations, enterprises, or IT-reliant systems. In this setting, SINT uses work systems as its basic analysis unit. SINT embodies the beneficial recurrent events of essential system interactions on the one hand, while also dealing with detrimental system conflicts and inefficient interactions on the other. Sociotechnical work systems are those systems in which humans participate in the performance of tasks in the work system, while all tasks within an automated work system are performed by machines. Sociotechnical systems acknowledge the need for joint optimization of social (people) and technical (machine) elements within systems to optimize performance (e.g. de Bruijn and Herder, 2009). As such, supply chains are seen as sociotechnical systems, because they comprise physical and social linkages that are collectively required to form a work system.

Here, we divide the industry supply chain and its interactions into two main systems: the supply chain system and the market system: (1) The *supply chain system* creates value in terms of goods and services to the ultimate customer. It includes all upstream and downstream strategies, decisions and policies; and (2) the *market system* embodies organizing mechanisms that bring production systems into balance with the demand for goods and services including the uptake of production. Shortcomings in this mechanism might affect the efficiency or fundamental operation of the market. Because systems exist to serve other systems (e.g. Ackoff, 1994; Checkland, 1999), it is critical for risk analysis to identify what systems are in play within the defense industry, understand what systems are being served and how those service systems are themselves being served. For this paper, both descriptions of systems proposed above are used to classify the objects that comprise the supply chain and market as systems. From a functional standpoint, objects make up the fundamental operations of the system and constitute three main parts; input, processes and output (e.g. Schoderbek *et al.*, 1985). Relationships here refer to the bonds that tie the system objects together, while attributes are essentially the characteristics (properties) of the system objects and the system relationships. Finally, environment refers to all entities that lie outside the system: A change in the environment can produce a change in the system, e.g. by affecting the performance of the system (Schoderbek *et al.*, 1985; Ackoff, 1971). Systems can take several forms; they can be closed, open, soft, or hard. Open systems transform inputs received from their environment before returning the resulting output to the environment (Jackson, 2003). Consequently, they are dependent on the environment, self-regulating and organized by information flow and use (Skyttner, 1996). Closed systems do not engage in exchanges with their environment. Boundaries are used to distinguish between hard and soft systems. The boundaries of soft systems are described as hazy, formless and generally organized to support their own goals (Siriram, 2011), using feedback mechanisms to facilitate objective-seeking behavior (Blanchard and Fabrycky, 2006) which might require human intervention. Hard systems are based on four fundamental assumptions (Simon, 1977; Siriram, 2011): (1) A clearly defined problem; (2) A problem that can be represented quantitatively by a model; (3) A problem that is embedded in a system regarded as purposeful; and (4) The system containing the problem is nearly decomposable. In this way, understanding of supply chain management and logistics concepts can be grounded in systems theory which can describe how value, total cost, optimization and related issues are integrated into the overall supply chain (e.g. Bechtel and Jayaram, 1997; Grant *et al.*, 2005).

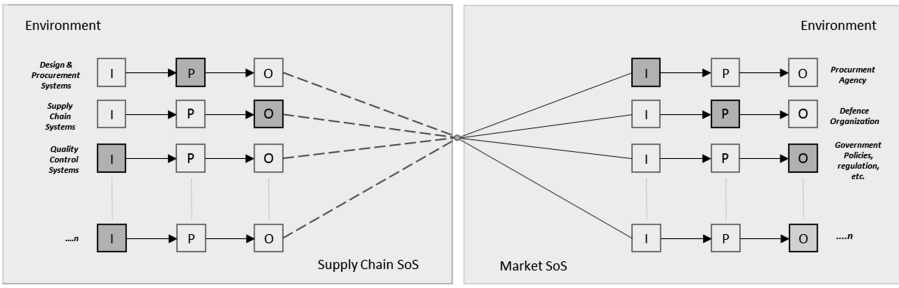
Supply chains involve numerous independent systems that are all, in some way, interdependent. As a result, a supply chain can be viewed as a SoS that has the qualities of being networked, fully integrated and made up of autonomous, independent entities (e.g. Boardman and Sauser, 2008). The level of operational and managerial independence of SoS systems are some of its crucial characteristics, where independence refers to the ability of the system to decide when and how to use its capabilities (e.g. Boardman and Sauser, 2006; Axelsson and Svenson, 2022). While systems within a SoS are diverse and contribute to the functioning of the SoS, contextualizing risks within the supply chain SoS network can provide different perspectives, which go beyond the typical linear cause-effect relationship conceptualization of risk (Schweizer *et al.*, 2022). These varied contributions can be characterized by unpredictable results or circumstances.

Boardman and Sauser (2006) identify five elements of a SoS. First, is autonomy, a feature where a SoS is free to pursue its intended purpose. Autonomy distinguishes between integral parts of a system and the autonomous system in its entirety. For example, the brakes of a car form part of the vehicular system and not a system of its own. Second, belonging, which maintains that component systems choose to belong to an SoS on a cost-benefit basis as well as for the greater fulfillment of their purpose. Third, is connectivity, which provides linkages between parts, elements, or subsystems. Fourth, because diversity may be essential for the sustenance of component systems of SoS, diversity is maintained by ensuring autonomy, dedicated belonging and open connectivity. Fifth, emergence, a property that characterizes the output or behavior of the SoS as difficult to pre-determine or restrict to outcomes that can be foreseen or deliberately designed.

Based on the preceding ephemeral overview of systems, a conceptual relationship is ascertained between the supply chain and market systems, and in so doing we establish the basis upon which differential characteristics of the different supply chains are investigated. Figure 1 depicts a conceptualization of a defense industry supply chain SoSs, divided into the supply chain and market system. This is based on the idea that supply chain systems, using input from and supported by processes from other constituent systems, develop output. This output is in turn used as input by other systems such as the market system.

4. Interview results, findings and interaction

The interviews involved open-ended questions to investigate the nature of the activities within the industry as well as the firm's relationships with its clients, customers and suppliers. The approach to analysis is interpretive and allows for the assessment of reality from the interviewee's perspective (Clark *et al.*, 2010), making its findings inductive and capable of supporting theory extension (Stake, 1995). We use Ind. 1, through Ind. 4 to identify the four organizations involved in the data collection process. The responses are organized into five characteristic areas: (1) structure, (2) process and procedures, (3) product development, (4) regulation, and (5) maintenance and upgrades. The first four were planned as part of the interview process. We chose to add the fifth area, maintenance and upgrades, based on interviewees' suggestions.



Source(s): Figure by authors

Figure 1. Schematic of industry system of systems (SoS) supply chain

4.1 Structure; the rising role of the intermediary in the market

In today's defense marketplace, state-affiliated and independent defense industry actors are required to seek financing to fund research and development programs. Organizations that cannot afford to develop new equipment end up as systems integrators of original equipment manufacturer (OEM) components. The Swedish defense industry is contract-driven and as such, there is no incentive to develop new, more sophisticated weapons systems or platforms.

> We never start the development of new products without a specific client specifying the product's desired capabilities. This means that our business is entirely contract-based. (Ind. 2)

The pull system, via a Just-in-time strategy, prevails in the industry where nothing is produced without a customer order.

> We never purchase materials and components for manufacturing without an underlying contract, i.e. we do not have any stocks of either materials or finished products. (Ind. 3)

Budget allocation from the state is an important determinant of orders from the Swedish Armed Forces to the defense industry. Given this allocation, further prioritization of actual needs is conducted by the Armed Forces, and the process could be quite lengthy.

> The Swedish government's defense decision signals a need and volume for upgrading and new procurement of equipment, but it is only when there are concrete budget allocations that procurement can take place. This means that it is difficult for us to know, if and when there will be an order from the Swedish Armed Forces. Since we do not start any business without a contract, this budget procedure means that delivery times will be long. (Ind. 2)

In addition, most Swedish defense industry firms support customers and foreign armed forces around the world, outside of the Swedish Armed Forces. In this multiple-customer environment, issues of priority for components, parts and production capacity come into play and may impact delivery times.

> The Swedish Armed Forces are handled in the same way as other customers. All customers are treated equally and a new order normally comes last in the queue. It may occur (but very rarely) that some form of redistribution of delivery is made in consultation with the customers concerned. (Ind. 2)

A consistent theme lies in reducing risk by not acting without a contract, i.e. not speculatively purchasing materials and components or starting product development without a client order. Low levels of defense research and development appropriations assigned to the local industry can weaken the role and influence of the state in the defense industry. Throughout the Swedish military drawdown, Swedish state ownership interests in the defense industry and other socially critical activities have waned. In this environment, the industry has become privatized and partially foreign-owned.

4.2 Process and procedures; baking-in critical infrastructure resilience

The industry has become more global, maintaining a large proportion of its subcontractors outside Sweden and the Nordic region.

> Although we have approx. 50% of our suppliers in our immediate region, we are completely dependent on foreign suppliers. (Ind. 1)

> We have 80% of our suppliers outside of Sweden. (Ind. 3)

> We have over 50% of our suppliers outside of Europe. (Ind. 4)

Given its substantial dependence on foreign suppliers, defense industry supply chain designs rely on international supplier availability. While this can be sensitive to disruption, it is beneficial during peace times due to low purchasing costs. Hence, there has been no need for close relationships with the suppliers, since deliveries have often not been time-sensitive.

However, there is recognition of supply chain vulnerabilities at the industry level.

> In the increasingly globalized world, our supply chains are also largely global. Although we do not use suppliers from politically unstable countries, we are sensitive to disruptions. Today, more than half of our suppliers are located outside the Nordic countries, and as we saw during the Pandemic, countries protect their interests. This means that even if we have a contract with a supplier, they are not allowed to deliver. This can be counteracted by the fact that these countries are dependent on our products and that thereby there is a mutual interest in import/export solutions even under cross-border restrictions. (Ind. 2)

The Swedish armed forces, together with the procurement authority Swedish Defense Materiel Administration (FMV) have recently begun looking into issues of assurance and security of supply. The stability of supply chains, access to skilled and competent staff and companies' delivery ability are some of the areas assessed.

> As a privately owned company, we do not take extra measures to ensure delivery capacity and endurance, unless it is contractually agreed with the customer. Of course, we have our contingency plans and backup solutions to deal with disruptions. In dialogue with the customer, redundancy in the supply chain can of course be created, but then the customer must bear the additional cost. (Ind. 3)

The Swedish defense industry has many different forms of contracts and agreements, depending on the customer's interest and needs. However, "everything" has its price (cost).

> In principle, we have different business models with all our customers. Our customers have different profiles in their demands on us as a supplier, which results in different business models. Of course, we do not enter into a contract/business model without believing that it will generate a surplus and contain little risk. (Ind. 3)

> Our agreements with the defense forces of different countries look different and contain different elements. For several customers, we have far more far-reaching contracts than the one we have with the Swedish Armed Forces. (Ind. 2)

> We have customers other than the Swedish Defense Forces, where we stock products and spare parts on their behalf. (Ind. 2)

In a sharp emergency, defense industry inventory must be available to the Armed Forces and the priority is that the Armed Forces can then use and maintain what they have.

> The 90 days of consumption that the Swedish defense wants to have access to in a crisis must be built up before the crisis comes. The defense industry has neither access to materials nor production capacity to produce anything in the short term. The disposal legislation does not help there are no gadgets to get. (Ind. 3)

The companies have action plans and security measures to meet contractual obligations. In addition to this, no extra measures have been taken (without it being contractually agreed), but now customers are beginning to demand measures to secure delivery capacity during a crisis.

Given the current rebuilding of defense capabilities, the diminished leverage of the state over the industry leaves it with no option other than existing market mechanisms. However, in the application of public procurement regulations, Swedish suppliers are not accorded any preference.

4.3 Product development; need for increased terms-specific co-value creation

As discussed in the supply chain management literature, product development lead time can range from 6–15 months for functional products and 1–3 weeks for innovative products;

however, for the defense industry, product type is usually a function of co-value creation between manufacturers and end-customers.

The defense industry believes that it is important to work closely to develop and create capabilities for the Swedish Armed Forces. This is interpreted to help signal the export credibility of the industry.

> The Swedish defense force often has a 30-year perspective on how long a product can be used before it is replaced with something else. This means that the products we sell continuously need to be serviced and upgraded, but we run into problems. Some components and subsystems that were relevant 15–20 years ago are no longer in production at the supplier and must be replaced with other solutions. This requires new tests and system integration. (Ind. 1)

For our products to be credible on the export market, it is a very big advantage that the Swedish Armed Forces use them.

> Since we do not develop our products in-house, we are completely dependent on the development taking place together with the customer. On the one hand, the performance then becomes what the customer desires and on the other hand, the development cost becomes part of the customer project. (Ind. 2)

Often the development and production time is significant, 3–5 years for one contract (contract scope typically 5–200 units). The delivery time thus consists of system integration/development, acquisition of components and subsystems as well as production and test time.

> Developing a completely new product is very demanding and takes a long time. The actual concept development and system integration often takes around 5 years, including tests together with the customer. Once the prototype is approved, production can start after the contract is signed. The delivery is often spread out in time, with, for example, delivery of 10 units per year. The first series-produced unit is delivered after 1 year at the earliest if materials and components have been procured in advance (at the customer's expense). (Ind. 4).

Weapon systems are often technically complex, extensive and expensive to develop and must be maintained and upgraded during their lifetime. Again, the industry takes some risk by not acting without maintenance and/or upgrade programs in place.

4.4 Regulation; at crossroads in the new self-funding era

When purchasing consumables, volume goods and procuring new platforms, the Public Procurement Act 2016:1145 applies, with exceptions only for essential security interests.

> All procurement with the Swedish Armed Forces as a customer takes place in line with the principles of public procurement. This has meant that our cooperation with the armed forces over a longer period has not been permitted because all possible suppliers must have access to the same information from the customer. I see that this can work for the purchase of pure standard and consumable goods, but for our products with long delivery times, closer cooperation over a longer period would be preferable. With this arm's length relationship and uncertainty about new orders, we cannot prioritize the Swedish Armed Forces but must base ourselves on the loyalty of other customers. (Ind. 2)

> What is special about the defense industry is that only states are customers and laws and regulations surround all imports and exports of military equipment. We depend on government permits for export. (Ind. 3)

> If there were to be a complete crisis with a customer and they needed faster delivery or a larger delivery, it is not particularly easy to take components from other customers' ongoing production. Partly because the components in products to different customers are not directly transferable due to different capability requirements and different system integration and partly because some components require end-user certificates and then cannot simply be moved to other customers'

deliveries without new certificates. If something like this could still be implemented, it must take place in dialogue with the customers concerned. (Ind. 2)

These are due to regulations such as International Trade in Arms Regulations (ITAR), which prohibit the retransfer or re-export of United States Munitions List (USML) items by foreign persons unless it is authorized by relevant export authorization. The ITAR framework (e.g. Nosanov, 2009) prohibits the export or transfer of USA-made products and spare parts, including the technical data connected to these products, to foreign or a third country, without an appropriate export license to do so. The USML lists all items, services and related technologies classified under the United States Arms Export Control Act and remains the basis of the ITAR regulation.

An industrial collaboration takes place in consultation with the states concerned so that the necessary permits exist for such collaboration. Collaboration is often based on suppliers in the customer's home country being involved in product development and production according to the customer's wishes. (Ind. 4)

Even in the case of industrial cooperation, in addition to the physical complexity of moving materials across borders, knowledge and expertise in regulations of the exporting and receiving countries is required. However, the export of military products can take place via industrial cooperation with suppliers in the customer's country.

The need to provide unequivocal defense at reduced costs while also improving ethical quality surrounding defense continues to drive regulation in this industry, including constraints on sources of financing. As such, manufactured products may not be swapped between customers, i.e. delivering one client's product to another customer.

4.5 Maintenance and upgrades; need for increased stock visibility

Since large (weapon) systems are often linked (locked) to the original supplier, the Armed Forces must purchase upgrades and maintenance from them.

It may seem strange that when the Swedish Armed Forces buy a product platform from us that they plan to use for 30 years, not at the same time ensure maintenance and upgrading. The explanation that exists is that there are large investments that must be spread over several budget years and that there are different budget items for acquisition and maintenance/upgrading. Since there are usually no other suppliers who can carry out maintenance and upgrades, the customer is forced to use us. This is not only a warranty issue, but the knowledge of the product and its components. Some customers think differently and want to do maintenance themselves. They then buy components directly from our subcontractors, but as is often the case, you cannot go to a completely different supplier to have advanced maintenance and upgrades performed. (Ind. 2)

The defense industry is perceived to have little or no information regarding the Swedish armed forces' stock levels for materials, spare parts, etc. even though they may be responsible for servicing and maintenance. However, recommended service intervals and maintenance operations are closely monitored.

As a supplier, we have little idea of how many replacement units and spare parts are out there with the armed forces, and the dialogue about the armed forces' consumption patterns is vague. Here, we would have liked a much closer cooperation to enable us prepare the production of both replacement units and spare parts. (Ind. 2)

To be an attractive supplier or as we wish to express it - a cooperation partner, we have chosen to stock a greater number of the most requested spare parts. This means that we can quickly deliver to the customer. (Ind. 1)

When advanced defense systems are purchased, there is an involuntary commitment to suppliers in terms of maintenance, upgrades, etc. However, the demanding nature of the

Swedish state as a buyer, for cost, delivery and services flexibility requires resources from suppliers to keep up with the technology and market trends. This, seen from the supplier's side can have negative impacts on the relationship as procurement lead times must be factored into the product or service lead time.

4.6 Interaction analysis

This section applies the SINT model (Alter, 2018) to analyze the conceptualized interaction between the different SoSs in Figure 1. Interactions among supply chain systems and environments are sociotechnical, involving optimized inputs from humans and machines (e.g. de Bruijn and Herder, 2009; Alter, 2018; Akeel, 2022). The analysis is undertaken to develop a clearer understanding of the role elements of the industry SoS play in such interactions, albeit at a higher abstraction level (Figure 3). This is so because collected data only spanned the defense industry actors working within the supply chain SoS as well as the market SoS environments. Undertaking analyses at lower abstraction levels requires considering perspectives from the stakeholders of the market SoS as well, i.e. customers. The model's five parameters include the purpose of interaction, characteristics and patterns of interaction, direct effects of interaction, interaction responses and outcome of interaction. Thus, we perceived connections between the SINT model and interview responses as input into this process.

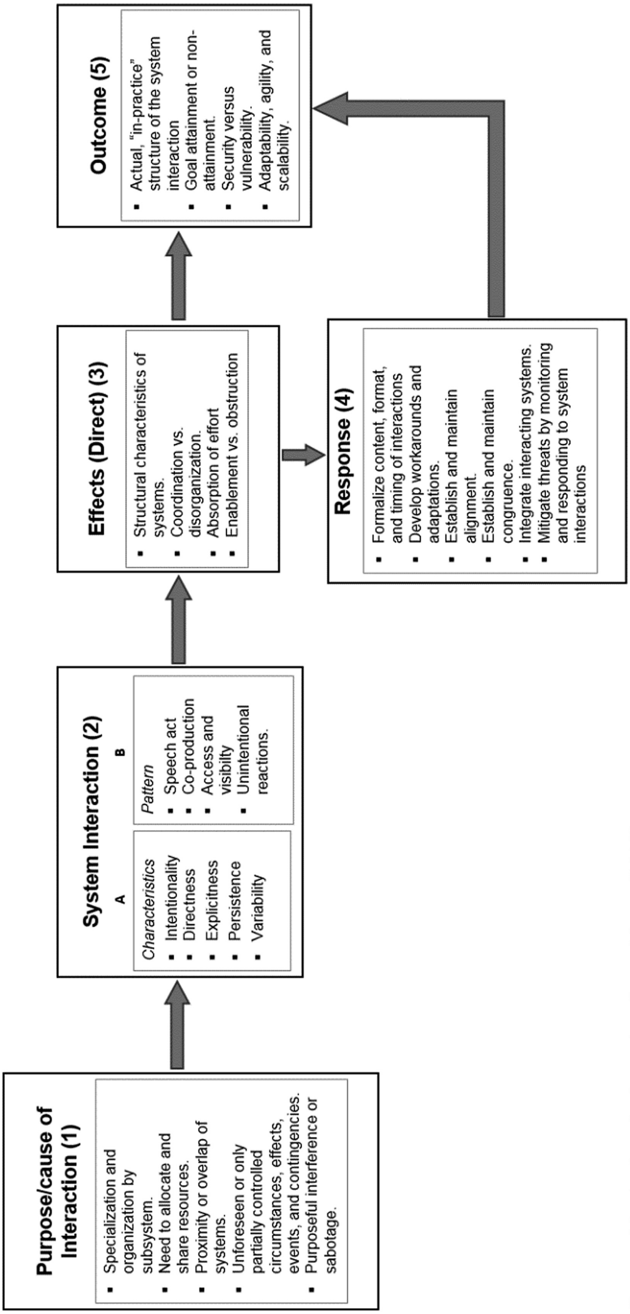
Based on Figure 1, three SoS elements are important for understanding the proper functioning of interactions within and across SoS structures. These include the environment, within which such SoSs are situated, the relationships that occur within this environment and the boundaries that delineate these systems within their own SoS and from other contextual environments. While the SINT model (Figure 2) remains the basis upon which interactions or relationships are analyzed, the other two elements are analyzed from a systems perspective.

We characterize the different defense industry SoS interactions within and between the two environments, based on the three elements discussed above in Figure 1.

Figure 3 depicts the three basic levels of interactions across the industry analyzed here. The supply chain SoS includes systems like quality control systems and procurement systems, which together with other systems make up the supply chain SoS. This is also true for the market system. Relationships in today's business environment comprise sundry players from a variety of countries, meaning that relationships can often take place in remote settings across geographic, relational and cultural boundaries. Bow-tie and diamond structures are typical relationship structures that can result from these interactions. The so-called Bow-tie structure focuses on one point of contact, usually, the buying-selling point, while the diamond structure uses several points of contact across both firms to ensure coordination, productivity and performance.

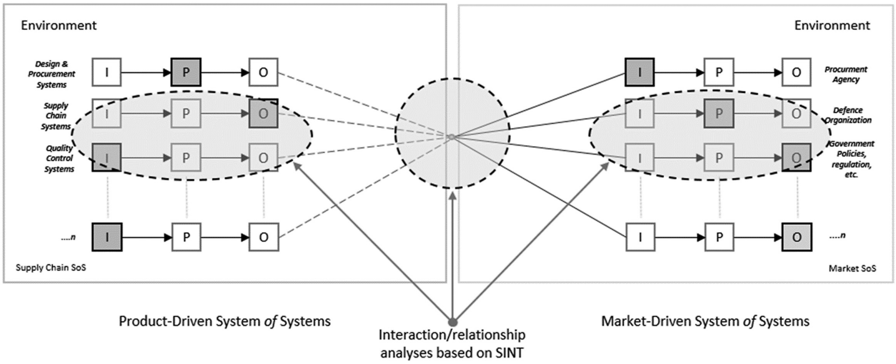
The inherent connectivity between systems and subsystems which allows for co-production in some form is made possible based on the idea of boundaries (Yourdon, 1989). They are invented within systems to maintain a sense of clarity and sanity, even though they could be sources of problems in the failure to realize that such boundaries have been artificially created (Meadows, 2008). Open systems depend on their environment, from which they receive input and which frame the ultimate goal of their output. The environment is thus a determining factor in the uniqueness of a system via the relation between the system and the context (e.g. Arbnor and Bjerke, 1997).

Based on the foregoing, Figure 4 depicts the relationship framework applied using the SINT model, and its results are presented in Table 1. Following from systems theory, the framework proposes that the environment within which systems and their constituting subsystems operate can affect how boundaries are constructed between systems, ranging from soft to hard. Boundaries in turn influence the type and structure of relationships that can develop between interacting entities.



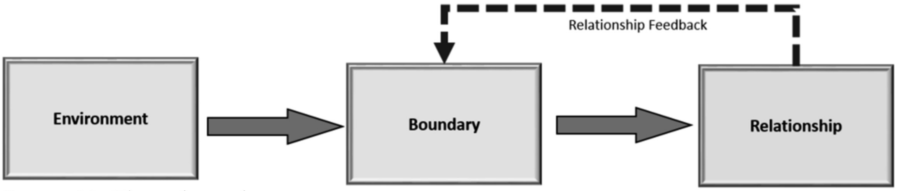
Source(s): Authors' adaptation from Alters (2018)

Figure 2.
System interaction theory (SINT) model



Source(s): Figure by authors

Figure 3. System-of-systems analyses across industry environments



Source(s): Figure by authors

Figure 4. Systems interaction analysis framework

Results from the analysis depicted in Table 1 characterize all three SoS interactions as open systems that depend on their environments, even though both SoSs are very different in terms of the nature of the work they do. This is straightforward, as closed systems neither receive from nor contribute to their outer environment.

Regarding boundaries, the supply chain SoS is classified as soft systems, with the market SoS as hard systems. Finally, the industry SoS is characterized as the coming together of the previous two SoSs and classified as a hybrid. In a hybrid, soft systems apply in some cases, while hard systems are more appropriate in other cases. For example, there may be a need to balance security classifications and visibility into inventory stock for maintenance, as discussed in section 4.5. In such cases, organizations or service providers must find ways of dealing with this, including using softer alternative methods.

5. Discussion and conclusion

While significant studies have investigated risk within supply chain systems (e.g. Spekman and Davis, 2004; Christopher and Peck, 2004), most of these studies have focused on traditional business industries. The changing aspects of the defense industry, including its evolving structure and relationships, are having an unknown impact on risk management, and this area has received little attention. Given the complexities of relationships in this industry, changes in the global ownership structures can influence how industries, their customers and suppliers perceive risk. By examining the interaction and experiences, via systems theory, of companies within this industry, this paper presents a first view of the situation, from the Swedish perspective.

	Environment	Boundary	Interaction	Relationship
Supply chain system of system (SoS)	Open Systems	Soft Systems	(1) Need to allocate and share resources (2a) Intentionality (2b) Co-Production (3) Coordination (4) Develop workarounds and adaptations (5) Adaptability, agility, and scalability	*Relational Cross Function Approach* (i.e. diamond structure); with many points across the supplier and customer organizations
Market system of system (SoS)	Open Systems	Hard Systems	(1) Specialization and organization by structure (2a) Directness (2b) Speech act patterns (unidirectional) (3) Enablement vs obstruction (4) Formalize, format, and time content of interactions (5) Actual, "in-practice" structure of the system interaction	*Transactional Approach* (i.e. the bow-tie structure); with one point of contact between supplier and customer
Industry level systems interaction	Open Systems	Soft/Hard Systems (Hybrid)	(1) Proximity or overlap of systems (2a) Intentionality (2b) Co-production patterns (bilateral) (3) Coordination (4) Establish and maintain alignment (5) Goal attainment or non-attainment	*Hybrid Approaches* (i.e. a combination of transactional and relational approaches)

Note(s): *Table legend:
1 = Purpose of Interaction; i.e. the purpose or cause of interaction between systems
2a = Type of Interaction (Characteristic); describes the type of interaction based on characteristics of the interaction
2b = Type of Interaction (Pattern); describes the type of interaction based on the pattern displayed by the interaction
3 = Effects; describes the impact interaction has on a problem or situation
4 = Response; refer to the impacts on operations or performance results of the interaction
5 = Outcome; refers to the overall result of system interactions from the interplay of details and individual and mutual characteristics of the interacting systems
Source(s): Alter (2018)

Table 1. Characterization of defense industry SoS interactions based on the SINT model*

Relationship results from SINT analysis show that the supply chain SoS for this industry is heavily tilted towards steady, long-term relationships. In contrast to the supply chain SoS, the market for this industry shows a preference for transactional relationships, i.e. relationships without long-term commitment to a single supplier. This could be because the industry as a rule develops products that have delivery lead times of up to 8 years. The preference of the market customers for short-term transactional relationships prompts the supply chain industry to be risk averse, only manufacturing to order. At the industry level, analysis shows that relationships go either way, depending on the type and sensitivity of the product or service. Given these results, our study goes contrary to the findings of Glas (2017), as we did not find any current overriding indication of preferential treatment of the defense industry towards the military, outside those with standing agreements on production or service. A possible explanation for this could be seen in the evolving structure of the defense industry ownership as well as in the growing deviation in the relationship between the industry and the market. This is especially evident in three of the five characteristic areas discussed in this study, including structure, processes and procedures and product development. As the defense industry expands its focus to the goal of satisfying a global market base, structure, processes/procedures and product development characteristics of the industry represent areas where rapid changes are most likely to occur.

At the systems level, what these findings seem to highlight is that, based on the autonomy and diversity elements of SoSs, when input and output (I-O) processes occur within the same SoS environment, it is easier to evaluate the impact/influence of a system on another system and as such enable the determination of risk and consequently risk mitigation measures. However, when the I-O processes do not occur in the same SoS, i.e. they span two or more environments, interaction analysis between SoS and individual systems themselves becomes more complicated. As such, for systems, interaction analysis, much like supply chain analysis, is important because the nature of the structure of system interactions within the industry determines the nature of competition in that SoS environment (e.g. *culled from* Porter, 1980). A goal of the systems analysis conducted here is to enable industry stakeholders to understand the different interacting systems and subsystems, including how these are linked, as one holistic system, much in the same way as scholars view the supply chain as a single analytical unit (e.g. Spekman and Davis, 2004). This analysis provides an approach to characterize and decipher underlying relationship types that are likely to generate vulnerabilities for the industry.

5.1 Conclusions

Our paper sought to investigate the characteristics of the defense industry for a better understanding of risks within the industry and how they could be managed. Literature on risks was reviewed with a focus on the SoS approach to characterizing the industry along the lines of structure, processes and procedures, products and regulation. Interview data from industry actors was used to support industry characterization as well as interaction characterization within different system environments using the SINT model. This led to a simple framework for identifying relationship types within SoS environments by analyzing the features of interactions that occur.

The framework comprises three stages: Environment, Boundary and Relationship. Environment describes the context within which interactions occur, boundaries work to ensure that systems are distinguished for clarity and to ensure appropriate connectivity between systems and could be hard and soft systems. Finally, relationship describes the structures through which interacting entities achieve their immediate, medium and long-term objectives of interactions.

5.2 Limitations and future research

Our study was motivated by the need to increase the understanding of the changing nature of relationships within the defense industry and its implications for risk in its supply chains. However, our research involved certain limitations. First, we only study certain parts of the Swedish defense industry, focusing on focal manufacturing firms, meaning that upstream and downstream stakeholders are not considered. While supply chain interactions are typically characterized by dyadic relations along the supply chain, involving customers, clients, suppliers, etc., future work should evaluate the value of the information sources not currently accounted for in this study, especially as it has to do with its biggest client, the Swedish armed forces, via its defense procurement agency (DPA), the FMV. As such, results should be treated as early hypotheses toward the formulation of risk management strategies for the defense industry. Also in this regard, because our research is reflective and interpretive, the results arrived at in this study may not be generalizable to defense industry sectors in different regions and countries.

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