Reducing lead times within military supply chains:

the development and application of an information fragmentation perspective

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Acknowledgements

Dear reader,

This master thesis presents the results of my graduation project conducted on behalf of the Dutch Ministry of Defence (MoD) in order to complete the MSc. programme in Complex System Engineering and Management at Delft University of Technology.

Last September, I started my graduation internship at the Directorate of Business Operations and Evaluation. I am grateful for the unique opportunity to write my thesis within this wonderful organisation. My father and uncle made me curious about the organisation, and I think it is exceptional that I had the opportunity to get a glimpse of what actually happens there. What motivated me is that I was able to write my thesis within this important organisation, gain some practical experience, and contribute (if only a little) to improving our safety.

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I hope you will enjoy reading my thesis.

Marit Boom
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Summary

Lead time reduction of military supply chain (MSC) processes is essential for well-functioning military organisations. Generally, the functioning of the armed forces is becoming increasingly important due to (inter)national developments. Moreover, MSCs are crucial for the success of military tasks (Prebilič, 2006). However, MSCs are complex and uncertain systems (Acero et al., 2020; Calbert et al., 2015; Prebilič, 2006; Sani et al., 2022; Sokri, 2014; Wang, 2000), including interdependencies between actors and processes (Kukovič et al., 2014; Muthoni et al., 2015). Flexibility is needed for MSCs to deal with complexity and uncertainty (Beamon, 1999; Rice & Caniato, 2003; Sani et al., 2022; Sokri, 2014; Stevenson & Spring, 2007; Tachizawa & Gimenez, 2010). Reducing lead times contributes to the flexibility of supply chains (SCs) (Cranfield School of Management, 2003; Jüttner & Maklan, 2011). Specifically, the relevance of lead time reduction for MSCs is determined by several sources (Acero et al., 2019, 2020; Loredo et al., 2015; Reinders, 2019; Sokri, 2014). Furthermore, primary and secondary SC processes are highly interrelated (Hines, 1993; Wong et al., 2018). Therefore, reducing lead times in primary and secondary SC processes is relevant.

Acero et al. (2020) argue that supply chain management (SCM) must be improved to minimise lead times in MSCs and to achieve flexibility. However, the current scientific literature is lacking related to lead time reduction in MSCs. Considering MSCs differ from commercial SCs, the scientific literature for general SCs is insufficient for MSCs (Calbert et al., 2015; Haraburda, 2016; Sokri, 2014; Weber & Gerde, 2011; Wong et al., 2018).

Furthermore, Marshall (2015) concludes that insufficient empirical research exists on information sharing within supply chain management (SCM) literature. SCs include material and information flows (Aitken, 1998). SCs are situated in a multi-actor setting. Information sharing is essential for effective MSCs. Wieland et al. (2016) identified the future research potential of "*enabling better interpretation of SCM information*" (p212). Thus, the relevance of information sharing for improving SCM, combined with the lacking scientific literature on lead time reduction in MSCs, indicates a new specific research area that contributes to reducing lead times in MSCs by focusing on information sharing.

Information sharing is a comprehensive concept; this research focuses on formal information sharing, which is defined (based on Lai and Yang (2017)) as the sharing of structured and traceable information, located in a formal setting. Inadequate formal information sharing results in the scattering of formal information throughout a multi-actor system referred to as 'information fragmentation'. Since information sharing is a crucial component of SCs, information fragmentation may influence the lead times of SCs (Rukanova et al., 2017). However, the issue of information fragmentation in terms of lead times in MSCs is not apparent, and neither is how to solve information fragmentation problems in MSCs. Therefore, the following question arises for this research focus: *how to reduce information fragmentation in order to reduce lead times in MSCs?* Two aspects are analysed to answer this question. Firstly, how information fragmentation is defined and whether information fragmentation is a problem regarding lead times in MSCs. Secondly, relevant problem-solving interventions that reduce information fragmentation in MSCs are addressed. The main research question is applied, in a case study, to one financial supportive MSC process since financial supportive processes are relevant for the functioning of MSCs generally (Alexandre et al., 2017; Loredo et al., 2015; Moeller et al., 2006; Stemmler, 2002; Um, 2017; Williams, 2017).

Different steps in the research are performed to approach the main research question. First, an information fragmentation perspective towards lead time reducing in MSCs is developed based on the literature; this perspective provides two propositions. Thereinafter, this information fragmentation perspective is applied to a case at the Dutch Ministry of Defence (the invoice case) to analyse whether the propositions are supported by practice. The invoice case is a financial supportive MSC process encountering problems related to lead times and formal information sharing. Additionally, two types of formal information are distinguished: process in practice and process design information. As a result, a problem related to the lead times in the invoice case is determined, including the relation with

information fragmentation (of formal process in practice and formal process design information). Consequently, the perspective towards reducing information fragmentation - for process in practice and process design information - is applied to the case.

Three main results are obtained in this study. Firstly, this research contributes with an additional perspective towards lead time reduction for MSCs. Secondly, applying the perspective results in identifying a problem in the invoice case: missing performance declarations within the invoice process. This problem is characterised by information fragmentation, which significantly affects the lead times of the supportive SC process. Lastly, applying the information fragmentation perspective to this problem makes clear that preventive and corrective problem-solving interventions, including boundary objects, can reduce information fragmentation and lead times in MSCs. Specifically for the invoice case, a track and trace system (integrating formal process in practice information) and an integrated process design overview (integrating formal process design information) contribute to solving the problem of missing performance declarations in the invoice process.

In further research, the proposed boundary objects should be further developed. Moreover, the effect of these boundary objects on information fragmentation and reduction of lead times can be quantitatively analysed. Furthermore, the impact of informal information sharing on lead times can be incorporated.

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Abbreviations

ARIS	Architecture of Integrated Information Systems
ATB	Aanvraag tot Bestellen
BBD	Besturen bij Defensie
BP	Business process
BPMN	Business Process Modelling Language
CDS	Commandant der Strijdkrachten
DO	Defensieonderdeel
DGB	Directoraat Generaal Beleid
DOSCO	Defensie Ondersteuningscommando
DTI	Digital Trade Infrastructures
EHR	Electronic Health Records
ERP	Enterprise Resource Planning
FABK	Financieel Administratie- en Betaalkantoor
HDFC	Hoofddirectie Financiën en Control
IM	Information management
LSS	Lean Six Sigma
MatLogCo	Materieel Logistiek Commando
MLF	Monitor Logistieke Facturen
MoD	Ministry of Defence
MSC	Military supply chain
OTCO	Opleidings- en Trainingscommando
PMM	Process model management
RFI	Request for information
SC	Supply chain
SCM	Supply chain management
VIS	Vertical Information System
VSM	Value Stream Mapping
WP	Work process

Translation list

Aanvraag tot Bestellen (ATB)	Application Requirements Proposition
Aanwijzing	Internal policy document
Besturen bij Defensie (BBD)	'Governance at Defence'
Behoeftesteller	Requester
Besturing & Innovatie	Governing and Innovation
Commandant der Strijdkrachten (CDS)	Chief of Defence
Directoraat Generaal Beleid (DGB)	Directorate-General of Policy
Directie Bedrijfsvoering en Evaluatie	Directorate of Business Operations and Evaluation
Defensie Bedrijfsontwerp	Defence Enterprise Design
Defensieonderdeel (DO)	Defence unit
Defensie Ondersteuningscommando (DOSCO)	Joint Support Command
Financieel Administratie- en Betaalkantoor (FABK)	Financial Administration and Management Bureau
Hoofddirectie Financiën and Control (HDFC)	Principal Directorate of Finance and Control
Inkoopfacturen (MM invoices)	Purchasing invoices
Inkoop(-proces)	Ordering process / purchasing
Ketenlogistiek	Supply chain (logistics)
Materieel Logistiek Commando (MatlogCo)	Materiel Logistics Command
Opleidings- en Trainingscommando	Education and Training Command
Secretaris Generaal	Secretary General
Goederenontvangst	Goods receipt
Prestatieverklaring	Declaration of performance
Werkinstructie	Work instruction

Chapter 1. Introduction

"*Protecting what we value*" ~
Ministerie van Defensie

Just a year ago, something happened that many people did not expect: Russia invaded Ukraine. The new reality has a considerable impact. Accordingly, the urgency to strengthen military organisations increases to protect national and international territories' security, freedom, and prosperity. Moreover, the Dutch Ministry of Defence (MoD) indicates the complexity and instability of the current (global) situation, which is likely to continue in the coming years (Ministerie van Defensie, 2022e). This complexity and instability can be observed in Russia's invasion and other threats such as organised crime, extreme weather conditions, and cyber-attacks (Ministry of Defence, 2022). Objectives are delivered in the MoD's white paper presented last year. Accordingly, the Dutch armed forces will increase their operational readiness, combat power and agility to defend and protect the Dutch territory and its allies (Ministerie van Defensie, 2022e). Besides this, multiple specific plans, investments, and strategies have been developed. Specifically, the white paper state that MoD will reinforce its supply chains (SCs) by enhancing the management and capacity in the coming years. Moreover, the MoD will heavily invest in support, innovation, and information-driven organisation and operation, which is possible due to the increased defence budget provided by the Dutch Government.

Military supply chains (MSCs) are crucial for the success of military tasks (Prebilič, 2006) and for achieving the military goals set by the MoD. Material flows are significant enablers of military operations. Not only for the Dutch armed forces but generally for military organisations well-functioning MSCs are vital.

Supply chain management (SCM) aims to improve the competitiveness of an SC (Stadtler et al., 2015). According to Stadtler et al. (2015), SCM includes integrating involved organisations and better-coordinating flows (material, information, and financial) to this aim. However, MSCs differ from commercial SCs (Haraburda, 2016; Weber & Gerde, 2011). According to Sokri (2014), MSCs have, on a basic level, the same elements as commercial SCs. However, Sokri (2014) shows that due to the characteristics of MSCs, the application of principles regarding commercial SCs is limited. Complexity and uncertainty characterise MSCs. Therefore, SCM is challenging for MSCs. This research focuses on MSCs to contribute to the current SCM literature. One vital aspect of MSCs will be central in this research: reducing lead times of MSC processes.

The following paragraphs outline the scientific relevance of analysing MSCs by introducing two knowledge gaps. The first is related to the reduction of lead times in MSCs, and the second is related to formal information sharing as a component of SCM. This research is scoped by a problem statement, a case, research questions and a research objective described in the second paragraph. As a result, the second paragraph ends by linking the research scope to the master's programme Complex Systems Engineering and Management (CoSEM) of TU Delft. Furthermore, this chapter concludes by describing the general structure of this thesis.

1.1. Knowledge gaps

The current scientific literature suggests further research related to specific research domains. For example, Yoho et al. (2013) substantiate the need for scientific research to improve MSCs. Many different aspects must be analysed to strengthen MSCs in the end. State-of-the-art literature indicates multiple directions for future research. The first step in scoping this research will be based on current academic suggestions. Based on this, two knowledge gaps have been formulated. A more comprehensive overview of the state-of-the-art literature relevant to these knowledge gaps is presented in chapter 2 (the literature background).

There is an increased urgency for better, quicker, and more robust military logistics to meet current military needs (Ritter et al., 2007). Improving SCs is essential for the success of military operations

(Sani et al., 2022). Heckmann et al. (2015) describe the urgency of "*the ability of a supply chain to overcome vulnerability*" (p.125). Specifically, improving flexibility is one of the essential methods to improve SCs (Rice & Caniato, 2003). Furthermore, Sokri (2014) suggests explicitly looking at the flexibility of MSCs.

Lead time reduction in MSCs is relevant to achieve flexibility in MSCs. Velocity is closely related to flexibility (Jüttner & Maklan, 2011). Subsequently, according to the Cranfield School of Management (2003), lead time is a crucial indicator of SC's velocity. Sokri (2014) defines delivery flexibility as "*the ability to meet short lead times*" (p.82). Thus, reducing lead times will contribute to the delivery flexibility of MSCs, which will improve MSCs.

The importance of lead time reduction of MSC processes does not stand alone. According to Sokri (2014), SCs are not only driven by time and quantity drivers but also by budget. Sani et al. (2022) and Sokri (2014) indicate, specifically for MSCs, the value of studying trade-offs between delivery time and costs in more detail. Lead time reduction should not be the main objective without including other requirements. According to Acero et al. (2020), requirements for a military organisation are that the criteria established in the military organisation should be ensured; therefore, the non-value-adding activities should be identified.

However, there is a lack of literature that addresses how the lead times of MSCs can be reduced. Acero et al. (2020) are among the first to look specifically at lead time reduction in MSCs. Their motivation is that the state-of-the-art literature showed a shortage of research related to the same purpose and application. Specifically, they distinguish between value-adding and non-value-adding activities, giving insights into lead time reduction without losing process value (with an increased percentage of value-adding activities). Acero et al. (2020) conclude that more research needs to be done on the lead time reduction of other MSC processes to improve MSCs ultimately.

Therefore, additional research on lead time reduction in MSC processes is considered relevant as it contributes to the ultimate target of MSC improvement. The first knowledge gap indicates the lack of scientific research on reducing lead times in MSCs.

Gap 1: lack of scientific research related to the reduction of lead times in MSCs.

Marshall (2015) concludes that insufficient empirical research exists on information sharing within SCM literature. Appropriate information sharing is essential for SC systems (Ganapathy et al., 2003). Furthermore, Yang and Maxwell (2011) argue that information sharing is essential for improving organisational efficiency and performance. Moreover, Acero et al. (2020) argue that SCM must be improved to minimise lead times in order to achieve flexibility in MSCs. The current literature on MSCs mainly focuses on the computational analysis of physical aspects. A conceptual overview - including information streams - is missing, although information sharing is a core aspect of MSCs (National Defense University, 2000; Zhang et al., 2019). Therefore, research on information sharing within SCM literature is needed, especially for MSCs.

Wieland et al. (2016) identified new essential research themes for SCM, which suggest interdisciplinary research to improve SC performance. The identification of future research potentials is presented in Figure 1. Research on people and behaviour seems interesting for improving SCM to reduce lead times when focusing on information exchange. In particular, "*enabling better interpretation of SCM information*" (p212). Specifically, Schorsch et al. (2017) suggest further research opportunities for applying a holistic view of SC decision-making and problem-solving. The more specific suggestion of Schorsch et al. (2017) is to analyse how information is acquired, for example, how information is presented.

	Sustainability	Risk management	Innovation	Analytics	Complexity
People and behaviour	• Managing perceptions of sustainability in the supply chain. • Influencing culture to increase sustainability in supply chains. • Closing the attitude–behavior gap of sustainability	• Managing risk preferences and risk perceptions. • Managing biases and heuristics in risk identification. • Optimizing the supply chain structure to manage risk.	• Dealing with resistance to supply chain innovations. • Managing irrational decision making in the innovation process. • Investigating culture of inter-organizational innovation.	• Improving decision-support tools in SCM. • Enabling better interpretation of SCM information. • Involving social media data in SCM analytics	• Accepting that SCM decisions are inherently imperfect. • Handling complexity when making joint SCM decisions. • Managing talents to better deal with complex situations.

Figure 1.Some future research potentials (Wieland et al., 2016)

Organisations' information-sharing behaviour can be distinguished into formal and informal information sharing, where formal information sharing occurs in a structured, traceable, and formal setting (Lai & Yang, 2017). The article of Maltz and Kohli (1996) describes two criteria for the distinction between formal and informal events. "*Following Stohl and Redding (1987), we delineate two criteria for characterizing a dissemination event as being formal or informal - verifiability and spontaneity*"; quoted from Maltz and Kohli (1996, p. 48). The concept of formal information sharing is further discussed in the next chapter.

Thus, combining the suggestions from the literature to contribute empirical research on information sharing for SCM improvement and the distinction of formal information sharing provides the second knowledge gap for this research.

Gap 2: lack of empirical research on (formal) information sharing as a contribution to the improvement of SCM.

Due to the importance of information sharing within SCs, lacking formal information sharing can be problematic for SCs. When formal information is needed to execute process steps, and this formal information is inadequate, incomplete, or missing, problems arise. Van der Aa et al. (2015) suggest that the relevant information should be available when needed. When the information is scattered throughout an organisation, referred to as ‘information fragmentation’, this can be problematic for SC processes.

It is unclear if information fragmentation negatively affects the lead times of MSCs. Furthermore, when information fragmentation is a problem regarding lead times in MSCs, by adding non-value-adding activities, it is unclear how information fragmentation can be reduced. Specifically, a perspective on information fragmentation towards lead time reduction in MSCs is missing in the current literature.

Combining the two presented knowledge gaps and adding the relevance of developing an information fragmentation perspective shows the specific gap in the literature addressed in this research.

1.2. Scope

The knowledge gaps indicate the direction of this study. Furthermore, the delineation of this thesis is specified by a problem statement, an objective, and research questions. The end of this section describes the link with the CoSEM programme. An empirical case is used as a data resource to approach this study. Moreover, the research design of this study considers this specific case's characteristics. The case is shortly described to link the research questions; a more detailed background of the case is included in the approach (chapter 3).

1.2.1. Problem statement

Generally, military organisations and, specifically, the MoD must increase their MSC flexibility to deal with arising threats and international developments. Due to the complex and uncertain character of MSCs, flexibility is essential. Lead time reduction of SC processes contributes to SC flexibility. Therefore, lead time reduction of MSC processes is desired.

Information sharing is essential for the functioning of SC processes. Lacking formal information sharing gives problems resulting in non-value-adding activities and, thereby, higher lead times.

For the MoD specifically, lead time reduction of their invoice process - as part of the MSC - is vital to becoming compliant with (inter)national legislation related to payment behaviour. Furthermore, lead time reduction should be achieved by reducing non-value-adding activities to ensure the quality of the invoice process remains.

1.2.2. General case description

The problem statement introduces the invoice process of the MoD. Since the MoD experiences problems related to lead times of their invoice process, this invoice process is selected for the case study.

The Ministry of Defence

This study generally focuses on SC processes in military organisations. Specifically, this study is executed in close collaboration with the MoD, a public organisation and part of the Dutch central government. The MoD shows its ambition in its white paper of 2022: "*The Netherlands and Europe must become stronger in order to be able to protect our freedom, security and prosperity, today and in the future*" (Ministry of Defence, 2022) (p.3).

The Dutch armed forces' primary mission is formulated in The Kingdom of the Netherlands constitution to defend and protect the kingdom (De Nederlandse Grondwet, n.d.). After decades of budget cuts, the role of the armed forces is becoming increasingly important due to recent international developments. Increased global tensions, especially Russia's invasion of Ukraine, show the extensive consequences of international threats and classic military conflict. However, as stated in the Defence White Paper of 2022, many other threats are currently impending, such as organised crime, extreme weather conditions and cyber-attacks (Ministry of Defence, 2022). Furthermore, the NATO Secretary General's Annual Report of 2020 states that global challenges arise due to threats like Russia's assertive, destabilising behaviour and the continuation of terrorism (NATO, 2021). These challenges indicate the importance of adequate functioning of the Dutch armed forces.

In Figure 2, the organisational chart of the MoD is presented, which indicates the organisational structure. Within the main structure of the MoD, tasks, responsibilities, and authority are allocated (Ministerie van Defensie, 2021c). MoD distinguishes different organisational elements/ 'defence units' (Dutch: defensieonderdelen: DOs). Besides this, more relevant information for the case study about the organisational structure and the different divisions of MoD can be found in Appendix H2.

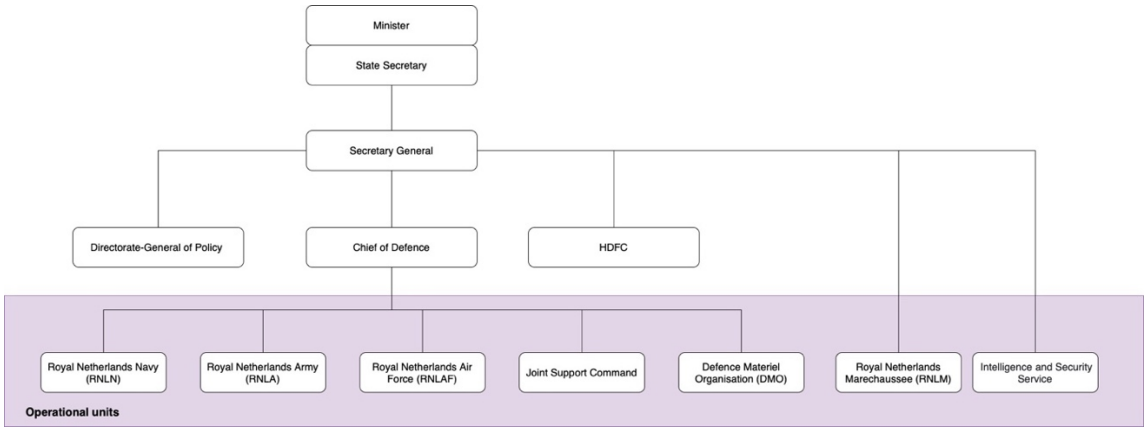

Figure 2. Organisational chart Dutch MoD (Ministerie van Defensie, 2021b)

MatlogCo
Within the Royal Netherlands Army is a unit included: 'Army Maintenance and Logistics Command' (MatlogCo). This command is responsible for maintaining all land systems, including vehicles and weapon systems, of the Dutch armed forces. Besides this, the expertise of MatlogCo is related to the maintenance of these complex systems (Ministry of Defence, n.d.). Specific assortments of goods are the responsibility of MatlogCo. Furthermore, within MatlogCo, one of the departments is the logistics department. This department is the client and provider of the case study. The logistics department focuses on the assortments covered by MatlogCo and the (re)supply of the Operational Commands (OPCOs) during military operations as well as in times of peace. Besides this, MatlogCo's logistics department has been assigned to maintain and conserve equipment (Ministerie van Defensie, 2021d). This study generally distinguishes the external supply of goods and services. Although many requests occur within the defence organisation, this study only looks at orders to external suppliers. The purchases related to external suppliers are linked to a payment process; this process is shortly discussed in the next paragraph.

Invoice process
Different support functions are related to MSC processes. One of these facilitating business processes is financial support. When the DOs of MoD make acquisitions with external parties, monetary compensation is required. Internal payments are sometimes also accomplished; these are disregarded during this study. For the external purchase of goods and services (e.g., exterior maintenance or reparation), the payment process is facilitated by invoices. There exist multiple different types of invoicing. Profource (2021) made a quick scan of the invoice process at MoD and argued that the inadequate payment behaviour by the MoD is mainly caused by purchasing invoices (Dutch: inkoopfacturen, MM invoices)[1]. Thus, this study concentrates on the processing of MM invoices, which is supported by the ERP M&F system[2] (SAP).

The invoice process supports the MSC processes in terms of the financial domain. However, the logistics section of MatlogCo is currently facing many problems related to invoicing. Their concerns appear from many open bills, error messages, incomplete orders, etc. (MoD01). The invoice process regularly suffers from high lead times (Ministerie van Defensie, 2020, 2021a, 2022d); furthermore, information sharing is a crucial aspect of the invoice process since information sharing is required for the facilitation of multiple procedural steps. This research generally focuses on information sharing to improve the invoice process regarding lead times.

The adequate functioning of the invoice process is essential to the MoD. The causes of inadequate functioning of the invoice process, which are related to formal information sharing, will be analysed in the research. Specifically, insights into integrating formal information to reduce lead times of the invoice process of MoD can be used to enhance other information sharing processes in MSCs. Based on the characteristics related to the scientific knowledge gaps, the case of invoicing at the MoD is also considered scientifically relevant.

1.2.3. Research questions
The general research objective, in combination with the scientific knowledge gaps, can be translated into a main research question. The main research question is specified to:

how to reduce information fragmentation in order to reduce lead times in MSCs?

As the knowledge gaps indicate, an information fragmentation perspective towards lead time reduction in MSCs is missing; therefore, this research develops one. Furthermore, this perspective is applied to a specific case, causing consideration of financial processes in MSCs (shortly introduced in the previous paragraph). Six sub-questions and sub-deliverables have been formulated to approach the main research

[1] Invoices from the Material Management Module in SAP ERP M&F
[2] ERP M&F system: Enterprise Resource Planning (ERP) system for material and financial logistic processes, which is provided by SAP.

question. Specifically, these sub-questions and sub-deliverables contribute to developing and applying an information fragmentation perspective towards lead time reduction in MSCs.

The first two sub-questions relate to the creation of a literature background. A literature background of several concepts is needed to be able to develop an information fragmentation perspective and to support the relevance of this perspective.

The first sub-question addresses the relevance of lead time reduction of MSCs (Table 1). Besides this, specifically, addressing the relevance of lead time reduction of financial supportive processes is included in this sub-question.

Table 1. Sub-question 1

	Sub-question 1
Aim	To obtain a literature background on lead times of complex, uncertain MSCs and the relevance of financial supportive MSC processes.
Question	Why is lead time reduction of financial supportive processes relevant for MSCs?
Deliverable	A literature background of MSCs, lead times and financial supportive MSC processes

In addition to the literature background obtained from sub-question 1, information about formal information sharing is needed. The second sub-question refers to the definition of formal information sharing and the relevance of formal information sharing for reducing lead times (Table 2).

Table 2. Sub-question 2

	Sub-question 2
Aim	To obtain a literature background of formal information sharing as a component of SCs
Question	How can formal information sharing be defined, and why is formal information sharing relevant to the reduction of lead times in SC processes?
Deliverables	A literature background addressing formal information sharing as a component of SCs and its relevance for lead time reduction of SC processes

Based on the literature background obtained in sub-question 1 and 2, it becomes clear that formal information sharing is essential to achieving lead time reduction. Lacking formal information sharing can result in information fragmentation, where no integrated overview of formal information exists. An information fragmentation perspective is developed by addressing the following two sub-questions. The third sub-question addresses the expected effect of reduced information fragmentation on lead times of MSCs, which results in the first proposition (Table 3).

Table 3. Sub-question 3

	Sub-question 3
Aim	To develop a perspective including information fragmentation and lead times based on the existing literature
Question	What is the expected effect of reduced information fragmentation on lead times of MSCs, based on the literature related to information fragmentation in an organisational or multi-actor context?
Deliverable	Proposition 1, which indicates the expected effect of information fragmentation on lead times in MSCs

From the characteristics of information fragmentation, a problem-solving dimension towards lead time reduction is added to the information fragmentation perspective. This problem-solving dimension includes boundary objects as a means to reduce information fragmentation. Chapter 5 elaborates further on the concept of boundary objects. The fourth sub-question addresses the expected effect of boundary objects on information fragmentation in MSCs; this results in the second proposition (Table 4).

Table 4. Sub-question 4

	Sub-question 4
Aim	To develop a perspective including boundary objects and reduced information fragmentation based on the existing literature
Question	What is the expected effect of boundary objects on information fragmentation in MSCs, based on the literature on boundary objects in SCs?
Deliverable	Proposition 2, which indicates the expected effect of boundary objects on information fragmentation in MSCs

Two propositions are the outcome of sub-question 3 and 4. Consequently, the information fragmentation perspective is applied to the invoice case of MoD, and the propositions are analysed in the case. The fifth sub-question relates to the first proposition; addressing this question results in identifying a problem related to information fragmentation and lead times within the invoice case (Table 5).

Table 5. Sub-question 5

	Sub-question 5
Aim	To analyse proposition 1 in the invoice case and to identify a problem in the case related to information fragmentation and lead times
Question	What current problem in the invoice case relates to information fragmentation and lead times?
Deliverable	An identified problem related to information fragmentation and lead times in the case

A problem related to information fragmentation and lead times within the invoice case is identified, addressing sub-question 5. In sub-question 6, the other proposition resulting from the information fragmentation perspective is applied to the invoice case (Table 6). This application results in the identification of two problem-solving interventions which integrate formal information in the invoice case.

Table 6. Sub-question 6

	Sub-question 6
Aim	To analyse proposition 2 in the invoice case and to identify two possible problem-solving interventions to integrate formal information
Question	How to integrate formal information in the invoice case to reduce information fragmentation?
Deliverable	Two problem-solving interventions to integrate formal information in the invoice case

By answering these six sub-questions, the main research question can be answered. First, two sub-questions result in the literature background needed to develop a valuable perspective on lead time reduction in MSCs and support the case's relevance. Furthermore, an information fragmentation perspective is developed while addressing sub-question 3 and 4. Consequently, this perspective is applied to the invoice case and results in empirical support of the perspective in practice. Thereby, the main research question is addressed.

1.2.4. General objective

Based on the identified knowledge gaps, the problem statement, and the research question, the research objective is formulated as follows.

To develop an information fragmentation perspective towards lead time reduction in MSCs. Applying this information fragmentation perspective should provide insights into the reduction of lead times of the invoice process of the Dutch Ministry of Defence (without losing process value).

1.2.5. Societal relevance

Well-functioning military organisations are crucial for (inter-)national safety and security; defence is widely regarded as one of the essential collective goods (Heeren-Bogers, 2018). A better understanding of the underlying reasons for the complexity of MSC is needed to improve the operations of military organisations. The invoice case is used to gain new empirical evidence, which contributes to a better understanding of the influence of formal information sharing on the lead times of MSCs. Furthermore, the outcomes of this research can be used to reduce information fragmentation and lead times of MSC processes.

This research contributes to the scientific understanding of problem-solving interventions to reduce formal information fragmentation and lead times. Concrete, this study analyses the problem of information fragmentation resulting in non-value-adding activities for the invoice case of MoD. Paragraph 3.2 will further discuss the relevance of the case study. Moreover, the study contributes with insights and a scientifically supported structure to reduce information fragmentation, which reduces lead times. The scientific perspective and insights can be relevant for the Directorate-General of Policy (DGB, Dutch: Directoraat Generaal Beleid) and the process participants within the MoD. However, this study focuses on the scientific contribution instead of the development of practical interventions.

Nonetheless, The Netherlands will heavily invest in the Defence organisation in the coming years (Ministry of Defence, 2022). This available budget can be seen as an opportunity to invest in SCs, innovation, and process management improvements within the MoD. Thus, the scientific insights from this study can contribute to the effectiveness of defence policy and the operability of the Dutch armed forces. Chapter 7 provides a more detailed interpretation of the results and a discussion of limitations.

1.2.6. Links to CoSEM

The importance of this research for national and international safety has been argued. The complexity of MSCs is also relevant to the master's degree programme in Complex Systems Engineering and Management. The MoD is an organisation dealing with uncertainty and complex threats (Ministry of Defence, 2022). The ongoing controversy between values, like efficiency and readiness or innovation and robustness, indicates the complex considerations of the MoD. Moreover, the focus on military SCs fits the CoSEM perspectives very well. The MSC system has physical aspects and links to institutional economics, organisational science, ethics, law, and process management. Material and information transactions between entities are the main elements of intra-organisational SCs (Zhang et al., 2019), indicating the relevance of the abovementioned aspects. The research approach contains a holistic system engineering perspective, while the process management perspective will be considered. A more comprehensive description of the complexity related to the topic of study can be found in chapter 2.

1.3. Structure of this thesis

The division characterises the main structure of the thesis into multiple parts. First, chapter 2 provides a literature background used as the analysis's starting point. In this literature background, several concepts are explained. Subsequently, chapter 3 concerns this thesis's general research approach. In this chapter, the research setup is described in more detail. Chapter 4 describes the tools and methods used in this research.

Furthermore, the remaining part of the thesis describes the analysis and research outcomes. Therefore, a perspective towards lead time reduction in MSCs is developed. This information fragmentation perspective provides two propositions presented in chapter 5. Consequently, chapter 6 describes the application of the information fragmentation perspective to the invoice case of MoD. Eventually, chapter 7 discusses validity, the interpretation of results obtained in the study and limitations. Altogether, the conclusions are made related to the research questions presented in this chapter, and the scientific relevance is discussed in chapter 8.

Chapter 2. Literature background

"Uncertainty is a system property characterizing the incompleteness of our knowledge about the system, its environment, and the conditions of its development"
~ Ivanov (2021, p. 3)

This chapter outlines a literature background regarding concepts that align with the research objective and the knowledge gaps described in the introduction. The first two sub-questions can be addressed by the results of the presented literature background. Addressing the first sub-question aims to obtain an understanding of why the reduction of lead times is relevant for MSCs. Additionally, the relevance of reducing lead times of financial support processes, in particular, was examined. Answering the second sub-question intends to obtain a better understanding of formal information sharing and the relevance of formal information sharing for lead time reduction in SC processes. Overall, this literature background motivates the relevance of the study.

Firstly, this chapter describes some general characteristics of military organisations, MSCs and their environment. Furthermore, the literature background illustrates a potential research area. The literature background gives input for the approach to address this research area. Moreover, choices made in this research can be explained using the literature background. In other words, the MSC characteristics introduced in this chapter substantiate the relevance of the main concepts, particularly lead times and formal information sharing.

2.1. Military supply chains

Military organisations are often large and complex, with a vertical hierarchical structure. However, the literature addresses the organisational structure of military organisations differently. Mintzberg distinguished five different organisational configurations concerning the components of the organisation and other coordination mechanisms (Mintzberg, 2006). Feld (1959) argues that the armed forces are an instance of bureaucracy. To Herder et al. (2017), a military organisation is a traditional machine bureaucracy due to its high hierarchical structure. However, they state that due to the more dynamic environment of military organisations, the organisational structure of a traditional bureaucracy does not fit anymore. In peacetime, the structure of the military organisations can be labelled as divisional, according to Heeren-Bogers (2018). Thus, different organisational perspectives on military organisations exist.

Historically, military processes and warfare have been linked to complex logistics (Prebilič, 2006). Pepper (1988) in Brick (2019) defines defence logistics as *"a system established to create and sustain military capability*" (p.1). As stated by Prebilič (2006), "*each interruption, or omission in the functioning of logistics, will be directly reflected in the military–defense capabilities of armed forces*" (p.160). Thus, logistics are essential for defence performance and capabilities.

NATO's (1997) definition of logistics includes various logistic functions, for example, the supply function; this entails all material and items used for the military forces (including equipment, support, and maintenance). The supply function of logistics implies the relevance of supply chain management (SCM). Logistics and SCM are closely related concepts, with SCM going beyond logistics (Christopher, 2011). Yoho et al. (2013) indicate that the definition of NATO (1997) for logistics is increasingly recognised as SCM because the logistical functions described by NATO also incorporate the management of external relations and information management (IM)(Christopher, 2011). This thesis approaches the problem from the SCM perspective.

SCs are crucial for successfully completing military tasks (Prebilič, 2006). Some elements of MSCs are characterised by the organisational structure of a traditional machine bureaucracy, but other elements can be related to different organisational structures. Labelling the military organisation and MSCs is for

this study not so decisive. However, the fact that bureaucracy is often mentioned in combination with MSC systems indicates the context of military organisations (Belcher et al., 2020).

Applying general SCM literature to a military organisation requires a different perspective. According to Weber and Gerde (2011), military organisations have some general characteristics related to the structure and dynamics of corporate organisations. Nonetheless, they also describe considerable differences regarding military organisations, such as the enforcement, employment contract and mission (Weber & Gerde, 2011). Moreover, focusing on SC elements, MSCs are much different from commercial SCs (Haraburda, 2016). For MSCs, the key driver is not the costs as it is in commercial SCs. More specifically, the key driver of MSCs is that it ensures the demand can be met, even when an (uncertain) disruption occurs (Calbert et al., 2015b). Since MSCs are the main elements of military performance, this MSC capability is crucial for national and international safety. Burns et al. (2010) state the following *"the metric for military SC success is readiness for war, not profit gain"* in Sokri (2014) (p.78). This statement substantiates the need for additional literature compared to conventional SCM literature because the focus for assessing MSC performance differs. Two aspects are outlined which characterise MSCs: uncertainty and complexity.

Uncertainty
Uncertainty is a system property occurring in any complex system, including SCs. Ivanov (2021) defined uncertainty as "*a system property characterizing the incompleteness of our knowledge about the system, its environment, and the conditions of its development*" (p.3). SC uncertainty must be managed because when it is not adequately addressed, it affects the cost, speed, quality, and responsiveness (Muckstadt et al., 2003). For military organisations, the aspect of uncertainty plays a severe role. International developments affect MSCs and their uncertainty, i.e., the military demand is uncertain due to the dynamic environment. The military demand is variable and (increasingly) unpredictable (Calbert et al., 2015; Sokri, 2014; Wang, 2000). The defence capabilities of a military organisation are immediately influenced by each interruption in supply (Prebilič, 2006); this illustrates the importance of flexible MSCs. This term (flexibility) will be addressed later in this chapter.

Complexity
A second aspect that characterises MSCs is complexity. Military organisations are primarily large systems with many different departments, people, and specialisations, where many interdependencies exist between actors and various processes. Since MSCs are core for military organisations, these organisational aspects characterise MSCs. Many different disciplines are involved in military organisations and MSC processes. First, the political and legislative components and technical, economic, and organisational aspects play a role. Military organisations are assessed as complex systems, including external and internal uncertainties. Moreover, warfare is highly complex (Prebilič, 2006). Some MSC components contributing to MSC complexity are described below.

Military supply chain components
Uncertainty and complexity indicate differences between MSCs and commercial SCs. Typically, an SC includes a material flow from the supplier to the demand side. For a military organisation, the demand side is expressed by operational units requesting material, equipment, and spares to fulfil their operational tasks. Information in the form of demand flows from the operating units to the supplier via formation headquarters (Wong et al., 2018). A visualisation presents these upstream and downstream network flows (Figure 3). Two other components of the MSC are the cost and time aspects.

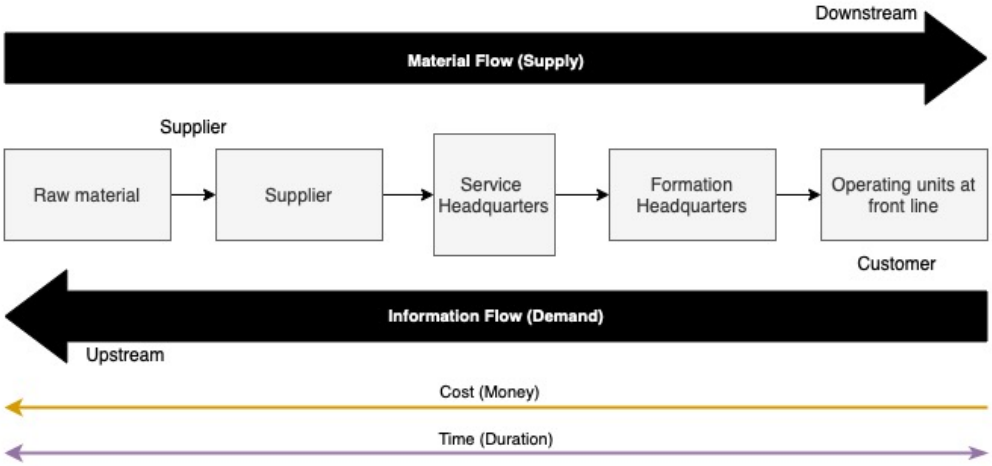

Figure 3. Military supply chain (Wong et al., 2018)

Different stakeholders are involved in an MSC, which results in a unique playing field. The various stakeholders have their tasks, objectives, behaviour, and interests. For a military organisation - a public organisation that provides protection and defence to the nation - the relationships with suppliers and customers are unique to other SCs (Wong et al., 2018). From the external supplier side, the objective is profit-making and product selling, as in general SCs. For military organisations, the customer value is related to the availability and capability of efficient and effective operation (Wong et al., 2018). Therefore, Wong et al. indicate the importance of a good and solidary relationship with the supplier to achieve cost and value advantages for both the supplier and the customer in MSCs.

Due to the multi-actor setting, information sharing in the MSC system is essential. According to Wong et al., sharing information - of all types - will result in cost reduction and improvements for both the military organisation and the supplier. The relevance of information sharing as a component of MSCs is further described in paragraph 2.3.

Besides the differences in network flows (material and information flows), MSCs contain different processes. The structure of an SC is generally determined by the network of stakeholders (SC members) and the links between them. Additionally, activities are linked to these SC stakeholders, which indicate processes (Lambert et al., 1998). Moreover, Lambert et al. (1998) describe the importance of SCM for SC process integration in order to stimulate process efficiency and effectiveness within the SC. The importance of integrating different SC activities is determined by Hines (1993). Hines (1993) distinguishes between primary and secondary SC activities, where the primary SC activities are of key importance for the SC stakeholders. According to Wong et al. (2018), Hines' model of SCs can be used for optimising MSCs. In this research, based on the distinction between primary and secondary SC activities, the distinction is made between primary and secondary MSC processes.

According to Kleijn and Rorink (2009), primary SC processes refer to the products' physical creation and distribution; supportive SC processes support the primary SC processes (Muthoni et al., 2015). Integration of the supportive process with the main activities is essential for MSCs. Primary MSC processes are in this research referring to the physical creation and distribution of material. Secondary MSC processes support the primary MSC processes.

Overall, this paragraph delineates some relevant components and aspects of MSCs. The following section elaborates on another element of MSCs: *lead time*.

2.2. Lead time

As indicated in Figure 3, one of the components of an MSC is the duration (Wong et al., 2018). Lead time, another term for the duration of a SC process, is a central concept in this research. This section presents a literature background to indicate the relevance of reducing lead times in MSCs. Appendix A gives an overview of the completed structured literature study. First, flexibility will be introduced.

Flexibility is a driver for the importance of lead time reduction in MSCs. After that, the results of the literature study are outlined.

Flexibility
Rice and Caniato (2003) describe the importance of flexibility for SCs. They state that flexibility is about an organisation's capabilities to respond to SC disruptions. More specifically, Tachizawa and Gimenez (2010) define supply flexibility as *"the ability of the purchasing function to respond in a timely and cost-effective manner to the changing requirements of purchased components in terms of volume, mix, and delivery date."* (p.214). Beamon (1999) states that SC flexibility is crucial for the performance of SCs since there are many uncertainties affecting SCs. The importance of flexibility is substantiated by other authors as well. Sani et al. (2022) describe the importance of flexibility specifically for MSCs. Sani et al. illustrate the consequences when, for example, military supplies are subjected to natural calamities, social crises, or terrorism. Conclusively, the supply and demand disruptions in the military environment, especially in warfare, can be substantial, and flexibility is needed to cope with these demand disruptions.

Stevenson and Spring (2007) performed a comprehensive literature review on general SC flexibility. Besides this, they explore the meaning of flexibility in an SC context. As a result, their research concludes that flexibility is multi-dimensional, that certain elements are more critical than others depending on the environment, and that it does not have to be demonstrated. Sokri (2014) states that one of the key performance indicators showing the responsiveness of MSCs is flexibility, which is essential for the success of military operations. Thus, Sokri suggests future research on MSC flexibility, which should focus on a multi-objective (time-cost-volume) approach.

Lead time reduction
Manders et al. (n.d.) performed a literature review on SC flexibility and concluded that SC flexibility includes many different dimensions. As flexibility can be divided into several subcomponents, the delineation of this study is further sharpened by establishing lead times as the primary focus. A factor closely related to flexibility is velocity, as determined by Jüttner and Maklan (2011). Besides this, according to the Cranfield School of Management (2003), lead time is a crucial indicator of SC velocity. Moreover, Sokri (2014) developed three metrics to assess MSC flexibility. Two of these metrics are related to delivery flexibility, defined in the research as "*the ability to meet short lead times*" (p.82). This statement substantiates focussing on the reduction of lead times in MSCs to contribute to flexibility of MSCs. Furthermore, Loredo et al. (2015) recommend reducing internal lead times to cope with demand fluctuations and uncertainty. Besides this, Reinders (2019) summarises that short lead times ensure quick responses to SC disruptions and that lead time is a key performance indicator for robustness in SCs in a military context.

Non-value-adding activities
Some references suggest how lead times can be reduced. For example, according to Muckstadt et al. (2003), adopting Lean philosophies to reduce lead times is one of the five principles of SCM to manage uncertainty. The Lean management methodology is derived from the Toyota Production System (Chiarini, 2013). Lean focuses on waste elimination, where waste can be seen as "*anything that does not add value to the end-product*" (Ikumapayi et al., 2019) (p.3277). Examples of types of waste are waiting (time) and defectiveness (lacking products or services) (Chiarini, 2013). Specifically, for the reduction of lead times in MSCs, non-value-adding activities resulting in higher lead times should be reduced. Acero et al. (2020) suggest further research on applying Lean methodologies to other military processes. Lean supply chains aim to respond quickly and profitably to marked demand fluctuations (Muckstadt et al., 2003). When solving problems resulting in non-value-adding activities, lead times of MSC processes can be reduced.

Lead time reduction in financial supportive processes
MSCs include supportive processes like financial supportive processes. The distinction between primary and secondary SC activities is determined at the beginning of this chapter. Supportive processes facilitate the primary SC activities. Inefficiencies and issues in the supporting processes will not always

directly influence the MSCs' main activities. However, as Hines (1993) and Wong et al. (2018) argued, good long-term relationships with the supplier and integration of the supportive process with the main activities are essential for MSCs. Reducing lead times in the financial supportive process is beneficial for several reasons. A summary is presented in Figure 4.

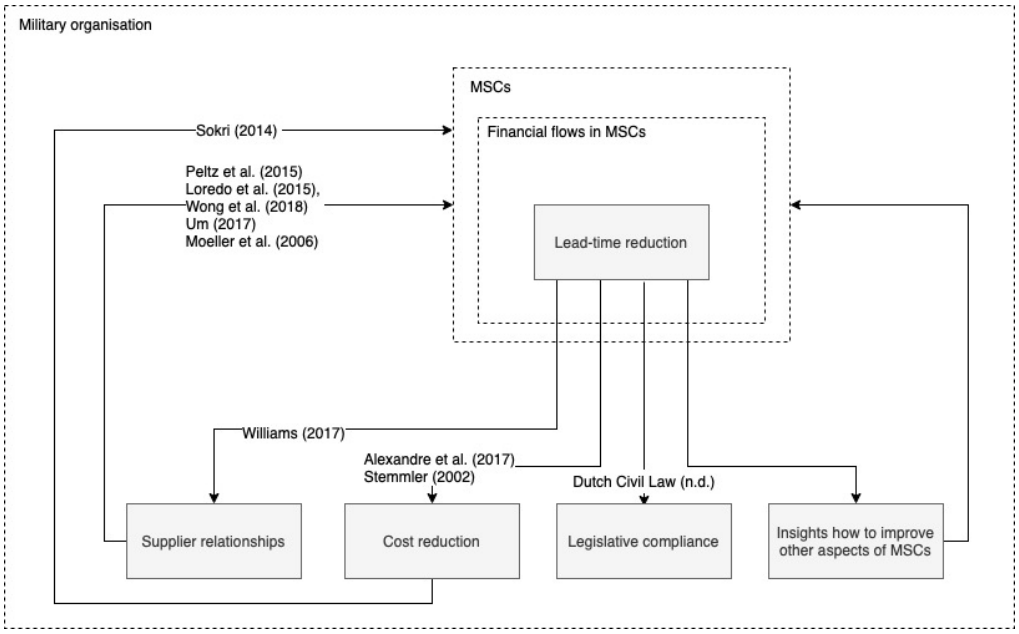

Figure 4. Summary of organisational relevance

Lead time reduction of financial flows in MSCs can influence the following aspects within the military organisation:

- supplier relationships;
- cost reduction;
- juridical compliance;
- insights into how to improve other aspects of MSCs.

References can substantiate the first three aspects. The fourth aspect is added because it is assumed that insights into lead time reduction in financial supportive processes of MSCs can be used to reduce lead times of other MSC processes.

1. Supplier relationships

The relationships between the military organisation and external suppliers are essential for the MSC processes. Peltz et al. (2015) describe that orders from defence organisations require more administrative work and deliver less profit for external suppliers than commercial clients. Thus, defence organisations must commit to more competitive advantages due to the less profitable relationship. Furthermore, the importance of a supplier relationship is discussed by Loredo et al. (2015), who indicate strong supplier relationships as an SC risk mitigation strategy. Paragraph 2.1 describes that the integration of SC players (like external suppliers) is essential for primary and secondary activities (like financial support) in MSCs (Wong et al., 2018). Therefore, supplier relationships are essential for MSCs, including their primary and secondary processes.

High lead times of payment processes do negatively influence supplier relationships. Williams (2017) argues that delayed payments and slow invoice processes may affect business relationships negatively. Therefore, to cope with uncertainty, supplier relationships are crucial. The importance of good supplier relationships is substantiated by Moeller et al. (2006); they state that professional supplier relationship management is needed due to the increasing dependence on suppliers. Furthermore, according to Um (2017), external SC integration (including supplier partnerships and close customer relationships) affects the flexibility of an SC.

2. Cost reduction

Optimizing the financial flows in SCs can result in cost savings (Stemmler, 2002). Moreover, Alexandre et al. (2017) state that an organisation achieves economic benefits when lead times are reduced and focused on saving costs. Furthermore, the military organisation has payment deadlines because of national legislation (Dutch Civil Law, n.d.). When the payment deadline is exceeded, a penalty or interest has to be paid. Lead time reduction of the payment process can result in better payment behaviour and cost savings. Moreover, as described in the introduction, SCs are driven by time and budget (Sokri, 2014). More specifically, Sokri (2014) concludes that flexibility is vital for MSC performance: "*flexibility is an important characteristic of a high-performance SC as it indicates the ability of the SC to respond in a timely and cost-effective manner to any change in the end-user demands and delivery dates*" (p. 84). Therefore, cost reductions contribute to the flexibility of SCs.

3. Juridical compliance

As described above, military organisations have payment deadlines (Dutch Civil Law, n.d.). Payments will be faster when reducing the lead times of financial flows within military organisations. Reducing lead times contributes to removing outstanding payments and increases compliance with legal obligations. Therefore, lead time reduction can contribute to the satisfaction of the legal payment term. Furthermore, governmental payment policies are critical to many suppliers in EU countries due to the government's size (Checherita-Westphal et al., 2016).

4. Insights into how to improve other aspects of MSCs

When this research identified factors that can support the reduction of the lead times of a financial supportive process of an MSC, these factors can apply to other military processes. These insights may be generalisable when similar delay causes are found in other MSC processes. Achieving lead times reduction of the financial supportive process by improvement can give insights; it can provide insight into how to improve other parts of SCs in a military organisation.

Thus, generally, this paragraph presents the relevance of lead time reduction of financial supportive MSC processes. Reducing lead times of financial supportive MSC processes can reduce costs and increases juridical compliance. Furthermore, reducing lead times of financial supportive MSC processes is important to improve supplier relationships. For military organisations, supplier relationships and cost reductions are important for the functioning and flexibility of their MSCs. The following paragraph will further examine the link of SCs to information sharing.

2.3. Formal information sharing

Aitken (1998) defined a supply chain as "*a network of connected and interdependent organisations mutually and co-operatively working together to control, manage and improve the flow of materials and information from suppliers to end users*" (p.67). From this definition, it becomes clear that the flow of information is an essential part of a supply chain. Even more so, this information flow must be controlled, managed, and improved. Moreover, information is a crucial element for SCM and is essential for enhancing SC performance (Kembro et al., 2014). However, information sharing is a concept used in many ways.

The term process information becomes applicable from a process perspective on SC systems. Van der Aa et al. (2015) define process knowledge as "*a particular type of corporate knowledge that relates to processes, their context, and their execution*" (p.3). Furthermore, they describe that the explicit process knowledge is captured as *process information* (Van der Aa et al., 2015). Using the term "explicit" asks for clarification. Van der Aa et al. (2015) describe that explicit process knowledge does not include tacit knowledge, which domain experts or process participants can provide. This study is further scoped by focusing on *formal* process information.

Generally, related to information sharing in organisations, a distinction can be made between formal and informal information sharing, where formal information sharing occurs in a structured, traceable, and formal setting (Lai & Yang, 2017). The distinction can also be found in the following quote "*we delineate two criteria for characterizing a dissemination event as being formal or informal-verifiability*

and spontaneity" from Stohl and Redding (1987) in Maltz and Kohli (1996, p. 48). Bartol and Srivastava (2002) state that formal interaction is a knowledge-sharing mechanism. However, this view indicates the formality of the interaction and not the information. Addressing only formal information (instead of all information) to identify problems related to SC lead times makes this study more feasible and focused. For this study formal information sharing is defined as: *sharing structured, traceable information, which is located in a formal setting,* by using the definition of formal information sharing from Lai and Yang (2017).

Furthermore, two types of formal process information are distinguished in this research: *formal process design information* and *formal process in practice information*. This distinction is also indicated by Van der Aa et al. (2015): "*contrast to information captured in e.g. process models, business rules, and text documents, which represents desired or supposed process behavior, so-called event data represents information about the reality of a process" (p.10).* Thus, for this study, formal process design information is the formal information that relates to the prescribed processes: including process models, business rules and text documents. The formal process in practice information refers to the formal information used in the execution of processes.

Formal process information is used to execute and enhance processes. However, when formal information is inadequate, incomplete, or missing, problems will arise. When the formal process in practice information is inadequate, incomplete, or missing, process steps requiring this correct formal information cannot be executed. This situation can result in waiting time or repair actions to correct this formal process in practice information. Therefore, formal process information is relevant to analyse problems related to the lead times of SCs. Furthermore, adequate and complete formal process design information is relevant to enhance process improvements. Van der Aa et al. (2015) suggest that process knowledge should be available when needed. However, an der Aa et al. (2015) specify the problem that process knowledge is often scattered throughout the organisation, referred to as 'information fragmentation'.

To conclude, information is essential for the functioning of SCs. Two specific types of information are relevant for SCs: formal process design information and formal process in practice information. When looking at SC processes, problems related to formal process information can affect the lead times of SCs. Therefore, formal process information is relevant for lead time reduction in SCs.

2.4. Closing remarks literature background

In this chapter, a literature background is provided. The chapter introduces several concepts related to military organisations. Specifically, the interest of this research goes to the complexity and uncertainty as two characteristics of military organisations relevant to SCM. These aspects of MSCs provoke additional research in the general SCM literature. Furthermore, the literature background gives insights into MSC components. Not only primary material flows are relevant, but also the information flows resulting from the multi-actor environment, cost, and time are vital for the functioning of MSCs. In the chapter, the need for flexibility in MSCs is argued, and this is further directed to lead time reduction. From this part of the literature background, the first sub-question can be answered, presented in chapter 8.

Additionally, focusing on financial supportive processes as part of MSCs is relevant because of four aspects: strengthen supplier relationships, obtain cost reduction, achieve juridical compliance, and generate insights into improving other aspects of MSCs. Moreover, this chapter describes the component of formal information sharing and its relevance. Specifically, the relevance of formal process information is defined for SCs. Inadequate, incomplete, or missing formal process information can be a problem regarding the availability of required information. The second sub-question can be answered based on this second part of the literature background, presented in chapter 8.

The chapter ends with the introduction of 'information fragmentation'. Questions arising from introducing *information fragmentation* are "what is information fragmentation?" "How is information

fragmentation used in the current literature?", "What is the effect of information fragmentation on lead times?" etcetera. Therefore, this study further elaborates on this term. The next chapter presents the research approach of this study. The chapter explains how these questions about information fragmentation are addressed in this research, using the structure of the research objective, problem and questions presented in the first chapter.

Chapter 3. Research approach

"If we knew what it was we were doing,
it would not be called research" ~ Albert Einstein

This chapter outlines the research approach. The characteristics of the scope formed input for the selection of an appropriate research approach for this study. Furthermore, the previous chapter introduced several relevant concepts. Based on the literature background, it becomes clear that additional research is needed to develop an information fragmentation perspective and apply this perspective to get empirical insights into lead time reduction in MSCs.

Specifically, two main aspects are described in more detail: the development of the information fragmentation perspective and the case study, where this framework is applied to the case. Altogether, this research approach directed this study by indicating the different research steps and their objectives.

3.1. General research strategy

Based on a better understanding of MSCs, and their components, the importance of reducing MSC lead times is outlined in chapter 2. Specifically, formal information sharing within these complex, uncertain MSCs has given input for additional scientific research. As concluded in the previous chapter, information fragmentation is a relevant term to analyse more in-depth. However, an information fragmentation perspective, including the definition of information fragmentation and its relations (with, for example, lead times), is missing for MSCs. This research provides qualitative research on the reduction of lead times in MSCs.

Therefore, this research starts with the development of an information fragmentation perspective. Existing literature is used to create this perspective specifically for MSCs. Consequently, two propositions can be derived from the information fragmentation perspective. The approach of developing the information fragmentation perspective and deriving two propositions (P1 and P2) is outlined in paragraph 3.2.

Subsequently, the perspective is applied to a case to test whether these propositions are confirmed by practice. Yin (2009) argues for the appropriateness of case studies for explorative research and explanatory research. In this research, the case study will apply explorative analysis to understand information fragmentation as a problem for MSCs. Furthermore, the case study is used for explanatory research to explain effects (related to P1 and P2) obtained from the literature included in the information fragmentation perspective. Suarez et al. (2016) state that case studies help understand complex social phenomena. MSCs are complex and uncertain systems (as described in chapter 2); therefore, the case study aims to understand whether information fragmentation is problematic for high lead times in these MSCs. Thus, on the one hand, the case study aims to contribute with insights about the reduction of lead times in MSCs (knowledge gap 1); on the other hand, the case study provides empirical insights into formal information sharing, which can contribute to improved SCM (knowledge gap 2).

Chapter 2 describes the importance of lead time reduction for secondary and primary MSC processes. Specifically, the relevance of financial supportive processes as a research topic is supported. Therefore, a financial supportive MSC process from the MoD is selected as a case study. Paragraph 3.3. provides more information about the case study at the MoD.

Eventually, the results obtained in the study are interpreted and discussed. Furthermore, conclusions are drawn regarding the main research question concerning the answers to the sub-questions, the research objective, and the research problem. An overview of the research approach is presented in Figure 5.

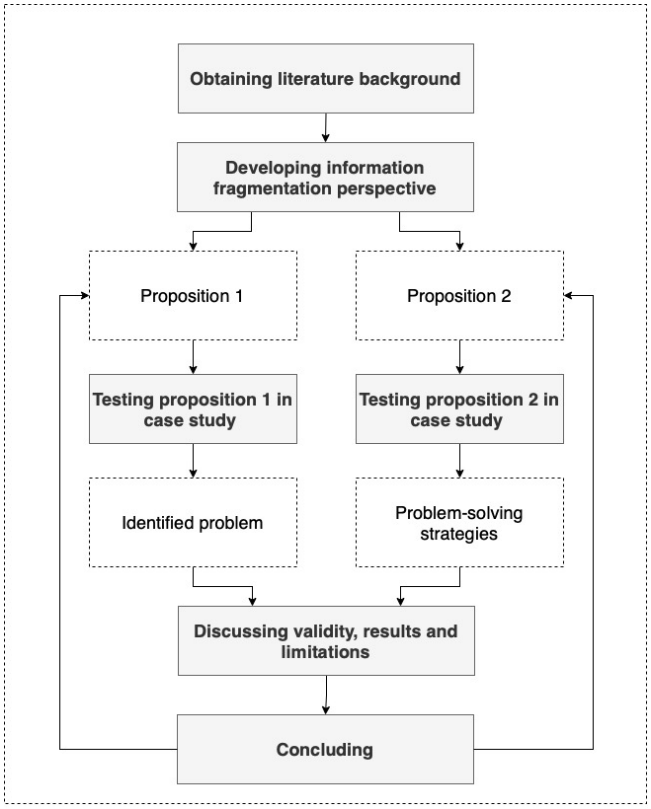

Figure 5. Research approach

3.2. Case study

The case selected for this study is the invoice process at the Dutch MoD. Currently, the MoD is facing problems related to lead times of the invoice process, resulting in many open bills, error messages, incomplete orders, etcetera (MoD01). The invoice process's functioning is essential to achieve well-functioning, flexible MSCs. Therefore, this case is selected for analysis by applying the information fragmentation perspective towards lead time reduction in MSCs. The current situation regarding lead times in the invoice process is further discussed in chapter 5.

In Figure 6, the case study design is presented. This figure shows the relationship between formal information sharing and lead time reduction for the case. The context of the case is also visualised. The invoice process at MoD is an example of a particular financial flow within MSCs. Formal information sharing, defined in chapter 2, occurs within invoice processing and beyond. Moreover, formal information sharing also takes place across the organisational boundaries of military organisations. Examples are the rules and regulations from (inter)national governmental organisations and the agreements between a military organisation and external suppliers.

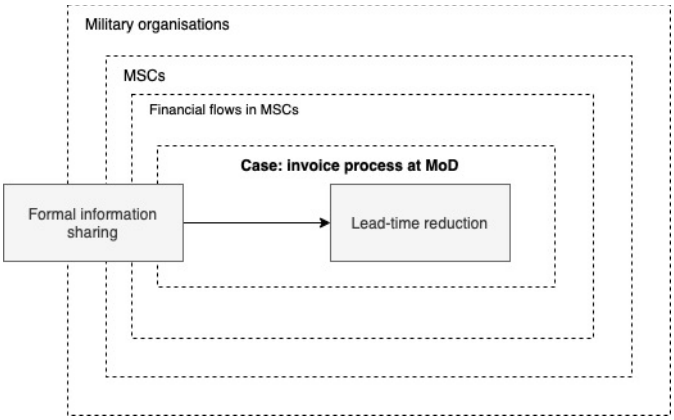

Figure 6. Case study design

The context of the financial supportive processes of MSCs and the role of these financial supportive processes in military organisations indicate the practical relevance of the case study. In addition, the invoice case study is examined to contribute with insights on information fragmentation and its relationship with invoice process lead times.

Case study approach

An approach widely used for analysing and solving lead time problems is DMAIC (including five phases: Define, Measure, Analyse, Improve, and Control, originating from Six Sigma[3] and commonly used in Lean). DMAIC is a cyclical approach to problem analysis and problem-solving. Several aspects of this approach were used, such as some related methods and tools (described in the next chapter, where the methods used are discussed), when analysing lead time issues in the case. However, the DMAIC approach is not entirely applicable to this exploratory study due to its structured setup in successive phases. Therefore, a different approach is chosen, which starts with developing a new perspective to explore whether an information fragmentation perspective is helpful in the practice of MSC processes. The invoice case is specifically analysed via two propositions. These propositions are derived from the developed information fragmentation perspective created using literature. Subsequently, the first proposition is considered in the invoice case by problem identification. The second proposition is considered by exploring two problem-solving interventions for the identified problem.

3.3. Closing remarks research approach

This chapter describes the research approach of this research. This research approach is developed to approach the main research question and objective. Specifically, two main aspects are described: the development of the information fragmentation perspective and the case study at MoD. Based on this general strategy and the introduction of the case characteristics, the research steps can be linked to the applied methods and tools.

[3] The Six Sigma management methodology is developed during the 1980s at Motorola (Shah & Deshpande, 2015). Six Sigma uses the DMAIC approach, including many tools, for solving quality problems (Furterer & Elshennawy, 2005).

Chapter 4. Methods

"*Technique and ability alone do not get you to the top;*
it is the willpower that is most important" ~ Junko Tabei,

In qualitative research, the design characteristics are flexible, evolving, and emergent, while quantitative analysis is more structured and predefined (Office of Research & Doctoral Services, 2015). Research from Venselaar and Gruis (2016) addresses intra-organisational SC dynamics for an SC issue using a case study approach. Since the problems related to lead times and (formal) information sharing in MSCs are not clear enough for quantitative testing and measuring the topic of interest, the flexibility of qualitative research is favourable. A case study is applied to obtain a better understanding of phenomena and test whether practice confirms two propositions. Furthermore, in this research, different methods and tools are used.

An empirical case study method is used in this research focusing on qualitative research. Currently, an accurate understanding of the problems related to lead times in MSCs is lacking. One case is selected to understand better the factors influencing the lead times in MSCs: the invoice case at the MoD. Before the execution of research with a focus on problem-solving, the problem must be understood first. Therefore, this research focuses on understanding the invoice case at MoD and identifying a problem related to information fragmentation and lead times.

Case study methods can help identify new or omitted variables and hypotheses. They can identify specific causal mechanisms and explain and model complex relationships using contingent generalisations (Andrew Bennett, 2004; Zainal, 2007). Using case studies allows us to investigate causal processes in the real-world (Krusenvik, 2016). In this research, the case study helps identify causal mechanisms influencing the lead times of MSCs. Moreover, the case study translates aspects of the current process in the invoice case into a process model. A process-tracing method supports the case study execution with the process analysis. The comparison is made between the actual process (**'process in practice'**) and the **'process design',** including the focus on formal information sharing.

The use of system analysis to investigate military problems is not new; it started long before 1961 (Snyder, 1973). Snyder identified that case material, and military decision-making studies were relatively limited at the time. Consequently, Snyder's publication contributes insights into the general system analysis of military problems. This research uses system analysis to analyse a specific issue related to the invoice process at MoD. Purely focusing on the invoice process would not be sufficient since the interaction with the ordering process influences the system of the invoice process. The MSCs addressed in this research relate to the invoice process and are linked to the supply of land systems, the reparation of land systems and the supply of supportive items needed for a mission.

This chapter further addresses the methods and tools applied in the research. A research flow diagram is presented in Appendix B to give an overview of the relationship between the methods, research steps and research questions. An overview of the selected methods and tools is presented in Appendix C.1.

Chapter 2 presented the literature background; therefore, some details about the creation of this literature background are provided in the first paragraph of this chapter. The second paragraph of this chapter contains the methods and tools used to develop the information fragmentation perspective. Furthermore, several different methods and tools are used in the case study. Paragraph 4.3 outlines these methods and tools.

4.1. Obtaining literature background

As a starting point, a structural literature study was performed. This study aimed to obtain a background of existing literature about MSCs concerning (the reduction of) lead times and the relevance of formal information sharing. The analysis was performed using different keywords and Scopus as facilitating database. In Appendix A, a visualisation of the structured literature study is presented. First, a selection

is made based on the publications' titles and abstracts. Subsequently, the full text is assessed for eligibility. Moreover, backward snowballing and forward snowballing techniques were used.

4.2. Development of an information fragmentation perspective

This study departs from the literature background and the implication of information fragmentation as a relevant factor for lead time problems in MSCs. However, an information fragmentation perspective toward reducing lead times in MSCs is missing. Therefore, this study develops one.

The concept of information fragmentation is introduced in the scientific literature. The first step for developing an information fragmentation perspective for MSCs is to understand the concept of information fragmentation and how this concept is currently used in literature. Furthermore, it was also examined whether these retrieved articles mentioned anything about lead times in SCs to indicate the relationship between information fragmentation and SC lead times. A structured literature study is performed to fulfil this first step. The literature study on information fragmentation aimed to obtain a background of existing literature using *information fragmentation* in an organisational or multi-actor context. The literature study is only completed for the application in an organisational or multi-actor context to exclude applications of this term (information fragmentation) in entirely different research areas (such as its application at the molecular level in the chemistry research field). The study uses different keywords and Scopus as facilitating database, resulting in 34 hits. First, a selection is made based on the publications' titles and abstracts (n=15). Subsequently, the full text is assessed for eligibility (n=14). Moreover, the backward snowballing technique was used, which delivered two additional publications. In total, 17 articles were selected. More details of the literature study can be found in Appendix F. The focus of the publications is assessed. Furthermore, a summary is made for one specifically relevant article, which applies information fragmentation in an SC context. From this literature study, an expected effect is formulated in a proposition. This first proposition indicates the problem of information fragmentation and the relationship between information fragmentation and lead times in MSCs.

As a result of the analysis related to information fragmentation, the concept of boundary objects is introduced. First, some explorative research is performed on boundary objects. This exploration aroused attention to consider boundary objects as an intended problem-solving intervention for information fragmentation. Subsequently, a structured literature review is carried out to obtain a background in the previous applications of boundary objects in combination with SC literature. The study was performed using different keywords and Scopus as facilitating database; this resulted in 8 hits. More details can be found in Appendix G. Firstly, a selection is made based on the publications' titles and abstracts (n=5). Subsequently, the full text is assessed for eligibility; all five publications turned out to be eligible. No additional snowballing techniques were used because the five papers have been considered sufficient. The main effects relevant to this research about information sharing, boundary objects and SC performance were summarised for each publication. Furthermore, the main insights from comparing the five publications were indicated. Moreover, the main effects (discussed in the summaries) are visualised in one figure. Conclusively, based on this literature study, a second expected effect is formulated as a proposition. This second proposition indicates the expected effect of boundary objects on information fragmentation in MSCs.

4.3. Case study methods

As argued in the research approach, a case study is performed to apply the information fragmentation perspective and test the propositions in practice. Empirical data are collected applying the information fragmentation perspective to the case. Specifically, the application of the perspective entails identifying a problem resulting from information fragmentation affecting the lead times of the invoice process. Furthermore, this perspective application entails the identification of possible boundary objects and testing the expected effect in the case. Interviews and a focus group session were primarily used to obtain relevant empirical data. Besides this, document analysis and quantitative data are obtained to contribute to the triangulation of empirical data. Yin, 2009) argues that incorporating a variety of data is a unique strength of case studies.

Interviewing
Semi-structured interviews (n=11) are conducted to obtain qualitative empirical case data. These interviews were exploratory in nature and used to understand the issues at hand. Interviewing is selected as the primary data collection method for the case study to have flexibility during the problem identification. Since the MoD is a complex organisation and the issues were not clear in advance, the flexibility of interviewing corresponds with the explorative nature of the research. In addition, the interviews are used as validation for previous analyses based on documentation, quantitative data, and other interviews. Appendix D presents an overview of the performed interviews, including the date of execution. This table includes codes for the reference in this thesis. All the interviews were held with internal MoD employees. The meetings were prepared in advance, and a list of questions was devised.

Moreover, field notes are made for all interviews to assess verbal and non-verbal communication, which refers to the different questions. At the earliest opportunity, all the notes were included in the elaboration of the interview. The prepared list of topics for one interview was sent in advance at the respondent's request (MoD09). Participants were selected based on consultation with the MoD. Some respondents were selected through a referral from MoD contact persons; others were approached by the corresponding researcher directly. All participants had to relate in some way to the invoice case at MoD as a stakeholder (including context setters).

Alshenqeeti (2014) indicates the advantages and disadvantageous of interviewing as a data collection method for qualitative research. Alshenqeeti describes that semi-structured interviews offer flexibility and freedom to interviewees and interviewers. This flexibility contributes to the explorative research approach of this study as it will enable adaptions during the interviews. However, interviewing is time-consuming, never completely anonymous, and inconsistencies may arise (Alshenqeeti, 2014). In this study, the value of the stakeholders' experiences is crucial, and insights into inconsistencies are for the problem exploration interesting. The anonymity of the respondents is pursued as much as possible. Furthermore, the data collection and storage align with the requirements of the respondents and the MoD.

Before the data analysis, the interview data were anonymised. The discussed themes were mainly determined prior to the interviews. The field notes of the interviews were categorised by these themes and nominal coded (coding is presented in Appendix D).

Focus group
Furthermore, empirical data are collected in the form of a focus group. The corresponding researcher facilitates the focus group in collaboration with an expert facilitator of the organisation (Directorate of Business Operations and Evaluation, section Governing and Innovation). Moreover, participants for the focus group were selected based on contacts obtained in the interviews and new connections acquired via the MoD network. The participants represent the different stakeholders of the supply chain related to the invoice process at MoD. Generally, participants are employees of the MoD from MatLogCo, the payment office, and another purchasing logistics department of the Royal Netherlands Army (OTCO[4]). The involved stakeholders are discussed in chapter 5. More details about the respondents are presented in Appendix E, and more details about the planning and content are presented in Appendix I.

The focus group aimed: to validate whether the stakeholders of the case acknowledge the mechanisms derived from the information fragmentation perspective in the invoice case. Specifically, this entails acknowledging the identified problem related to information fragmentation and lead times and exploring two problem-solving interventions, both including a boundary object. During the focus group an interactive presentation is given by the researcher about the research topic and findings, including points for discussion, questions, and assignments (e.g., brainstorming session).

The primary data obtained during the focus group are forms, including answers to questions and sticky notes used in the brainstorming session. The forms included the responses of the respondents to the

[4] OTCO: Education and Training Command (Opleidings- en Trainingscommando)

questions. Noting the answer before discussing the question helped the respondents form an answer to the question and as input to the discussion. The answers to the questions written down on paper are referred to according to the coding provided by Appendix G. The brainstorm sticky notes were coded by colour, where yellow sticky notes were general ideas, green sticky notes for chances, advantages and positive points and pink sticky notes for challenges, disadvantages, or concerns. The output of the brainstorming session is referred to according to the coding provided by Appendix G.

Besides this, the discussion is observed, and citations are analysed. It was decided not to audiotape the session to make the focus group low-key and to pursue freely expressed opinions. External observers attended the session to ensure adequate records and interpretation of the data. The observers have been briefed and used a protocol presented in Appendix I. Non-verbal and verbal communication is observed, and field notes have been made. All the participants signed an informed consent, which addresses data collection and processing of personal data and sensitive information. All data are anonymously incorporated in this thesis. A central concern of focus groups is generalisability. However, for exploratory research, the issue of generalisability is not crucial (Byers & Wilcox, 1991). The results must be carefully interpreted while making conclusions for general MSC processes.

Document analysis
Document analysis is performed for the collection of case study data. The document analysis includes documentation accessible via the MoD databases and publicly accessible references. Specifically, the references relate to legislation, MoD policy and regulation, ARIS[5] process descriptions, earlier research, and MoD documentation. The publication portal at the MoD and the internet were used to obtain the documents. Document analysis has advantages like its efficiency and the lack of reactivity (Bowen, 2009). These advantages contribute to getting insights efficiently without the need for reflexivity. However, the documents may be deficient in detail and have low retrievability (Bowen, 2009). Since the incompleteness or accessibility of documents can also be part of the problem situation, these disadvantages are interesting for this research. Besides this, Bowen (2009) indicates the possibility of biased selection for document analysis, which is disadvantageous for the research quality. The interviewees were also asked for suggestions on any additional relevant documents related to the processes to overcome the negative consequences of biased selectivity. The documents selected for the case analysis were stored - in line with the regulation of the MoD - using different (sub-)labels related to the topic. Relevant subsections are marked, and notes are added to the documents to support the analysis.

Quantitative data
Additional quantitative data are used where possible and accessible. Due to the constraints in data accessibility and the capabilities of information management (IM) at the MoD, the availability of quantitative data at the MoD is limited. The quantitative data characterise the current invoice process at the MoD. Lead times of steps in the invoice process have been attempted to be retrieved. However, due to the dependence on the external organisation (MoD) and their capabilities in data analytics, quantitative data are only supplementary used. Quantitative data are retrieved from the digital environment of the MoD in line with the regulation. For specific data, a graph or visual is directly retrieved from the MoD; for other data, aggregations are made in the form of a figure or table.

Process design versus process in practice information
The data analysis of all the retrieved case-related data can be divided into two collections: data related to the process design and data associated with the process in practice. The '**process design'** contains all formal information focusing on the prescription of the process. Thus, the process design includes policy, legislation, work instructions, process descriptions, traceable procedures, and formal stakeholder relations. The **'process in practice'** information contains all information used during the execution of the process and about how the process is functioning. This information includes, for example, quantitative data, actors' perspectives on the process, insights into the actual process functioning, and documentation in the form of reflection.

[5] ARIS is an Enterprise Management System used at the MoD (further explained in chapter 5)

Data analysis
The empirical data obtained in the case study relate to the information fragmentation perspective. Several data analysis methods are used to explore and identify a problem related to information fragmentation and lead times in the case.

Generally, systems modelling is used to structure the empirical data. Yin (2011) suggests that the data analysis of a case study can start with systematically organising the data by identifying hierarchical relationships, making matrices, and using other arrays. The Office of Research & Doctoral Services (2015) determined that data analysis in qualitative research includes three steps: preparation and organising data, reduction into themes, and presentation of the data in narrative or graphical form. In this research, those three steps are included.

First, a stakeholder analysis is performed, and a 'formal chart' is created to present stakeholder relations. Furthermore, different modelling techniques are used to conceptualise the data as a process conceptualisation (process map). For the presentation, graphical modelling approaches are applied. Systems modelling is used to conceptualise and analyse the system of the selected case using Diagrams.net. This data presentation methodology is relevant for analysing supply chain processes because it helps to overview the process. BPMN is a common modelling language for visually representing (business) processes and information systems. Therefore, a BPMN is made for the invoice case.

Additionally, Value Stream Mapping (VSM) is used to visualise information and material flows concerning lead times to indicate where in the process relatively high lead times occur (Turkyilmaz et al., 2013; Żywiołek, 2016). VSM can be used to identify activities that do not add value for the customer; this can contribute to the reduction of non-value-adding activities and the efficiency of the process (Gremlin, 2016). Specifically, VSM can be used for supply chains (Suarez et al., 2016) to reduce process lead time (Acero et al., 2020; Chowdhury et al., 2016).

Furthermore, process tracing is applied as a method to analyse the process in practice. Process tracing is a valuable tool because the research will be case-related qualitative research (Collier, 2011). George and Bennett (2005) define process tracing as the examination of *"histories, archival documents, interview transcripts, and other sources to see whether the causal process a theory hypothesizes or implies in a case is, in fact, evident in the sequence and values of the intervening variables in that case"* (p.6). Beach and Pedersen (2013) distinguish three different uses of process tracing: theory-testing, theory-building and outcome explaining. The last one focuses on the case and the explanation of historical results. This research focuses on how the process in practice related to invoicing is going and how information fragmentation elements negatively influence lead times. Tansey (2007) states that interviews with key players can validate an initial overview of events retrieved from documents. Besides this, Tansey (2007) argued that interviews could give insights into the decisions and actions behind certain circumstances. These interviews are especially relevant for process tracing. Insights into the process in practice can help identify problems related to information fragmentation and lead times. Furthermore, insights into the process in practice can be compared to the process design.

As described in the previous chapter, several methods and tools related to the DMAIC approach are used in the research. Appendix C.2 details these tools and methods and their relationship with the DMAIC approach.

4.4. Closing remarks methods
This chapter described the applied methods and tools for this study related to the different research steps. Since the literature background is already presented in chapter 2, this study will move on to the following research step: developing the information fragmentation perspective. The next chapter presents the outcomes of the literature study.

Chapter 5. Information fragmentation perspective

"*All models are wrong, but some are useful*"
~ George E.P. Box

Chapter 2 introduced several components of MSCs relevant to this research. The chapter ends with substantiating the relevance of developing an information fragmentation perspective towards lead time reduction in MSCs. Accordingly, this chapter presents the next research step: developing the information fragmentation perspective.

This chapter starts with a further introduction to the term *information fragmentation*. As a result of a literature study, an understanding of information fragmentation is obtained; this is the first part of the information fragmentation perspective. Specifically, several indicators for information fragmentation are outlined. Furthermore, information fragmentation is related to lead time reduction in SCs. Consequently, from the information fragmentation perspective, the first proposition is derived (paragraph 5.2.).

Assuming information fragmentation increases lead times by adding non-value-adding activities, information fragmentation is considered a problem for MSCs. In that case, it is relevant to include also a problem-solving dimension in the information fragmentation perspective. Indeed, several articles in the literature review substantiate the problematic characteristic of information fragmentation. Hence, certain publications have already addressed approaches to reduce information fragmentation.

One practice reported by the current literature to integrate information is using *boundary objects* (Caccamo et al., 2022). Section 5.3. elaborates on this concept and completes the information fragmentation perspective – developed in this study – with a problem-solving dimension. As a result, a second proposition is derived, which is presented in section 5.4. Finally, paragraph 5.5 overviews the entire information fragmentation perspective, including the derived propositions.

5.1. Information fragmentation

This paragraph presents the results obtained in the structured literature study, which is performed to identify how the term *information fragmentation* is applied in the current scientific literature. Moreover, literature about process information fragmentation is considered specifically interesting for this research; this concept is introduced and described in subparagraph 5.1.2. Indicators for information fragmentation are outlined based on the retrieved literature. Furthermore, information fragmentation is related to SC lead times (5.1.4). With this, the first part of the information fragmentation perspective is determined. From the literature related to information fragmentation presented in this paragraph, a proposition about the effect of information fragmentation on the lead times of MSCs can be derived. This proposition is shown in the next section.

5.1.1. Information fragmentation in the literature

Information fragmentation in the context of organisations or multi-actor systems is a term used in the current scientific literature. A structured literature study is performed to get insights into how this term is applied and how it can be defined (see Appendix F for more details of the literature study). However, the articles selected in the literature study use the concept of information fragmentation differently and have a particular focus. Information fragmentation is characterised using some examples.

Several articles focus on the problem of information fragmentation in the context of personal information management (Copic Pucihar et al., 2016; Trullemans & Signer, 2014; van Helvoort, 2011; Warraich et al., 2018). Personal information is spread over different applications, devices and Web Services, and other information is stored physically, which leads to information fragmentation (Trullemans & Signer, 2014). Perhaps, we recognise it ourselves: we often use different email addresses, storage facilities (computers, laptops, cloud-based storage, online environments, physical papers, etc.) and different devices (a mobile phone for work and a private one). The fact is that the use of many

different systems is not always supporting workability. Warraich et al. (2018) focus on digital information and state that information fragmentation creates challenges in managing personal digital information. They define information fragmentation as "*Information located in different devices or in different places in a single device"* (p.714). Copic Pucihar et al. (2016) illustrate information fragmentation in practice for project-related information: "*support information for a project was often found outside the project folder (in reference, other project and dump collections) and core information was not necessarily stored in the project collection folder*" (p. 505). Van Helvoort (2011) performed a literature review on the personal information management of information workers and concluded that the main problem experienced by information workers is the fragmentation of information over different devices and collections. Conclusively, using many different systems and devices is not always practical for personal information management and leads to problems.

The diversity of storage systems can lead to problems, not only regarding personal information. Specifically for the health sector and the focus on Electronic Health Records (EHR), two articles were found (Chao, 2016; Plazzotta et al., 2015). The lack of structured documentation in EHR results in fragmented patient data (Chao, 2016). Currently, the information is often incomplete and comprehensive and uniform documentation is often missing (Chao, 2016). In the context of the health sector, Plazzotta et al. (2015) state that integrating health-relevant information is needed to improve healthcare and academic tasks since now the access for healthcare professionals to relevant data is often hindered.

Multiple authors describe the consequences of using different applications, devices, technologies, and services (Lee & Shin, 2015; Trullemans & Signer, 2014; Warraich et al., 2018; Bao et al., 2016). For instance, Bao et al. (2016) address information fragmentation for software developers, which is about the information across different applications. Lee and Shin (2015) mention the influence of separate applications, technologies, and services on the fragmentation of personal information.

In contrast, another publication gives valuable insights and discusses an SC case. Rukanova et al. (2017) address information fragmentation in supply chains. Consequently, they indicate several relevant aspects of information fragmentation. Rukanova et al. (2017) identified several elements, which are already highlighted above with other references. Three of these aspects are explained below.

Firstly, the diversity in systems, devices and applications is an aspect of information fragmentation in SCs. As described above, the diversity of storage systems can generally result in information fragmentation. Especially for SCs, Rukanova et al. (2017) state that a fundamental issue in SCs is the following: "*information about transactions resides in different business and government systems, which lead to fragmented pockets of information*" (p. 184). Therefore, the diversity in included systems, devices, and applications is considered a relevant aspect of information fragmentation in SCs.

Secondly, the hindered accessibility to information for stakeholders is an aspect of information fragmentation in SCs. As described above, Plazzotta et al. (2015) mentioned the importance of access to relevant information. Furthermore, Rukanova et al. (2017) distinguish between technical barriers and non-technical barriers to information sharing in SCs. They indicate that non-technical barriers are related to legislation and strategy. Specifically, Rukanova et al. (2017) determine that stakeholders are often reluctant to share or may not even legally share information. The lack of information sharing hinders access to this information for other stakeholders. Therefore, hindered accessibility to information for stakeholders is considered a relevant aspect of information fragmentation in SCs.

Lastly, the difference in documentation standards is an aspect of information fragmentation in SCs. As described above, Chao (2016) indicates the problem of unstructured, incomplete, non-uniform and incomprehensive documentation in EHR, which results in information fragmentation. Rukanova et al. (2017) state that using different standards and lacking interoperability of systems and sectors result in information fragmentation in SCs.

Additionally, a fourth aspect indicated by Rukanova et al. (2017) is the involvement of multiple stakeholders and their (lack of) interaction. According to Rukanova et al. (2017), the involved

stakeholders are crucial as users and providers of information. Therefore, these stakeholders play a key role and must deal with the consequences of information fragmentation. Moreover, they conclude that the complex multi-actor context makes it difficult to counter information fragmentation. Different stakeholders are involved in activities or processes, which affects information fragmentation (Rukanova et al., 2017; Van der Aa et al., 2015).

In the next paragraph, the publication of Van der Aa et al. (2015) is summarised, and valuable insights related to information fragmentation and the influence of stakeholders are presented. The authors specifically address process information fragmentation; the next paragraph also describes what process information entails.

5.1.2. Process information fragmentation

Van der Aa et al. (2015) specifically analysed the fragmentation of process information. Van der Aa et al. argue that process-related information fragmentation results in considerable organisational problems. For example, they illustrate that the fragmentation of process information is a problem for stakeholders and the development of a comprehensive overview of their operations.

Dumas et al. (2013) argue that process rules are often not explicitly defined and that domain experts or specialised process participants operate based on diverging assumptions. These domain specialists hold some of the process knowledge. Other process knowledge can be controlled explicitly using documents, models, and systems; however, this process information is often spread over several heterogenic sources (Van der Aa et al., 2015). Van der Aa et al. describe that process documentation is often related to the perspective of the stakeholder who has created the document. For example, a general process description created by a department head can differ from the technical specification created by the operational staff. The involvement of different stakeholders and process participants is an interesting aspect of information fragmentation. Van der Aa et al. (2015) do not explicitly address the stakeholders' accessibility to information sources, but Van der Aa et al. (2015) indicate the importance of the availability of process information.

Causes of process information fragmentation

Van der Aa et al. (2015) describe two ways of processing information fragmentation occurrence: when sources contain different information and when sources use different representation formats.

The heterogeneity of process information sources has increased because of the different stakeholders involved. The separate sources include different information. In addition to the information held by process participants and their sources, external information may also be relevant to business processes (Van der Aa et al., 2015). Möhring et al. (2015) describe that extrinsic data (rules and regulation, informal relationships, related information sharing, and the enterprise structure) are also sources, which include process information.

Moreover, the representation of the (relevant) process information can be a problem for the integrated overview of information. Primarily, this is a consequence of stakeholder preferences. Furthermore, the diversity of artefacts due to different representation formats contributes to the fragmentation of information (Van der Aa et al., 2015).

5.1.3. Information fragmentation indicators

Several aspects have been described by the literature indicating the occurrence of information fragmentation. Not all sources specify information fragmentation in the context of process information as Van der Aa et al. (2015) did, and none is focused specifically on MSCs. However, Rukanova et al. (2017) focus on SCs and addressed four elements of information fragmentation. Other references also mention these elements. Furthermore, these elements are used in this study as indicators for the presence of information fragmentation.

Table 7. Information fragmentation elements

Information fragmentation indicators	Reference
Multiple stakeholders involved	Rukanova et al. (2017) Van der Aa et al. (2015)
Multiple systems, devices, and applications included	Rukanova et al. (2017) Van der Aa et al. (2015) Lee and Shin (2015) Trullemans and Signer (2014) Warraich et al. (2018) Bao et al. (2016) Van Helvoort (2011) Hanrahan et al. (2014)
Accessibility to information is hindered for stakeholders	Rukanova et al. (2017) Plazzotta et al. (2015) Corradini et al. (2007)
Different standards/representation formats	Rukanova et al. (2017) Van der Aa et al. (2015) Chao (2016) Hanrahan et al. (2014)

5.1.4. Information fragmentation and lead times

In light of this study's objective, the relationship between information fragmentation and lead times must be considered. The elements presented in the previous section (Table 7) can indicate the occurrence of information fragmentation. Moreover, several sources indicate the effects of information fragmentation.

Generally, information fragmentation is addressed by the literature as a problem (Bao et al., 2016; Copic Pucihar et al., 2016; Corradini et al., 2007; Hanrahan et al., 2014; Huo, 2015; Lee & Shin, 2015; Plazzotta et al., 2015; Rukanova et al., 2017; Trullemans & Signer, 2014; Van der Aa et al., 2015; Van Helvoort, 2011; Warraich et al., 2018). For example, Van Helvoort (2011) states that information fragmentation is the biggest problem experienced by people related to personal IM. Rukanova et al. (2017) relate the information fragmentation problem in SCs to two significant contemporary societal challenges: reinforcing safety and security and reducing inefficiencies. Specifically, Rukanova et al. (2017) determine that reducing information fragmentation in SCs strengthens safety and security and reduces inefficiencies.

Some other sources also imply the effect of information fragmentation on efficiency. According to Van der Aa et al. (2015), process information fragmentation results in considerable problems, including diversity in stakeholder expectations. Moreover, process information from multiple sources must be combined to fully understand the process (Van der Aa et al., 2015). Van der Aa et al. (2015) indicate that these additional actions can be '*quite tedious*'. This word choice implies the effect of process information fragmentation on efficiency.

Specifically, the literature also supposed the effect of information fragmentation on time. Khan (2023) states that enhancing information sharing and overcoming information fragmentation eliminates unnecessary time delays. Furthermore, Rukanova et al. (2017) determined that reduced information fragmentation of supply chain information increases the efficiency of the process. Moreover, the specific effect of information fragmentation on the waiting times in SCs is described by Rukanova et al. (2017). Waiting time is indicated as a waste (Chiarini, 2013). Given these points, information fragmentation results in non-value-adding activities and affects the SC lead times.

Altogether, the concept of *information fragmentation* is defined and applied differently in the literature. However, generally, information fragmentation is considered a problem. For MSCs, no publication is found, although one publication focusing on SCs was retrieved during the literature study. This

publication illustrates the problem of information fragmentation in the functioning of SCs (Rukanova et al., 2017). Four information fragmentation indicators are defined using this reference of Rukanova et al. Furthermore, the literature addresses process information fragmentation explicitly (Van er Aa et al., 2015). The article of Van der Aa et al. (2015) supports explicitly three of the four information fragmentation indicators defined in this article. The consequences of information fragmentation can be diverse. For this research, the literature can support the relationship between information fragmentation and time. Rukanova et al. (2017) specify the problem of information fragmentation as a problem within SCs regarding SC lead times.

5.2. Proposition 1

The previous paragraph ends with identifying a relationship between information fragmentation and SC lead times. The effect indicated by Rukanova et al. (2017) is that information fragmentation increases the lead times of SCs by adding non-value-adding activities and waiting time to the SC process.

Since no references apply information fragmentation in the context of MSCs and MSC lead times, this effect is not yet supported for MSC specifically. However, it can be expected that for MSCs, information fragmentation also adds non-value-adding activities to the MSC process and thus increases the lead times of MSCs. Thereby, the first proposition derived from the information fragmentation perspective is formulated. The expected effect of information fragmentation on the lead times of MSCs is visualised in Figure 7.

P1. Information fragmentation leads to higher lead times of MSCs due to non-value-adding activities to the process.

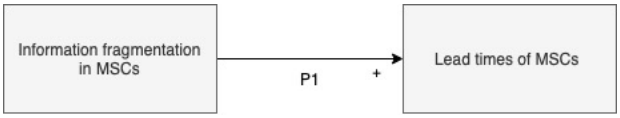

Figure 7. Proposition 1

Assuming that this relation for MSCs is supported by practice, information fragmentation can be seen as a problem in terms of the lead times of MSCs. Consequently, including a problem-solving dimension in the information fragmentation perspective would be beneficial. I.e., a way to reduce information fragmentation in MSCs is considered. The following section will extend the information fragmentation perspective by looking at information fragmentation reduction.

5.3. Problem-solving dimension of the information fragmentation perspective

The previous section introduced the concept of information fragmentation by presenting the results from the literature study. Besides the characteristics of information fragmentation and its relationship with lead times, some retrieved sources describe interventions for reducing information fragmentation in an organisational/multi-actor context. Some of the insights into information fragmentation reduction are described in subparagraph 5.3.1.

Furthermore, boundary objects are selected explicitly for problem-solving related to information fragmentation and lead time reduction in MSCs. In subparagraph 5.3.2., the concept of boundary objects is introduced as means to reduce information fragmentation. From this literature analysis, another proposition (proposition 2) is derived, which is presented in the next paragraph.

5.3.1. Approaching information fragmentation

Several articles selected in the literature study on information fragmentation in organisational or multi-actor contexts focus on designing mechanisms, frameworks, or artefacts to deal with information fragmentation. For example, Huo (2015) developed a project called "All in Pieces", which addresses information fragmentation in the context of (social) media. However, the contribution of this project remains with the participant's experience and the creation of awareness about media technologies. Furthermore, Corradini et al. (2007) introduce a Service Management System to support the visibility

and accessibility of e-Government services for end-users. This system integrates governmental services to simplify, fasten, and increase the quality of services. Corradini et al. (2007) show that integrating information has multiple benefits. Besides this, Bao et al. (2016) designed a framework and prototype to address information fragmentation specifically for the daily work of software developers. However, this article does not address the applicability in other fields than software development. Therefore, this framework will not be applied to information fragmentation reduction in MSCs. To conclude, these publications do not present specific designs easily applicable to address information fragmentation in the context of this research.

Approaching process information fragmentation
Van der Aa et al. describe two steps of approaching process information fragmentation: detect and resolve inconsistencies between sources and integrate information captured in separate sources. First, inconsistencies in the information related to the same process should be detected and resolved. These inconsistencies can lead to ambiguous process operation and reflection. Second, the process information should be integrated. Therefore, according to Van der Aa et al. (2015), gathering all relevant process information together is insufficient. The process information should be aligned to ensure consistency between the different information.

Van der Aa et al. (2015) illustrate two challenges (C1 & C2) due to process information fragmentation and the defragmentation tasks described above. The authors explain that defragmentation is about the ability to relate different information to each other. The challenges are visualised in Figure 8.

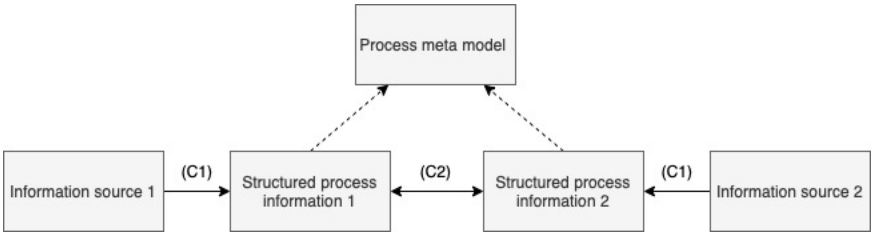

Figure 8. Challenges of process information defragmentation (Van der Aa et al., 2015)

Challenge 1 (C1) is about extracting a structured overview of the process information in an interpretable format. Challenge 2 (C2) is about aligning the structured process information to integrate the information. Moreover, the process meta-model can be seen as the integrated overview of the structured process information. From the information fragmentation perspective of this research, process information is integrated when overcoming both challenges; thereby, information fragmentation is reduced. Based on this view towards information fragmentation reduction, a closely related term can be introduced: boundary objects.

5.3.2. Boundary objects
Organisational boundaries separate specialised (sub)units from external units and from other (sub)units in the organisation (Tushman & Scanlan, 1981). According to Tushman and Scanlan (1981), these organisational boundaries are characterised as communication boundaries, where communication across boundaries is difficult and inherently unambiguous.

Boundaries can be spanned by individuals (boundary spanners) who understand both sides of the boundary and by selecting the relevant information to disseminate it on the other side (Tushman & Scanlan, 1981). Furthermore, non-actor entities exist (boundary objects), which can accomplish boundary spanning. Star (1989) defined boundary objects as: "*objects that are both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use, and become strongly structured in individual-site use.*" (p.46). Star states that these boundary objects are valuable for solving heterogeneous problems.

Specifically, the role of boundary objects in integrating relevant information is explicitly determined by Caccamo et al. (2022). Boundary objects can be seen as a means of addressing the challenges indicated by Van der Aa et al. (2015).

The topic related to boundary objects for improving information sharing is combined with SC literature. A structured literature analysis is performed to understand how boundary objects are applied in SCs and what relations are analysed. A combination of key terms is used, including boundary spanning related to information sharing and SCs, in order to get insights into the existing literature. More details about the executed literature study are presented in Appendix G. Furthermore, Appendix G3 provides the main insights obtained from the study.

The literature study summarises the causal relations tested in five different publications. As presented in Appendix G, all publications analysed the influence of a particular boundary object on inter-organisational information sharing (all significant for SC exploitation). Furthermore, all publications support the relationship between improved inter-organisational information sharing and SC performance (Appendix G2 and G3). SC performance is specified by the articles differently. For example, according to Dong et al., boundary objects are addressed as "inter-organisational systems"[6] (IOS) to enable knowledge sharing and improve the joint performance of collaborating firms.

Only one of the selected articles addresses the impact of boundary objects specifically for SC lead times (processing time) (Xu et al., 2016). Xu et al. (2016) conclude that the boundary object analysed in their publication – a vertical information system (VIS) – influences the processing time in SCs. None of the articles includes the effect of intra-organisational information sharing as a component of SCs. Dong et al. (2017) specifically determine the influence of institutional distance (including regulative distance) on IOS-enabled knowledge sharing (this is further explained in Appendix G). The publication concludes that there is no significant effect of regulative distance.

5.4. Proposition 2

Based on the findings from the literature study on boundary objects in SCs, it can be expected that boundary objects also improve information sharing in MSC processes. The second proposition is derived from the dimension of problem-solving of information fragmentation in MSCs and the literature study on boundary objects. It is expected that boundary objects will reduce information fragmentation in MSCs when a structured overview of the process information can be extracted in an interpretable format (C1) and when this structured process information can be aligned to provide an integrated overview (C2). The derived proposition for reducing information fragmentation in MSCs is presented in Figure 9.

P2. *Boundary objects reduce information fragmentation in MSCs if structured overviews of the information are extracted, in an interpretable format, and aligned into an integrated overview.*

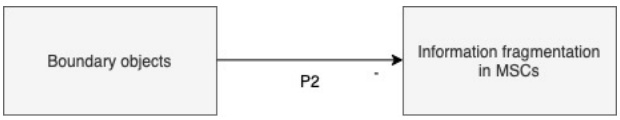

Figure 9. Proposition 2

5.5. Conclusion information fragmentation perspective

The results obtained in this chapter contribute to the answers to sub-question 3 and 4. The chapter starts with developing the information fragmentation perspective by introducing the concept of *information fragmentation*. Four indicators for the problem of information fragmentation in SCs are defined.

[6] IOS are defined as "*IT applications deployed to exchange information between firms*" (Dong et al., 2017) (p.1)

Furthermore, the expected effect of information fragmentation on the lead times of MSCs is indicated by proposition 1. The information fragmentation perspective addresses information fragmentation as a problem regarding the lead times of MSCs. Therefore, a problem-solving dimension is added to the information fragmentation perspective. From a literature study, it becomes clear that process information must be extracted from the different sources as a structured overview in an interpretable format (C1). Consequently, this structured process information must be aligned (C2) to reduce process information fragmentation. Based on the definition of boundary objects and the found effects of boundary objects on information sharing in SCs and SC performance, it is expected that boundary objects contribute to reducing information fragmentation in MSCs by overcoming the two challenges (C1 and C2). The derived propositions are presented in Figure 10.

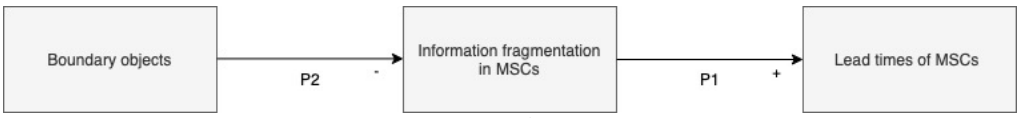

Figure 10. Set of propositions

Now that the propositions are derived from the information fragmentation perspective of this study, empirical research must show whether the expected effects apply to MSCs and exist in practice. The next chapter will apply the information fragmentation perspective developed in this chapter to a case of the MoD.

Chapter 6. Case study

"In theory, theory and practice are the same.
In practice, they are not" ~ Albert Einstein

The research focuses on formal information sharing and its influence on the lead times of MSC processes. The previous chapter introduced several concepts relevant to analyse financial processes as a component of MSCs. Specifically, two propositions related to the information fragmentation perspective are obtained. In the case study, the information fragmentation perspective is applied, and these propositions are tested. The case study is restricted to one financial process as a component of an MSC: the invoice case of MoD. Generally, this chapter describes how formal information sharing affects the lead times of the invoice process at the MoD. Specifically, a problem related to information fragmentation is analysed.

This chapter starts with an introduction to the invoice process and its link with a general ordering process at MoD as it takes place within the complex organisation. Subsequently, the second paragraph summarises findings related to information fragmentation as a problem for the high lead times of the invoice process. The interface between the ordering and invoice processes causes a specific information fragmentation problem regarding lead times. Paragraph 6.2 specifies this problem in terms of the information fragmentation perspective and describes the results in terms of the first proposition. Consequently, paragraph 6.3 applies proposition 2 to the invoice case. This section thus examines how to address the problem in the invoice case. Several referrals are made to Appendix H throughout the chapter, where performed analyses and retrieved case data are presented.

6.1. Invoice case

MatlogCo provided the case for this study. More information about the starting point of this study is provided by Appendix H1. The case study started with an exploration of the organisation, the stakeholders, their problem perceptions, and processes related to the invoice case. Multiple interviews with stakeholders were conducted, and documents and quantitative data were analysed to explore the invoice case. This paragraph presents the invoice case.

6.1.1 Invoicing at MoD

The MoD is a large and complex organisation. Chapter 1 provides a short introduction to the Dutch defence organisation. The MoD, like other military organisations, faces increased threats and international tensions. Therefore, the MoD should be able to act quickly in times of crisis (Ministerie van Defensie, 2022e). The defence white paper of 2022 specifically mentions the importance of strengthening the MSCs.

The current developments and the characteristics of the organisational structure of MoD influence military operations. The organisational structure of the MoD indicates hierarchical layers. Moreover, the structure shows great diversity and a wide range of operational specialisms. Operational components are divided into different process domains (Ministerie van Defensie, 2021c). Supply chain logistics (Dutch: 'ketenlogistiek') is part of the ‘Material Logistics’ process domain. These SC processes include the ordering processes (Dutch: ‘Inkoop’) as a part of the primary processes in MSCs. Payment is part of another process domain (Ministerie van Defensie, 2021c).

The invoice process is linked to the ordering process when external orders are placed. Based on the goods or services delivered, the external supplier sent an invoice to the payment office of MoD. A well-functioning payment process is important for the MoD to fulfil its legal obligations, reinforce its relationships with external suppliers and, in the end, for well-functioning MSCs. The importance of reduced lead times of financial supportive processes in MSCs is scientifically substantiated in chapter 2 (visualised in Figure 4). These causal relations also apply to the specific invoice processes of MoD, thereby showing the relevance of reducing the lead times of MoD's invoice process.

Currently, the lead times of the invoice process of MoD are considered too high. The payment behaviour of the MoD must be improved (MoD04). Some invoices are outstanding for 587 days (Appendix H6.2.). 'Sitrap' documentation[7] of the MoD shows the payment behaviour of MoD for 2022 (until week 49): 91,83% of the invoices are paid within the payment term (Ministerie van Defensie, 2022d). Furthermore, other obtained quantitative data show the payment behaviour of the Royal Netherlands Army compared to the payment behaviour of MoD for weeks 20 to 46 of 2022 (Appendix H6.1). The percentage of the invoice paid within the payment term of 30 days is for the Royal Netherlands Army, for which MatLogCo accounts for a large share of orders, worse (94.3%) than for MoD generally (95.1%). Based on these data, a difference between Royal Netherlands Army and MoD is observed. Specifically, according to the Sitrap documentation of week 49, the payment behaviour of M&F invoices is worse (86,78%) than the general payment behaviour of MoD (91,83%). At the FABK, a programme called 'FENIKS' and a project called 'Blijvend Beter Betaalketen' has already been launched to improve the payment behaviour of the MoD.

The invoice process consists of different process activities, which are prescribed by process design information. Mainly, process activities at the MoD are embedded within an organisational framework indicating how the processes should be executed. Interestingly, processes are not (entirely) executed following this prescribed policy (Appendix H4.2). Albert Einstein already posited: *"In theory, theory and practice are the same. In practice, they are not."*. And it is, of course, a bad sign when obligations are violated or neglected. However, not all information about 'how things should go' is always clearly present or findable. The fact that formal information describing the processes upfront is sometimes incomplete, incorrect, or not accessible is one observation during the research. In addition, comparing the execution of processes with their intentions and the prescribed process was the starting point for problem identification in this research. Therefore, differences between the '**process design**' and the actual process execution ('**process in practice**') are used to indicate problems.

6.1.2 Invoice process design

The MoD state that preparation and deployment (Dutch: gereedstelling en inzet) is not possible without supportive processes (Ministerie van Defensie, 2021c). The invoice process is a financial process supporting the primary MSC processes. The process design of the invoice process is indicated by components varying from general prescriptions, including the organisational-wide arrangements, to task-specific instructions and roles and responsibilities of actors. Moreover, different parts of the process design are interrelated or influence each other. The financial processes related to invoicing are linked to the primary SC process of purchasing and procurement (Ministerie van Defensie, 2021b). Thus, solely focusing on the financial processes would be insufficient when analysing the problem in the invoice case. The relevant scope for exploring the problems related to invoicing includes the relation with physical processes and more general policy and regulation affecting the system since these can be related to the difficulties experienced. Insights into the process design generally relate to three aspects. Firstly, which actors are involved in the invoice case? Secondly, which rules and regulations prescribe the processes in the invoice case? Lastly, how is the invoice process designed within the MoD?

Multi-actor context

Different actors are directly or indirectly involved in the invoice process. The process of invoicing is launched by the operational units (in this example, the end-user) and their demand. Based on the request for equipment, goods, or services, an ATB (application for needs fulfilment) process is initiated. As described in chapter 1, the invoice case is provided by MatLogCo. Therefore, the multi-actor context is described for MatLogCo as the purchaser. When MatLogCo cannot fulfil the demand of the end-user with its internal capacity, it can purchase goods and services externally. Besides this, MatLogCo proactively manages its assortments by purchasing goods. Long-term contracts are mainly undertaken to facilitate external procurement (mostly from the purchasing department ('Inkoop'). Additionally, the contract management role is often assigned to another party within MatLogCo. Besides this, planner or assortment manager from MatLogCo can place an order with an external supplier based on specific contracts to order goods or services.

[7] Internal MoD data: "Sitrap week 49 2022 gedraaid op 2022-12-14.pdf"

External suppliers provide services and goods favourably in line with the order. When ordering goods, mostly a warehouse employee of MoD receives the goods. When ordering services, the system (e.g., the vehicle) returns to the user. Subsequently, the external supplier sends an invoice to the Defence organisation. Consequently, receiving the invoice at MoD provokes the processing of the invoice. A fundamental unit for the execution of the payments is the Financial Administration and Management Bureau of the MoD (FABK). This authority includes the Financial Service Center (FSC), which is responsible for paying the invoices. Appendix H2 provides additional information derived from the stakeholder analysis, including the relevant actors and a formal chart showing the relations between the actors.

Rules and regulations
Formal process design information largely determines the process design of the invoice case. An example of key external legislation for the invoice process is the Dutch legal payment term, which determines that there is a standard legal payment term of 30 days (Dutch Civil Law, n.d.). Another example of key legislation for the invoice process is the governmental payment standard, which determines that 95% of the invoices to suppliers paid within 30 days – (Ministerie van Financiën, n.d.-a). Moreover, the following internal policy document is, in particular, relevant to the invoicing process: "Aanwijzing HDFC-001: Financieel beheer" (Ministerie van Defensie, 2018). This policy document describes the invoice process; a relevant passage is presented in Appendix H3. Furthermore, Appendix H3 provides additional relevant internal and external rules and regulations.

Different systems and databases contain rules and regulations related to the invoice case. External rules and regulations were retrieved from several databases[8]. Internal rules and regulations were obtained from different systems and databases[9].

Process model - ARIS
The MoD uses designs to specify which tasks are to be performed by whom within a given process. These descriptions are integrated into the Defence Enterprise Design (Dutch: Defensie bedrijfsontwerp). The Architecture of Integrated Information Systems (ARIS) is an Enterprise Management System with different modules integrated as a meta-model for process modelling. ARIS is used at MoD for Process Model Management (PMM) and includes process models following the Business Process Modelling and Notation (BPMN). Additional information about ARIS is presented in Appendix H4.1.

Analysing the ARIS process models for the invoice case shows the incomplete nature of formal information about business processes and the process descriptions (Appendix H4.2). The operational units have the task of designing and prescribing the operational processes. In the case of the invoice process, FABK has the task of designing and prescribing the operational processes. Furthermore, the Principal Directorate of Finance and Control (HDFC) is responsible for more overarching business processes associated with the financial domain. Currently, all the process designs in ARIS are being newly created, and so are the financial processes. Specifically, two employees from FABK and HDFC contributed to overview the development of the process model (MoD04, MoD06). The transition to new process designs in ARIS starts for the financial domain by mapping the current processes. For the financial domain, the initial ARIS models are not complete (MoD06). The current incomplete overview of the processes in ARIS is extra complicated since some outdated process models and prescriptions are still included (Appendix H: Figure H. 4). The transition to new process models goes slowly and incrementally.

> *One of the employees developing the process models mentioned the disadvantages of the transition. The models would be immediately visible in ARIS while they are primarily under development. The state of process models would cause increased confusion in the organisation (MoD06). Besides this, outdated process models cannot always be removed due to the*

[8] E.g., https://www.overheid.nl, https://www.officielebekendmakingen.nl, https://www.rijksfinancien.nl/
[9] E.g., "N-schijf", "MP-bundels", "Publicatieportaal", SharePoint, hard copy

interconnectivity with other processes and the SAP transactions (MoD04). A process model should be only visible to employees when the model is finished, checked, and linked with the SAP applications. In the meantime, concept versions should not be visible (MoD04).

It is unclear which processes are up to date, in progress or outdated (MoD04). The status of ARIS models has complicated the search in ARIS for the currently used process prescription for the invoice process. Another example substantiates the lack of a proper overview.

> *During this research, ARIS was consulted to obtain the process designs related to the invoice process. Multiple process designs were found. However, none of the work process designs proved to be up to date (Appendix H: Figure H. 4). Numerous process steps or work processes were not even incorporated into ARIS. The business process design "registreren en betalen facturen" (registering and paying invoices) was not developed. However, during the research, there was still (temporarily) the possibility of accessing an incomplete business process.*

Since ARIS is a tool to aggregate information related to organisational processes, the incompleteness of ARIS models is addressed as an issue of current operation with implications for clarity and transparency of formal information. However, as described earlier, the entire process design of the invoice consists of more than only the ARIS process models. Regulations in the form of legislation, directions, policies, procedures, and work instructions largely determine the process design. Furthermore, for employees, the status of the ARIS process models does not seem to affect daily work (MoD04, MoD10).

> *The ARIS process models are connected to applications in the SAP environment, thus transaction codes in SAP are used for different transactions. Furthermore, based on one of the explorative interviews, it became clear that transaction codes in SAP are mostly connected to a particular step in the process (MoD04). The primary motivation for creating (new) ARIS models is to support the implementation of S/4HANA[10] within the organisation (MoD04, MoD06).*

The restricted use of ARIS process models for process execution (MoD04) substantiates the fact that the incompleteness of the process model has only a limited effect on the execution of process steps. Furthermore, the process design discussed in this section (5.2.1) includes much more than these ARIS models.

6.1.3 Invoice process in practice

Based on the description of the process design, the question arises whether the actors and the system act in line with the regulation and prescribed processes. This section will give an overview of the invoice process in practice results obtained from the interviews, document analysis and quantitative analysis. The data are conceptualised by making use of systems modelling (Appendix H5). Quantitative data indicate the performance of the invoice process. Besides this, process tracing offers insights into the considerations and behaviour of actors.

Process in practice conceptualisation

To capture reality in a model is an unfeasible challenge. However, capturing components of reality in a model to say something about the actual situation can be helpful. Based on the interviews with employees involved in the operation or the invoice process management, a process conceptualisation is made. A simplification of the link between the ordering process and the invoice process is presented in Figure 11.

[10] S/4HANA: the new version of the used ERP system SAP

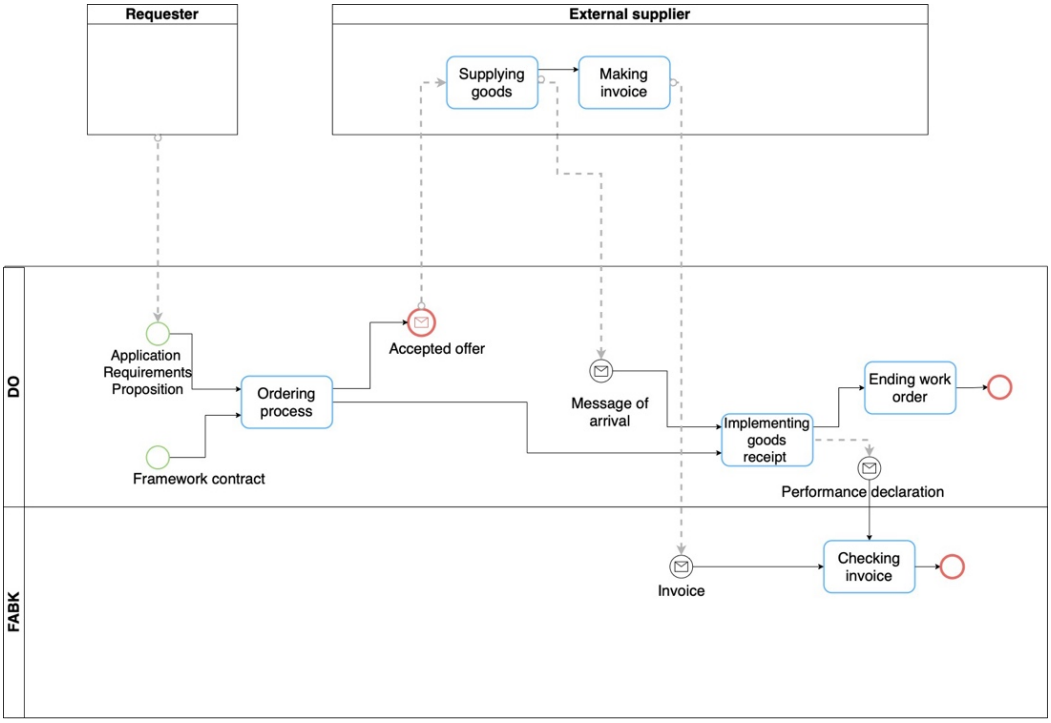

Figure 11. Simplified BPMN

Generally, this model presents two processes within the MoD: the ordering process and the invoice process. Two general types of the ordering process can be distinguished: the ordering of goods and the ordering of services. A more detailed BPMN for the ordering of services is presented in Appendix H4. This model is validated by MoD11. Furthermore, the processes are much more complex in reality than the BPMN shows due to the variety of options in the process steps.

Returning to Figure 11, this BPMN shows a simplification of the ordering process of goods. When needed, a purchase order for specific goods (or services) is created by the DO in the ordering process. Consequently, the external supplier sends an invoice to FABK.

The most relevant aspect of this BPMN is the intertwining of processes taking place at the DO, FABK and external suppliers. Specifically, the link between the ordering and payment processes becomes apparent. When an external supplier sends an invoice to MoD, this invoice will not immediately be paid. After FABK registers the invoice in the SAP system[11], the invoice will be checked by FABK. For checking the invoice, a *service entry* (in case of a service order) or *goods receipt* (in case of a goods order) must be provided by the DO. Based on the implementation of the service entry or goods receipt in SAP, SAP automatically generates a *performance declaration* (Dutch: prestatieverklaring), which is the input for checking the invoice. When fourteen days after the invoice registration the (right) formal information needed from the DO is missing, a Request for Information (RFI) is sent to the person who placed the order in SAP. The link between the ordering process and the invoice process is indicated by the performance declaration.

In terms of formal information, as described in chapter 2, the performance declaration has been considered as formal information needed for FABK to proceed in the process. Furthermore, most process steps are facilitated by information transactions in SAP, which are also addressed as formal information. Besides this, specifically the ordering of services, an email must be sent by the external supplier to the planner at MoD, including the message of completion. This email is also addressed as formal information and is needed for the requestor to provide the service entry.

[11] Electronic invoices are automatically registered in SAP, pdf invoice must be registered manually in SAP by FABK employees.

6.2. Missing performance declaration

Located at the interface of the ordering and invoice processes at the MoD, problems occur related to missing performance declarations in SAP. Missing the performance declaration is a consequence of not entering the service entry (in cases of an ordered service) or the goods receipt (in cases of ordered goods). This action must be initiated by the planner (for services) or the warehouse employee (for goods) by entering the service entry or goods receipt in SAP (MoD11). The performance declaration is necessary to continue the payment process, i.e., when the performance declaration is missing, the payment office (FABK) cannot verify and pay the invoices (Profource, 2021). The problem of missing performance declarations for invoicing is mentioned in multiple interviews (MoD02, MoD03, MoD08).

Besides this, this interface is the point where a primary SC process is linked to a supportive process. As indicated in chapter 2, well-functioning supportive processes are important for the performance of the primary SC processes. Therefore, adequate integration between these two (primary and supportive) processes is necessary. The missing performance declaration problem implies the lack of integration of these two processes.

For multiple reasons, the fulfilment of the goods receipt or service entry in SAP can be delayed. A distinction can be made between root causes related to actions or omissions of MoD (internal root causes) and root causes related to actions or omissions of external parties (external root causes). Possible formal information sharing root causes identified are presented in table. These root causes are validated by MoD11.

Table 8. Root causes for missing performance declaration

	Missing goods receipt	**Missing service entry**
External root causes	No goods delivered	No service executed
	Wrong goods delivered	The missing message of completion
	Wrong quantity delivered	Missing proforma invoice in the message of completion
		Service is not in line with the order
Internal root causes	Blocked contract in SAP	Blocked contract in SAP
	Long processing of checking at the warehouse	Capacity problems
	Delivery location deviates from the warehouse	
	Capacity problems	

All the identified root causes do have something in common. First, based on the occurrence of one of the root causes, the service entry or goods receipt is not implemented in SAP, and so no performance declaration is generated by SAP. Therefore, all of these are reasons for lacking formal information sharing. Moreover, some of these can also be caused by the lack of formal information sharing.

One of the characteristics of the interdependency of the stakeholders is the lack of an integrated overview of the formal information needed to execute the processes. An example can be given:

> *Contract management is important to keep the contracts in SAP up to date. One of the employees of MatLogCo, who is responsible for the contract management of specific contracts (MoD10), illustrates a lack of capacity to fulfil the contract management tasks adequately. Other employees are accountable for implementing the contracts in SAP (MoD10). When a contract is not up to date in SAP, no service entry or goods receipt can be implemented in SAP which is in line with the invoice so that no* performance declaration *will be formed. Finding out why the process is disrupted takes a lot of time. Besides this, the employees at the payment office (FABK)*

are not aware of the root cause of why there is no performance declaration*. Meanwhile, several RFIs are being sent to the person who created the ATB, but they cannot update the contract…*

This example indicates the consequences of lacking contract management for the processing of invoices. In this case, the root cause is located internally in the MoD. The following example indicates an external root cause for missing performance declarations.

Supplier X does not do business with Defence very often. Significant maintenance was carried out on one of Defence's vehicles. The job was done, and then the invoice was sent by supplier X to FABK. The invoice is in line with the ATB, but this is not visible for FABK. What is experienced by the employees of FABK is that a performance declaration is missing, so the invoice cannot be booked. What is in the contract but what Supplier X has forgotten is sending a message of completion, including the proforma invoice, to the Defence planner. As a result, the planner does not know that the service has been delivered and, therefore, cannot implement the service entry in SAP. Consequently, Supplier X sent another invoice to MoD, which caused another problem for the payment office. The lead times of the payment process increase, and the repair actions take a lot of effort and time.

Generally, when a performance declaration is missing it may be due to different previous steps in the process. The problem of missing the performance declaration in the invoice case is indicated by the empirical data. The following quotes illustrate the problem experienced by two stakeholders in SC:

"*You only get the information when there is already a problem*" ~ MoD18

"*You are always dependent on other people to do something*" ~ MoD16

During the focus group, multiple questions were asked to the respondents, which prompted discussion among stakeholders. One of the stakeholders states the following about the missing performance declaration problem during the focus group:

"That there is a discussion arising about this, does indicate that something is wrong" ~ MoD13

The next paragraph addresses the extent of the problem related to the missing performance declarations for the invoice process and relates the problem to the lead times of the invoice process.

6.3. Invoice case lead times

When a missing performance declaration occurs, many (repair) actions must be taken by the employees of MoD, which costs time (MoD18). The additional waiting time and repair actions to obtain the correct formal information regarding the performance declaration results in higher lead times.

"*It takes a lot of time to correct everything*" ~ MoD18

A letter by the State Secretary for Economic Affairs and Climate to the President of the House of Representatives[12] already reported on the deficient payment behaviour of the MoD in 2017 (Keijzer, 2018). The letter indicates the main reason for the non-compliance with the governmental payment standard as the invoice issues related to invoicing processing in ERP M&F, specifically due to the late submission of performance declarations. Furthermore, in 2021 Profource (2021) made a Quick scan of the invoice process at MoD and substantiated the missing performance declarations as a cause for higher lead times of the invoice process.

Based on the dataset retrieved on the 30th of November 2022 from the MoD (Appendix H6.4.), all the outstanding invoices for longer than 30 days are selected (n = 2208). For 643 invoices, the indicated

[12] Letter of Government: 31490 Nr.242.

reason for outstanding payment is the absence of a declaration of performance; this is about 29% of the invoices. Furthermore, MatLogCo analysed their 100 oldest outstanding invoices (performed on 18-10-2022). The results are presented in Table 9. For the combination of missing service entries or goods receipts, the percentage is 59%. Both reasons result in missing declaration of performance.

Table 9. 100 oldest invoices MatLogCo

Reason for outstanding	Number of invoices
Missing service entry	32
Missing goods receipt	27
Double invoice	18
Price difference	15
Waiting for a credit invoice	2
Incorrect invoice	2
Error in SE/wrong position	2
Future delivery date	2

An explanation for the missing performance declaration is mentioned by an employee of FABK that there is a dependence on DOs, and there are doubts about whether employees of the DOs have enough knowledge about the execution of this step (MoD02). From the perspective of DOs, argumentation is given by a planner responsible for the service entry in SAP. This employee state that they (the planners) depend on the external suppliers to execute this specific step in the process (MoD03).

6.4. Information fragmentation in the invoice case

6.4.1. Information fragmentation indicators

The concept of information fragmentation is introduced in the previous chapter. Different aspects which can cause information fragmentation are present in the case. The information fragmentation perspective presented in the previous chapter includes the identification of four indicators of information fragmentation. These indicators are addressed for the invoice case and specifically for the occurrence of missing declaration of performance.

1. **Multiple stakeholders involved**

The ordering and invoice processes are in different process domains and executed in other DOs. The problem when no performance declaration is provided involves multiple actors and highlights the interdependencies between the various players (QR02-MoD12, QR02-MoD13, QR02-MoD14, QR02-MoD15, QR02-MoD18). The external suppliers, payment office, contract managers, purchasers, assortment managers and planners can all be involved in the invoice issues. The missing performance declaration causes many repair actions for the involved stakeholders. Furthermore, information about why and where the problem originates is needed to resolve the outstanding invoice. To obtain the relevant process in practice information, stakeholders depend on other players. All these repair actions influence the lead times. As a result, the process occasionally deviates from how it is prescribed[13] (MoD06).

The effect of the dependence on other stakeholders on lead times is indicated by several participants (QR03-MoD12, QR03-MoD14, QR03-MoD18). In addition, the need for the integration of stakeholders and the improvement of communication is indicated by several participants (QR03-MoD13, QR06-MoD14, QR06-MoD18, QR07-MoD18).

[13] Based on for example: “Steekproef ADR - AVPL 360 - Ontbreken getekende order in BO pos 10”

One of the characteristics of the multi-actor context of the invoice case is the large extent of different external suppliers. Some of them do business with the MoD frequently, others only occasionally, and there are large companies but also small companies. Figure 12 presents a visualisation of the stakeholders, including their interdependencies.

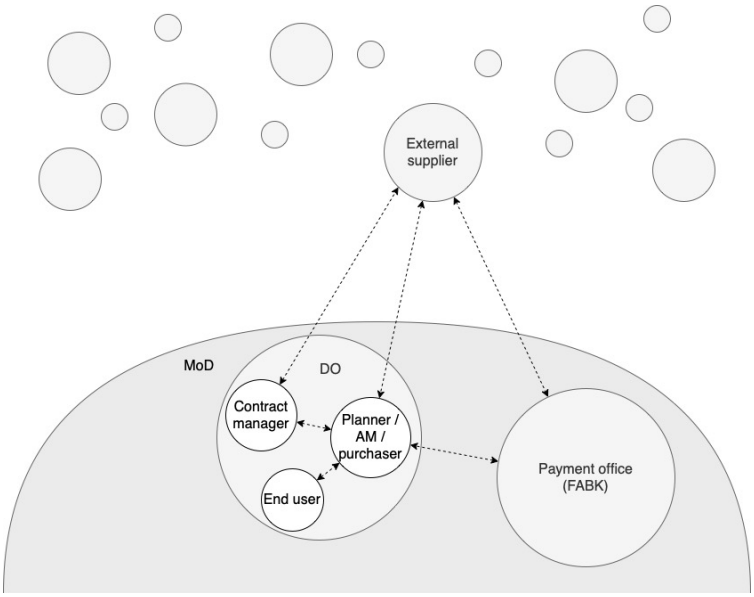

Figure 12. Visualisation of interdependencies between stakeholders

2. **Multiple systems, devices, and applications used**

Formal process design information
The formal process design information of the invoice case is spread over different systems and applications. ARIS process models, internal rules and regulations can be found via different internal sources. External rules and regulations can be found in different Dutch and international legal databases. The diversity in sources containing formal process design information related to the invoice became clear during the research.

The formal process in practice information
Different systems are used (SAP, mail) by the actors to execute different process steps. Ministerie van Defensie (2015b) states that besides ERP M&F (SAP), other specific systems are used for invoice processing. This reference generally indicates the diversity and the use of separate IT applications in different process domains MoD-wide and the related lack of integration of processes. Furthermore, relevant formal process in practice information is stored in separate systems, e.g., Monitor Logistieke Facturen (Monitor for outstanding invoices). Besides this, actors summarise data in MSWord and MSExcel (e.g., 'Sitrap' documentation, weekly MS Excel overviews and the MSWord analysis of MatlogCo's 100 oldest outstanding invoices).

3. **Accessibility to information is hindered for stakeholders**

Formal process design information
The formal process design information of the invoice case is not only spread out over different systems, devices and applications, the access to the formal process design information is also limited. The accessibility to the relevant formal process design information was hindered for the researcher during the study as well as it is hindered for the relevant actors in the invoice case. Currently, an improvement programme at MoD includes the implementation of a new document management system ('DefDoc') to increase the accessibility of information. Specifically, this will also contribute to the accessibility of formal process design information like rules, regulations, and process prescriptions (MoD07). However, the implementation of DefDoc will take several years before it functions properly (MoD07).

The formal process in practice information
The accessibility to specific formal information in SAP is restricted for actors. SAP makes use of transaction codes linked to specific process activities. Furthermore, these transaction codes are linked to positions so that the dedicated employees do have access to the specific formal information (MoD04). Moreover, email correspondence is not accessible to employees other than the addressed people.

> "*I do not get the SAP notification, which means I cannot proceed in SAP… Why do I not know that the contract has expired?... There is little or no communication at all*" ~ MoD17

> "*The SAP system is a puzzle*" ~ MoD12

4. **Different standards/representation formats**

Formal process design information
The discussion during the focus group shows differences in perspectives from stakeholders towards the process. The responsibility to execute certain process steps is not always clear for stakeholders. People do have different associations with terminology and process steps.

> "*If you ask ten people to state what a performance declaration is, then you get ten different answers*" ~ MoD15

The following question clearly summarises the current challenge in the missing performance declaration problem and the payment process: "*what is my role and what do I have to do, including who do I have to inform?*" (MoD15). At a higher hierarchical level, the processes are coordinated, but on a detailed process level, every DO is free to choose its own design, standards, and representation of formal process design information as it is in line with the rules and regulations set by policy.

The formal process in practice information
For employees, the process in practice information is not unambiguous. Sometimes a proforma invoice is sent by the external supplier via email, sometimes not. Employees at MoD do have their own way of working, which results in different standards. The difference in representation formats of formal process in practice information also results from the use of different systems and documentation.

6.4.2. Information fragmentation affecting the lead times
This first part of the case study includes the identification of an information fragmentation problem related to the lead times of the invoice process at MoD. The first proposition derived from the information fragmentation perspective is applied to the invoice case. Figure 13 presents the first proposition for the case.

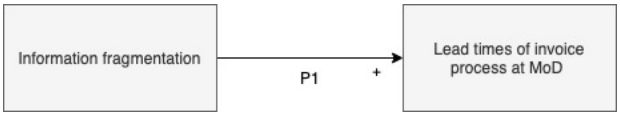

Figure 13. Proposition 1 applied to the invoice case

The missing declaration of performance in the invoice case of MoD is recognised as a problem resulting from information fragmentation. Besides this, the empirical data show the effect of missing performance declarations on the lead times of the invoice process at MoD. Related to this effect of information fragmentation on the lead times, several comments by stakeholders are made during the focus group. The following quotes relate to the influence of information fragmentation on the process lead times.

> "*Because you are dependent, sometimes it can take a week, but we can't wait that long... Often you have to start over, and then you end up in a vicious circle*" ~ MoD14

> "*Because you did not do what I (eventually) did, you have to wait so long*" ~ MoD17

Consequently, stakeholders form their "*own opinions*", *and then* "*it takes time to correct everything*" ~ MoD18

"*If there is no communication to the person who made the order, nothing happens"* ~ MoD12

The empirical data show that the process design of the invoice case is incomplete, incoherent, and not completely accessible. Furthermore, different systems and databases are used to store formal process design information. This indicates fragmentation of formal process design information. The current process design results in the occurrence of missing performance declarations. Since the formal process design information is fragmented, missing performance declarations occur. Therefore, the fragmentation of formal process design information contributes to the occurrence of missing performance declarations. Besides this, information fragmentation of formal process in practice information results in missing performance declarations. The formal information about the execution of processes is often incomplete, limited accessible, and stored in different systems. For all formal process information, multiple actors are involved in using and creating the process information.

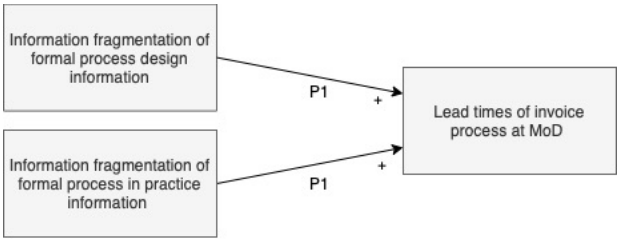

Figure 14. The effect found in the invoice case related to proposition 1

Thus, two types of information fragmentation are identified for the invoice case of MoD, both resulting in missing performance declarations (Figure 14). Consequently, the occurrence of a missing performance declaration results in higher lead times of the invoice process by adding non-value-adding activities in the SC process. Both types of formal process information fragmentation are included in figure 14. In this figure, the first proposition is specified to the results obtained in the invoice case of MoD.

6.5. Problem-solving of information fragmentation in the invoice case

In previous paragraphs, a problem resulting from information fragmentation in the invoice case is addressed: missing performance declarations. Consequently, this paragraph will focus on problem-solving to approach this problem, which currently results in non-value-adding activities and higher lead times of the invoice process.

As introduced in chapter 5, the information fragmentation perspective of this study includes a problem-solving dimension. Specifically, boundary objects are introduced as problem-solving interventions to reduce information fragmentation. Since both preventive and corrective problem-solving can approach information fragmentation problems, two boundary objects are considered for the invoice case. The expectation is that both boundary objects reduce information fragmentation in the invoice case of MoD (presented in Figure 15).

The first boundary object regards a preventive problem-solving intervention. This preventive problem-solving is the implementation of a boundary object in the form of an 'integrated process design overview'. The preventive boundary object creates an opportunity to improve the process design in the multi-actor context. Sub-paragraph 6.5.1 will elaborate further on this integrated process design overview.

Furthermore, the second boundary object regards a corrective problem-solving intervention. The corrective problem-solving is the implementation of a boundary object in the form of a 'track and trace system'. This corrective boundary object can help to reduce lead times by reducing waste of time – as a consequence of finding out what is wrong and why the performance declaration is missing - within the

process in practice. More specific process improvements can be realised by overviewing the root causes of delays. The overview in the track and trace system will include more detailed formal information on lead times and root causes. Sub-paragraph 6.5.2. elaborates further on what this corrective intervention entails.

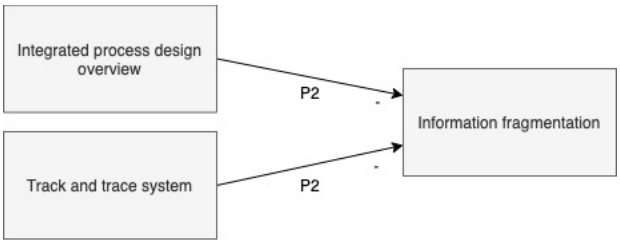

Figure 15. Proposition 2 applied to the invoice case

6.5.1. A preventive boundary object: integrated process design overview

The designed preventive intervention includes a preventive action to eliminate the cause of the potential occurrence of missing performance declarations[14]. To be able to improve the process from a multi-actor perspective - when the information about the process design is fragmented throughout the organisation - an integrated overview of the process design information is helpful. Moreover, the integrated overview of the process will facilitate stakeholder discussion. Besides this, the shared process design overview helps to identify process improvements on a higher level than a single section or department.

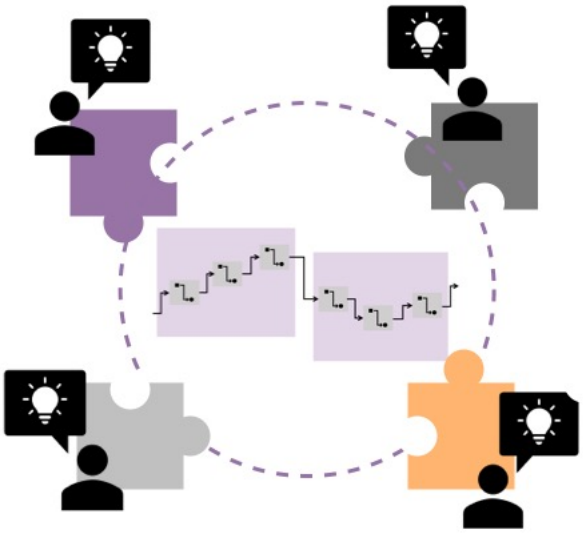

Figure 16. Integrated process design overview visual

The boundary object creates an overview of the entire process, understandable for each stakeholder (Figure 16). Furthermore, the characteristics of a boundary object must be incorporated. Thus according to Star (1989), the design should be "*plastic enough to adapt to local needs" (p.46)* of the stakeholders and "*robust enough to maintain a common identity across sites" (p.46).*

An opportunity exists within the MoD regarding ARIS. Currently, the MoD is already occupied with the process modelling in ARIS. However, the main reason for this is supporting the implementation of S/4HANA within the organisation (MoD04, MoD06) and not the structural improvement of processes. Nevertheless, the potential advantages of an integrated process design in ARIS for improving business processes are not entirely unknown (MoD06). ARIS can both show processes on high-level and more specific characteristics of processes, which must be in line with each other.

[14] Formulated considering the definition of ISO for preventive action (ISO 9000: 2015 3.12.1)

The shared process overview shows the integration of formal process design information. This creation of the overview can be used as a starting point for further discussion involving the different stakeholders and their perspectives. Furthermore, the shared process overview can serve as a cornerstone for the identification, design and implementation of upfront optimisation possibilities and process modifications. The integrated process design overview aims to reduce the fragmentation of formal process design information, which is a specification of proposition 2. This relationship is visualised in the following figure (Figure 17).

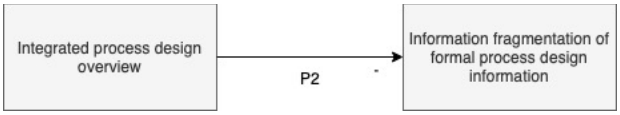

Figure 17. The expected effect of integrated process design overview related to proposition 2

Focus group outcomes

The participants presented at the focus group discussed possible improvements in the process design. Furthermore, the focus group gave the impression of enthusiasm and willingness from the stakeholders to optimise the process design. The brainstorming session indicated an advantage of an integrated process design as that the process overview will support the "*exact formulation*" of the process (BO01).

During the focus group, several primitive ideas for process adaptions and optimisation were mentioned by the respondents. For example, an adaption where the commander is authorised to check the order and to implement the performance declaration in SAP when the performance declaration is missing (QR07-MoD15).

> "*A fallback solution, so that the commander can also authorise"* ~ MoD15

Currently, DigiInkoop invoices will be replaced by SAP Ariba[15]. In this research, the focus is not on the DigiInkoop invoice but on the MM invoices (as described in chapter 1). However, during the focus group session, it became clear that SAP Ariba has opportunities which can also be beneficial for MM invoices.

During the brainstorming session of the focus group, another advantage of process optimisation is identified, which has to do with standardisation. The processes are currently different per DO; making a uniform process seems to be an advantage for process optimisation.

> "*Each contract manager now defines his own process. There should be one process, uniformity in the work process"* ~ MoD14

Creating a structural process improvement is not always obvious, possible, or feasible in the short term. Therefore, another intervention focusing on reducing lead times - when missing performance declaration occurs - is described in the next section.

6.5.2. A corrective boundary object: track and trace as an information facility

A corrective intervention is primarily conceived to cope with the current process in practice. When the performance declaration misses in the process, the lead times of the invoice process directly increase. Finding out why the performance declaration is missing, what the required next steps would be and who is responsible for the action takes time due to the fragmentation of relevant information.

Another boundary object can help to reduce the lead times related to the repair actions resulting from missing performance declarations. Since many stakeholders exist in practice (e.g., the number of external suppliers), using boundary spanners will require much human capacity. Linked to the boundary spanners are boundary objects (non-actor entities). The boundary object proposed here intends to create

[15] SAP Ariba: a new application replacing DigiInkoop (MoD04)

an integrated overview to eliminate information fragmentation resulting in a missing performance declaration and prevent information fragmentation of missing performance declarations again[16].

The proposed boundary object can be captured under the term ‘track and trace’ system. Shamsuzzoha and Helo (2011) state that there exists no universally accepted definition for track and trace. They use tracking in terms of the collection and management of information related to the location of products or delivery items and tracing in terms of storage and retention of historical information about the manufacturing and distribution of products. For this study, tracking implies collecting and managing formal information related to the current location within the ordering and invoice process. For this study, tracing indicates storing and retaining formal historical information about the ordering and invoice process until the current state.

An impression of a possible track and trace system for the invoice case is visualised in Figure 18. The proposed track and trace system will show the relevant information to each stakeholder differently, based on the characteristics and needs of the stakeholder. An example of differences between the visualisation of the same information for different stakeholders is presented in Figure 19. The track & trace system in Figure 18 offers specifically a possible setup for an external supplier.

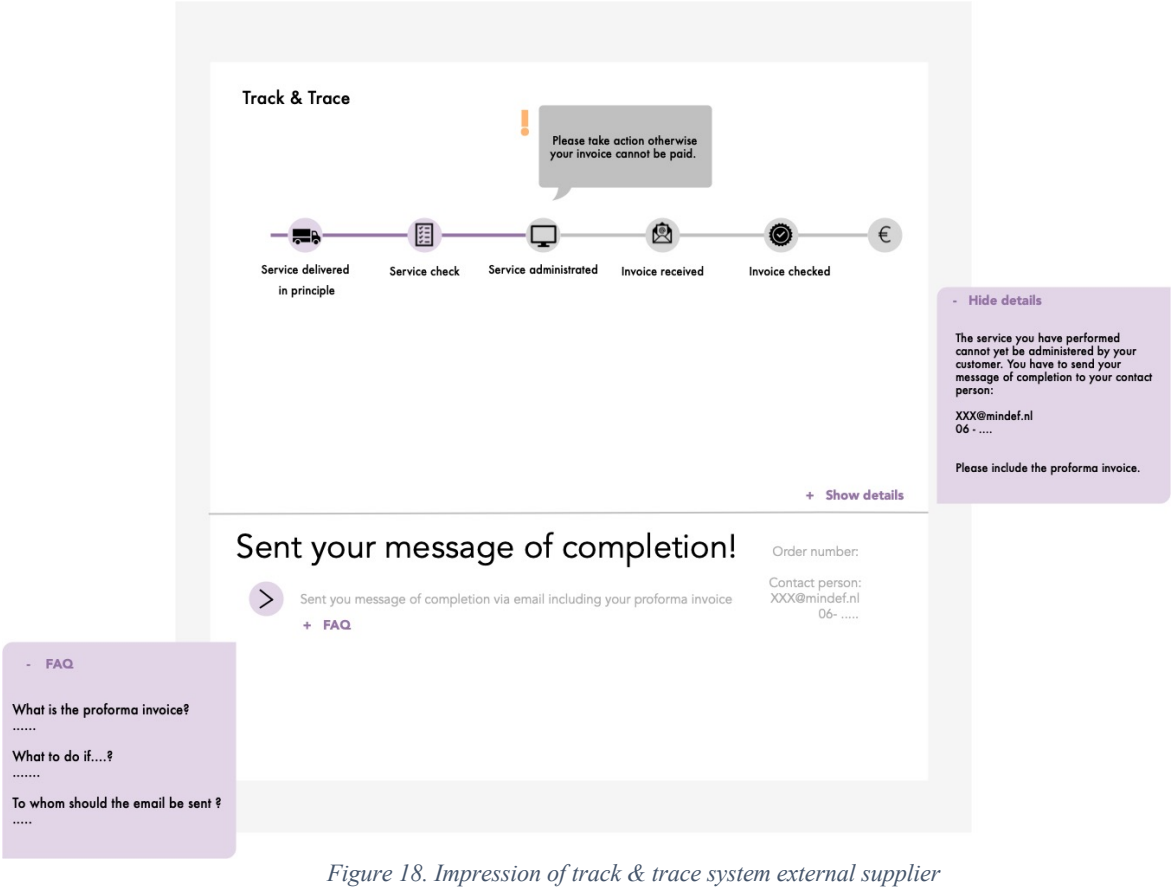

Figure 18. Impression of track & trace system external supplier

[16] Formulated considering the definition of ISO for corrective action (ISO 9000: 2015 3.12.1)

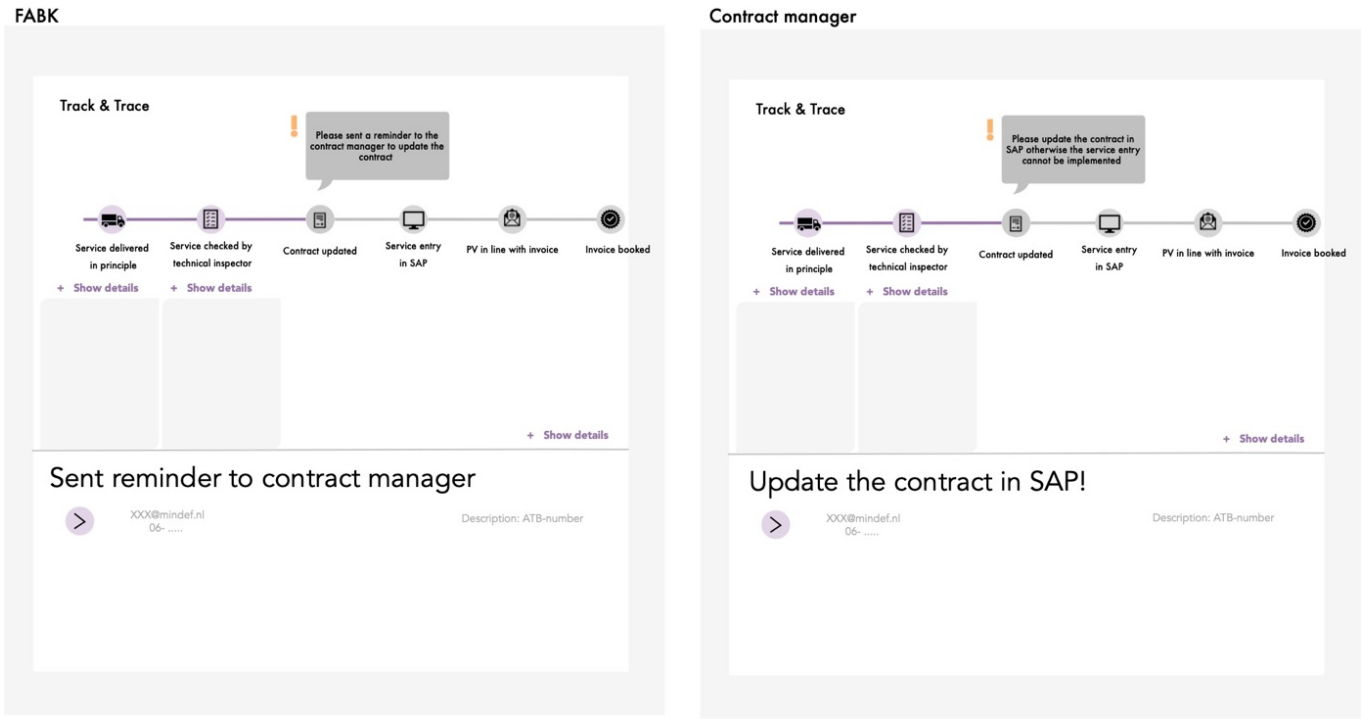

Figure 19. Impression track & trace system MoD

The proposed boundary object facilitates process information integration related to ordering and invoice processes. The track and trace system shows the relevant information related to the order and the invoice and where in the process, a problem occurs. This overview is helpful for the stakeholders in the process. Specifically, the proposed track and trace system has different advantages compared to the current situation.

First, the system asks for a more detailed record of formal information about who, what, where and when in the process. Consequently, the root causes of a missing performance declaration can be easier assessed by the formal information recorded. Thereinafter, the process steps will be registered in more detail in the integrated information facility. Currently, different process steps are non-digitally executed. Therefore, these process steps are not traceable for many stakeholders. The track and trace system will require more digital registration of sub-steps but will make them traceable for those who need it.

Second, the system can stimulate proactive actions by stakeholders. Specific employees are made responsible for performing a specific task instead of one employee being responsible for the final performance declaration implementation. This also allows the relevant employee to be directed in carrying out the action. This also applies to the external supplier. When an invoice is incorrect, incomplete, or double, the external supplier can be informed. Besides this, when another requirement for the external supplier is inadequately or not executed, this can be communicated via track and trace. For example, when the external supplier did not send the message of completion, including the proforma invoice, to the planner, this can be indicated at the interface of the track and trace system (as shown in Figure 18).

Third, the identification of the current position in the process is accessible to all stakeholders. An up-to-date overview of the process will show all stakeholders where the process is stuck and who is responsible for the next step in the process. Problems occurring at MoD do not have to be communicated in detail with external suppliers. However, updating that the MoD is in the process of resolving a problem and specifically indicating to the external supplier that the external supplier does not need to act can be valuable. The system can even point to specific contact details should the supplier have any questions.

Fourth, the outstanding actions can be managed by addressing the responsible stakeholder (the one who is in charge of the next step in the process) in a focused way. Instead of sending an RFI to the planner, the responsible employee can be contacted directly.

Moreover, management or policy sections can also use the system to evaluate and learn from mistakes. An overview of all orders and where these orders get stuck in the process (in more detail than is kept in the current system) can provide opportunities to eliminate specific root causes. Besides this, the detailed record of process information contributes to the identification of lead times in more detail. This advantage can contribute to IM.

Besides the indicated advantages of a track and trace system for the invoice process, a track and trace system also gives some concerns. It is useful to consider these concerns in any further development of the track and trace system. First, the track and trace system's technical feasibility must be analysed. Favourably, the track and trace system is compatible with the current possibilities in SAP. Second, due to the more detailed record of formal information, all the steps must be digitalised and captured.

Generally, the track and trace system integrates the formal process in practice information. The expected effect is that the track and trace system contributes to the availability and accessibility of process in practice information for the involved actors. When a missing performance declaration occurs, the non-value-adding activities, including the waiting time for the relevant information, are reduced by the track and trace system. Furthermore, based on historical information, insights into process performance and problems can be easier identified, which contributes to prevent these problems and to take proactive actions for future problems. Figure 20 shows the expected effect of the track and trace system as a specification of proposition 2.

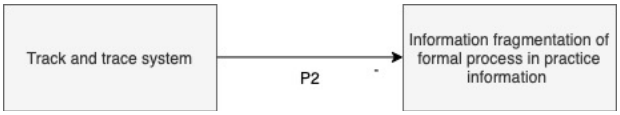

Figure 20. The expected effect of the track and trace system related to proposition 2

Focus group outcomes

During the focus group, the possibilities of a track and trace system are discussed. Multiple ideas can be incorporated by the track and trace system. Furthermore, some (dis-)advantages are indicated by the focus group outcomes.

One point that was mentioned by respondents is that the external suppliers need to be "*brought up*" (MoD12, MoD14). This problem-solving perspective would approach the external root causes of missing performance declarations. Considering the track and trace system, the system may serve some form of instructive information. The external supplier can be instructed with specific procedures on how to continue to get insights into why the invoice has not been paid. Thus, from the perspective of this research, track and trace can have the possibility to instruct external suppliers.

During the brainstorming session of the focus group, different advantages of a track and trace system for the invoice process were mentioned. Track and trace can help "*to analyse the source of the problem*" (BO02), and track and trace system causes clarity in roles and responsibilities within the MoD: "*within the MoD, it is clear who has to do what*" (BO02). Besides this, the track and trace can be used to clarify the invoice process at the MoD for the external supplier: "*there is time to clarify the invoice process*" (BO02).

> "*Create more clarity in the process, especially that you make it more transparent and what everyone is responsible for*" ~ MoD16

However, during the brainstorming session, concerns were specified too. The implementation of a track and trace system will require recordings of process steps in more detail. "*The question is how people will react to that because it means even more monitoring and bureaucratism"* (MoD16). Furthermore,

MoD16 indicates that it will be challenging to assign roles and responsibilities for steps in the process but that it will help.

6.6. Concluding remarks

This chapter generally presents empirical data obtained during the case study, these data are used to address sub-question 5 and 6. This chapter started with a description of the invoice case at MoD. The process design is indicated and the process in practice is analysed. From the analysis, it becomes clear that missing performance declarations are a problem at MoD, significantly influencing the lead times of the invoice process due to non-value-adding activities. The problem of missing performance declaration is analysed by applying the information fragmentation perspective. Specifically, the four indicators for information fragmentation were evaluated.

Consequently, the problem-solving dimension of the information fragmentation perspective is also applied to the invoice case. Specifically, two preliminary boundary objects are introduced, one preventive and one corrective. Firstly, an integrated process design overview aims to integrate formal process design information. Secondly, a track and trace system aims to integrate the formal process into practice information. The focus group provides insights into the two problem-solving interventions. What exactly can be derived from these empirical data is discussed in the next chapter. Chapter 7 begins by outlining the validity of the study. In addition, the main research findings will be interpreted. Moreover, the limitations of the research will be discussed.

Chapter 7. Discussion

"That there is a discussion arising about this, does indicate that something is wrong" ~ MoD13

This chapter discusses the validity, implications, and limitations of the performed research. After the validity of the research is discussed, the results presented in previous chapters are interpreted. Subsequently, additional limitations of the study are determined.

7.1. Validity

Different aspects have been considered to ensure the case study results' validity. During the entire project, there was close collaboration with the case study stakeholders. Involving MoD employees in the study contributed to the validity. For example, this research used an iterative setup to increase the opportunities for stakeholder validation. Multiple interviews validated the previous findings and conceptualisations.

In qualitative research, as in this study, the convergence of the different research data contributes to the validity (Carter et al., 2014). The various data collection methods (e.g., via documents, interviews, and quantitative data) and different data sources (N=16, employees of MoD) contribute to the triangulation. Moreover, the involvement of two additional observers during the focus group further enhances the validity; specified by Carter et al. (2014) as 'investigator triangulation'. Even though these measures have been taken, the validity should be considered to ensure the research's quality. For this purpose, different types of validity are critically examined. Maxwell (1992) determined five types of validity relevant to qualitative research: descriptive, interpretative, theoretical, generalisability and evaluative validity.

Generally, several aspects of the research setup and execution detriment the validity of the research. One or more types of validity are related to each concern. According to Maxwell (1992), descriptive validity is the primary aspect of validity since the other types depend on descriptive validity. Regarding descriptive validity, Hayashi et al. (2019) determined that "*the researcher does not embellish or distort the information, situations and facts reported are those that were seen and heard*" (p. 100). The focus group and interviews are deliberately not audio-taped to avoid drawbacks on data reliability. However, this has consequences for the (descriptive and interpretative) validity because the observation took place simultaneously with the interviews. Nevertheless, there was also third-party observation during the focus group session, which reduces the likelihood of inadequate field notes. Since a shared complete process design is still missing for the invoice process at the MoD, there was no possibility of validating the general (BPMN) process model of this research (Appendix H: Figure H.6) by comparison with the process design of the MoD.

The interpretative validity of this research can be questioned since multiple interviews and a focus group were not audio-taped. However, the researcher always had to make interpretations of the data. Therefore, various steps of stakeholder validation have been incorporated during the research to avoid misinterpretation.

The current research combines scientific references to develop an information fragmentation perspective. The question regarding theoretical validity is whether the theory validly accounts for the phenomenon in the case (Maxwell, 1992). The propositions obtained from the information fragmentation perspective are applied to the invoice case of MoD. Other SC case studies, including the effect of boundary objects on information sharing and SC performance indicators, have been performed before. However, this research specifies a type of information sharing (formal information sharing), a specific performance indicator (lead times) in the military context. Moreover, the focus of the study is on information fragmentation. The theory validity is tested by only one case. Additional case studies should strengthen the theory validity.

Furthermore, the internal generalisability validity can be discussed. The primary research data are obtained using interviews and a focus group session. For both methods, the short period of observation is detrimental. Furthermore, the respondents' perspectives can be potentially incompletely expressed, which can cause false inferences (Maxwell, 1992). In this research, multiple employees of MoD were interviewed and participated in the focus group. However, only 16 employees of a large organisation have been consulted related to the invoice case. Some employees have experience or are involved with other (MSC) processes. As a result, the external generalisability of the research is considered. However, additional case studies should complement to generalise to other military processes. The external generalisability validity can be seen as restricted in this research.

Based on the critical view towards the validity of this research, evaluative validity is considered in this research. Recommendations for further research have been made, which are presented in chapter 8.

7.2. Interpretation of results

The different sub-questions formulated in chapter 1 are addressed during the research, which provides multiple results. The results are divided into four sections. Firstly, the results obtained from the literature background are discussed. Secondly, the results from developing the information fragmentation perspective are interpreted. Furthermore, the results retrieved from the case study and the application of the information fragmentation perceptive are discussed. Conclusively, the generalisability of the case study results is discussed.

7.2.1. Obtaining a literature background

The literature background provides multiple results. These results are not the core of the study; however, they enable adequate answering of the main research question. Generally, the literature background supports the scientific relevance of this research and choice made.

The rationale 'reducing non-value-adding activities and lead times in MSCs, increases the flexibility' is a starting point for this research. The literature background shows that financial supportive processes are highly interrelated with primary MSC processes. Reducing lead times of financial supportive MSC processes contributes to external supplier relationships and cost reduction and thereby to MSC flexibility. Besides this, insights into lead time reduction in financial supportive MSC processes can be used to reduce lead times in other MSC processes. Furthermore, focusing on a financial supportive MSC process has an intrinsic value of improving the financial supportive process itself: complying with legislation.

Information sharing is essential for MSC processes. This study focuses specifically on formal information sharing. The definition of formal information sharing can be discussed since other perspectives on formal information sharing can exist. The focus on formal information sharing has increased the feasibility of the study. Moreover, from the research, it becomes clear that missing performance declaration in the invoice case is a significant problem for lead times. Since the performance declaration is typically a piece of formal information, the relevance of adequate formal information sharing is supported. Since lacking integration of formal process information is problematic for SC processes, the concept of information fragmentation is applicable. From the literature background, the relevance of developing an information fragmentation perspective towards reducing lead times in MSCs became clear.

7.2.2. Development of the information fragmentation perspective

The development of the information fragmentation perspective results in a theoretical understanding of information fragmentation, a rationale about how information fragmentation can be problematic for lead times in SCs and a rationale about how boundary objects can reduce information fragmentation.

As expected, the literature study shows that the concept of 'information fragmentation' is not yet widely used. Especially in the context of lead time reduction for MSCs, the information fragmentation perspective adds a new perspective to information sharing problems related to lead times in MSCs. The information fragmentation perspective starts from the reasoning that reducing non-value-adding

activities and lead times in MSCs, increases flexibility. Consequently, the effect of boundary objects on information fragmentation is motivated. However, additional (in-)direct effects of boundary objects on MSC flexibility are not included.

The first proposition (P1) states that the expected effect of information fragmentation on lead times in MSCs is positive. I.e., based on the literature, information fragmentation can be expected to result in higher lead times in MSCs. Specifically, the reasoning for this proposition is that information fragmentation can result in non-value-adding activities, which increase the lead times. This proposition is primarily based on the publication of Rukanova et al. (2017), which is the only retrieved publication related to information fragmentation in SCs.

The second proposition (P2) states that the expected effect of boundary objects on information fragmentation is negative. I.e., it can be expected that implementing boundary objects reduces information fragmentation in MSCs. The literature shows the possibility of boundary objects to reduce information fragmentation. Boundary objects respond to the multi-actors context and the diversity in sources and representation formats to increase accessibility. Boundary objects can increase the accessibility by integrating information and presenting it in an understandable format.

7.2.3. Application of the information fragmentation perspective to the invoice case

The developed information fragmentation perspective is applied to the invoice case of the MoD. The application of the information fragmentation perspective results in the empirical assessment of the two obtained propositions (P1 and P2) by analysing the invoice case.

An identified problem related to information fragmentation and lead times in the invoice case

The lead times of the invoice process are considered too high in relation to the legal payment term, especially for the Royal Netherlands Army. Although the quantitative data (Appendix H: Figure H. 7.) show satisfactory payment behaviour for MoD wide, the payment behaviour is considered worse in practice. The data of this analysis only include the paid invoices, while outstanding payments are not included. Therefore, the payment behaviour is considered unsatisfactory.

One problem related to information fragmentation and lead times in the invoice case is found. This problem is characterised by a missing performance declaration between the ordering process and the invoice process checking. Multiple issues related to the invoice case were indicated during the explorative research; the problem of missing performance declarations is specifically selected due to its information fragmentation characteristics and significant impact on lead times.

Since the information fragmentation perspective includes four indicators of information fragmentation, these four indicators (Table 7) are specifically considered for the problem of missing performance declarations. The empirical data evaluated these four indicators in the invoice case. The multi-actor context of the invoice case shows the diversity of involved stakeholders. Furthermore, these stakeholders depend on each other and the formal process information for the execution of the process steps. For the formal process design information and the formal process in practice information, a diversity of sources is used to store the formal process information; this results in different standards and representation formats for both types. Furthermore, the accessibility to formal process information is limited in the invoice case for both types of formal information. The problem of missing performance declarations is considered a problem resulting from information fragmentation.

Moreover, when a performance declaration is missing, stakeholders must wait and search for formal information, increasing the invoice process's lead times. The information fragmentation perspective results in a proposition that state the effect of information fragmentation on MSC lead times by adding non-value-adding activities to the process. Specifically, the empirical data show that the problem of missing performance declarations results in non-value-adding activities. Furthermore, the empirical data prove that these non-value-adding activities increase lead times.

Sometimes the absence of a performance declaration is accurate since the service is not (correctly) executed or the goods have not been delivered (correctly). In these cases, these invoices should not be paid by MoD to ensure the quality of the invoice process. Thus, the problem is not just the absence of the missing performance declaration but the information fragmentation resulting in the ambiguity of process in practice information and outstanding invoices, which add non-value-adding activities to the process.

Two boundary objects to integrate formal information in the invoice case
Two problem-solving interventions are identified to approach the missing performance declaration problem. Both interventions include a boundary object, and both are considered relevant. However, the further research should quantify the effect between boundary objects, formal information fragmentation and lead times of the invoice process. Besides this, only preliminary interventions are designed in this research. In other words, the two problem-solving interventions are only starting points for further development. Thus, the results regarding the boundary objects as problem-solving interventions obtained in the research are limited. The focus group supports these preliminary interventions as possible problem-solving interventions based on the data obtained. The two interventions seem to be logically beneficial. Here, two mechanisms indicate the application of the propositions in the invoice case.

The preventive intervention includes a boundary object in the form of an integrated process design overview. In what way this boundary object contributes to the reduction of lead times is presented in Figure 21. Related to the aspects of the definition of Star (1989), this boundary object is *plastic enough* on a detailed level of the process design to *adapt local needs and constraints* of the stakeholders, including task specificity. Generally, the process design will show on a high level the process design for all stakeholders as a *common identity across sites*. The boundary object reduces formal process design information, which can reduce the lead times by process optimisation and mistake proofing. Besides this, creating the boundary object asks all relevant stakeholders to involve in the discussion. Since the current ARIS modelling at the MoD already shows the feasibility of an integrated process design overview, the technical feasibility is plausible.

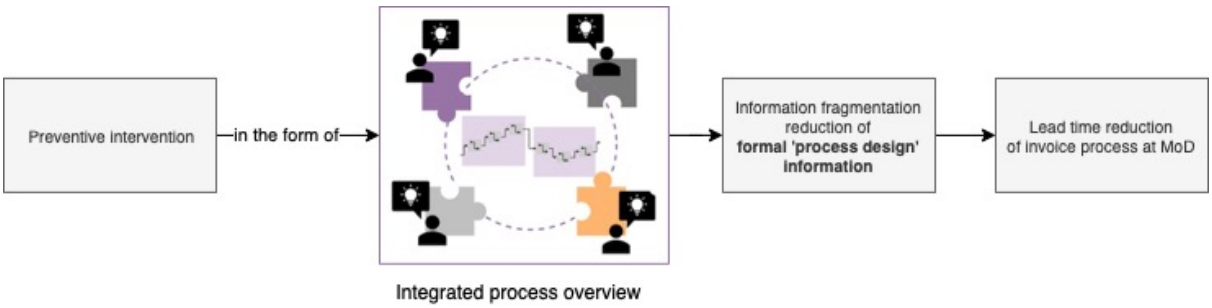

Figure 21. Mechanism integrated process design overview

The question of whether it would be beneficial to create an integrated process design overview is answered because the discussion during the focus group was not about whether the overview should be made but how the process can be improved. The usefulness of creating the detailed process design overview can be supported by the enthusiasm and willingness of the stakeholders to optimise the process, which is observed during the focus group.

The corrective intervention includes a boundary object as a track and trace system. How this boundary object contributes to the reduction of lead times is presented in Figure 22. Related to the aspects of the definition of Star (1989), this boundary object is *plastic enough* on the interface level of the track and trace system to *adapt local needs and constraints* of the stakeholders, including the necessary information for the specific stakeholder. Generally, the track and trace system will integrate all process in practice information (in more detail than currently is recorded at MoD); the track and trace system is for all stakeholders as a *common identity across sites*. This boundary object aims to reduce the fragmentation of formal process in practice information which can reduce the lead times by faster repair actions and preventing other mistakes (e.g., double invoices). The track and trace system requires the

record of formal process in practice information in more detail; it also requires more detailed roles and responsibilities of the MoD employees. These requirements may have implications for the level of bureaucracy. The question here is whether the increasing bureaucracy/monitoring is desirable. Besides this, the technical feasibility must be analysed in further research, including the compatibility of the track and trace system with the ERP system (SAP) used at MoD. An innovative project for implementing a track and trace system for logistic resources to improve the logistical staging area (SA) has been successfully completed (Ministerie van Defensie, 2022f). The success of the innovative project supports the technical feasibility of track and trace systems within the MSC processes of the Dutch armed forces.

Furthermore, the track and trace system can identify the root causes of the missing performance declarations. It can help analyse them and develop preventive measures that reduce lead times. Based on the definition used by Dong et al. (2017) for IOS, the track and trace system can be seen as an IOS. Dong et al. (2017) analysed the negative influence of regulative distance on IOS-enabled knowledge sharing and SC performance; they concluded that there is no negative effect. This study did not specifically examine the regulatory distance between MoD and its external suppliers. However, even if there is a regulative distance (which is plausible), it will most likely not negatively affect the effectiveness of the track and trace system.

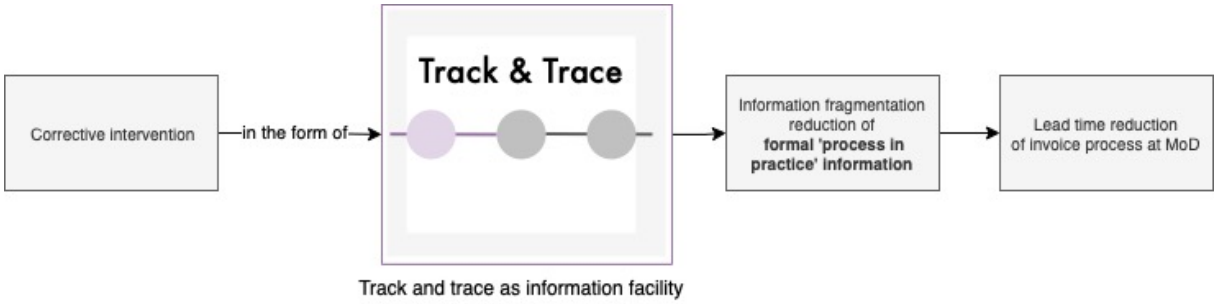

Figure 22. Mechanism track and trace information facility

Both boundary objects contribute to reducing information fragmentation by addressing the challenges (C1 and C2), as indicated by Van der Aa et al. (2015). The integrated process design overview extracts a structured overview of the formal process design information in a process design overview interpretable for all stakeholders (C1). Moreover, the integrated process design overview aligns all formal process design information (C2). The track and trace system extracts formal process in practice information in more detail than currently is recorded within the invoice case (C1). The track and trace system aligns all formal process in practice information and shows the relevant formal process in practice information in an interpretable way to each stakeholder (C2). Since the boundary objects are not designed in detail yet, follow-up steps are recommended; these are discussed in chapter 8.

7.2.4. Confirmation of propositions

The case study at the MoD provides empirical insights into the existence of effects formulated by the propositions in practice. The explorative nature of the case study resulted in preliminary insights. Especially the insights on the effects of the proposed boundary objects are primitive. However, the obtained data indicate the occurrence of the effects in practice. Since the indicators for information fragmentation are present for the problem of missing performance declaration, and support is given for the relationship between this problem and the lead times of MoD, the first proposition (P1) is confirmed by practice for the invoice case at MoD. Specifically, the fragmentation of two types of formal process information - resulting in missing performance declarations - supports the non-value-adding activities resulting in higher lead times of the invoice process.

It is premature to confirm the existence of the effect of boundary objects on information fragmentation in the invoice case. Therefore, additional research is required to support the proposed effects of the developed problem interventions. Figure 23 specifies the effects of the invoice case of MoD based on the propositions formulated in chapter 6.

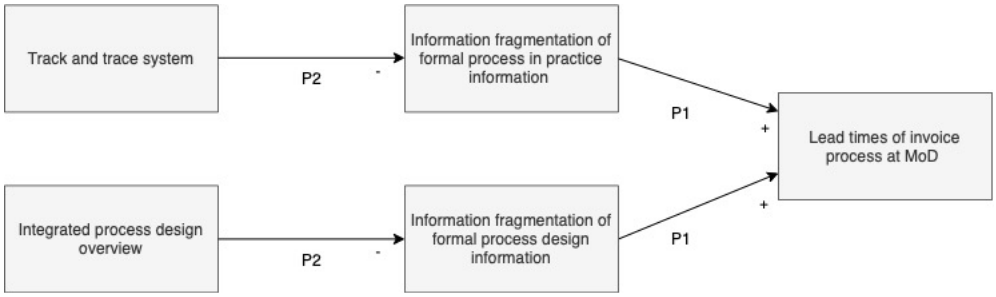

Figure 23. (Expected) effects found in invoice case related to propositions

7.2.5. Additional research results

Other remarkable results that do not contribute to the answer to the main research question are obtained during the research. For example, the implementation of electronic invoicing (e-invoicing) stipulates the context of invoicing at the MoD. During the study, data related to the e-invoice adoption and execution of the process at MoD are gathered. The implementation of e-invoicing is legally determined in the Dutch procurement law. Besides this, e-invoicing should be faster and more secure and make fewer mistakes than conventional invoicing (Rijksoverheid, n.d.). However, the quantitative data (Appendix H: Figure H. 7. and Table H. 3) do not support the faster processing of e-invoices compared to pdf invoices.

Another example is the general finding of inertia within the MoD. The operation of numerous processes (e.g., the request for a defence pass) and the implementation of innovation within the organisation (e.g., S/4HANA) match the organisational structure and complexity. Especially the bureaucratic character of the organisation enlarges the formal information sharing dependence on processes. These characteristics generally contribute to the syrupy (Dutch: ‘stroperigheid’) of processes in military organisations.

7.3. Limitations

The performed research does have its limitations related to the approach, execution, and generalisability. The study's validity is discussed in paragraph 8.1, which indicates a first set of limitations. Besides the validity, the study has its limitations.

7.3.1. Choices and assumptions

Several choices and assumptions are made during the study and procedure, each providing a more specific focus. For example, the choice to focus on boundary objects can be explained, but whether boundary objects are better than other preventive or corrective interventions is not analysed. This limitation also applies to other choices in the research process. Besides this, simplifications and assumptions sometimes influenced the research quality. Furthermore, data accessibility is described below as a separate limitation.

Another example is the simplified BPMN and process conceptualisation, which is used to overview to invoice process. Due to the complexity and diversity of the related processes, it was not feasible to conceptualise all the details of these processes. The details in the process design conceptualisation would have been beneficial, and therefore, it is one of the significant practical and scientific recommendations (described in the next chapter).

7.3.2. Data accessibility

A substantial disadvantage of this research is the low reliability in terms of quantitative data. The lack of accurate, complete, and reliable reporting makes it difficult to quantify the effect of missing performance declarations on the lead times of the invoice process. However, the obtained quantitative data have been added to identify the problem. Moreover, the fact that IM is an area of concern for the MoD is also part of the problem. In addition, there is a practical and scientific recommendation to capture and examine the lead times of different processes at a more detailed scale.

7.3.3. Execution

Some limitations of the research are indicated, reflecting on the execution of the research. Firstly, in retrospect, the literature study on information fragmentation has been given a more dominant role in the research than previously expected. Therefore, more Boolean search terms could have been added. Only articles including the key term ‘organisational’ or ‘multi-actor’ are included. This search string could have been expanded by including synonyms, variations, and American-English translations. However, the current literature review provided sufficient references to define information fragmentation.

Secondly, reflecting on the execution, it is suggested to include a reflection in terms of flexibility in further research. As a starting point for this research, included in the research question and objective, the delineation is made to focus on reducing lead times in MSCs as a contribution to the flexibility of MSCs. However, the current research does not examine the contribution of the boundary objects the flexibility of MSCs at MoD. It can be expected that proposed boundary objects contribute to reducing MSC lead times but include another (in) direct side-effect on flexibility. However, since lead time reduction can be seen as a stand-alone objective for the case of the invoice process (due to the necessary legal compliance), no further evaluation of flexibility is made.

7.3.4. Generalisability

The research approach and analysis are focused on the invoice case of the MoD. This focus meant that little consideration was given to the problem of generalisability and applicability of the designed boundary objects to other domains in MSCs and beyond. The generalisability is partly discussed in paragraph 7.1 (validity). Some additional comments are made related to the generalisability of the research. First, only one case is studied in detail, which has negative consequences for generalisability. However, the problems related to information fragmentation will likely (based on the observations during the time at the MoD) occur throughout the whole organisation. E.g., “*logistic blindness*” is mentioned by MoD as a problem within the operational supply process of logistic resources (Ministerie van Defensie, 2022f). Besides this, in the explorative research, more generic comments have been made by the employees of MoD for different process levels (e.g., DOO programme etc.). Additional research be added by analysing other cases of internal MoD or external.

7.4. Concluding remarks discussion

This chapter discusses the validity, gives an interpretation of results and discusses the limitations. The next chapter will provide the conclusions and recommendations related to the performed research. Careful consideration of the concerns is necessary to provide valuable conclusions. Subsequently, recommendations are provided for further research related to the aspects discussed in this chapter.

Chapter 8. Conclusion

"You don't make progress by standing on the sidelines
whimpering and complaining.
You make progress by implementing ideas."
~ Shirley Chisholm

This research has offered different results and insights that generate answers to the formulated research questions. Six sub-questions are approached in this research to be able to answer the main research question. The conclusions are drawn based on the research findings and interpretation of these results presented in the previous chapter. Together the conclusions show the research outcomes concerning the problem defined in the first chapter.

This chapter provides an overview of the answers to the research questions, the scientific relevance of this study and recommendations for further analysis while considering the discussed validity, results, and limitations from the last chapter.

8.1. Answers to the research questions

This paragraph addresses the research questions formulated in the first chapter of this thesis. Accordingly, the first two sub-questions relate to the literature background. The answers to these sub-questions provide the relevance of the development of an information fragmentation perspective towards lead time reduction in MSCs. Subsequently, the third and fourth sub-question relate to developing the information fragmentation perspective. The last two sub-questions can be answered with the case study applying the information fragmentation perspective. As a result, the main research question can be answered at the end of this paragraph.

Answer to sub-question 1

The first sub-question is formulated as: *why is lead time reduction of financial supportive processes relevant for MSCs?* The second chapter provides a literature background of concepts central to this research. Generally, the literature background includes information related to MSCs and several MSC characteristics. Three conclusions are made based on the literature background.

First, from the literature study, it becomes clear that lead time reduction is vital to achieving flexibility in MSCs. One of the elements resulting in SC flexibility is lead time. Some authors refer to 'velocity' (Jüttner & Maklan, 2011). Sokri (2014) defines delivery flexibility specifically for MSCs as "*the ability to meet short lead times*" (p.82). From a broader perspective, flexibility and short lead times are essential for SCs to cope with uncertainty and to increase SC responsiveness. Especially, MSCs are complex systems; therefore, lead time reduction is challenging but essential to contribute to MSC flexibility.

Second, both primary and supportive processes are essential for the functioning of MSCs (Kleijn & Rorink, 2009; Muthoni et al., 2015; Wong et al., 2018). Specifically, lead time reduction of financial supportive processes is relevant for MSCs. Concentrating on the lead time reduction of financial processes is scientifically appropriate. Insights into the lead time reduction of supportive MSC processes contribute to understanding how to reduce lead times in other (e.g., primary) MSC processes.

Thirdly, lead time reduction of financial supportive processes is practically relevant for MSCs. Reducing lead times of a financial supportive process contributes to supplier relationships (Moeller et al., 2006; Um, 2017; Williams, 2017) which is relevant for SC flexibility (Loredo et al., 2015; Um, 2017). Furthermore, reducing lead times of financial supportive processes result in cost reductions and legislative compliance, which are relevant to military organisations and affect the performance of MSCs.

Answer to sub-question 2

The second sub-question addresses another aspect of MSCs which is formal information sharing. The second sub-question is formulated as follows: *how can formal information sharing be defined, and why*

is formal information sharing relevant to the reduction of lead times in SC processes? Therefore, the literature background provides insights into the definition of formal information sharing and its relevance for lead time reduction in SCs. Three conclusions are drawn from addressing this research question.

First, formal information can be defined as: *sharing structured, traceable information, which is located in a formal setting,* by using the definition of formal information sharing from Lai and Yang (2017). This definition indicates that formal information is structured, traceable and located in a formal setting.

Secondly, formal information sharing is scientifically interesting as a component of SCM. Improved SCM contributes to the reduction of lead times of MSCs. Information is a crucial element for SCM and is essential for enhancing SC performance (Kembro et al., 2014). Furthermore, formal information sharing is a subset of information sharing. Primarily due to the dependence on formal information in the process steps of an SC, this type of information sharing is relevant for improved SCM and to reduce the lead times of SCs. The problem of lacking formal information sharing for SC lead times is supported by Rukanova et al. (2017); lacking formal information sharing results in waiting time and non-value-adding activities. Therefore, formal information sharing is relevant to the reduction of lead times in SC processes.

Thirdly, information fragmentation seems problematic for MSCs. However, the current literature does not provide a perspective on information fragmentation towards lead time reduction in MSCs. The literature does not apply the concept of information fragmentation on MSCs to characterise lead time problems resulting from non-value-adding activities. Moreover, the literature does not address problem-solving of lead time problems in MSCs by focusing on information fragmentation.

Answer to sub-question 3

The third question is formulated as follows: *what is the expected effect of reduced information fragmentation on lead times of MSCs, based on the literature related to information fragmentation in an organisational or a multi-actor context?* Answering this sub-question includes two steps. Firstly, identifying how the literature report on information fragmentation in an organisational or multi-actor context. Secondly, relating information fragmentation to reducing lead times in MSCs. Three main conclusions are retrieved addressing this sub-question.

Firstly, the information fragmentation perspective developed in this study includes four indicators of formal information fragmentation in MSCs. Four indicators are retrieved from the existing literature. The publication of Rukanova et al. (2017) is used as a primary reference. Specifically, the involvement of multiple actors, diversity in used systems, applications and storages, diversity in representation formats and standards, and limited accessibility for actors to relevant formal information indicates the occurrence of information fragmentation.

Secondly, the information fragmentation perspective developed in this study addresses information fragmentation as a problem for lead times in MSCs. The term information fragmentation is used differently in the existing literature. However, generally, information fragmentation is acknowledged by literature as a problem related to information sharing. Furthermore, Rukanova et al. (2017) address the problem of information fragmentation for SCs. Specifically, the effect of information fragmentation on the waiting times in SCs is described by Rukanova et al. (2017). Therefore, information fragmentation is considered a problem for *lead times* in MSCs.

Lastly, for MSCs, the expected effect of reduced information fragmentation is that the lead times can be reduced by decreasing the non-value-adding activities. Based on the literature study on information fragmentation, it is expected that when the information fragmentation can be reduced, this will result in the reduction of repair actions and waiting time, which influence the MSC lead times. This effect is formulated as proposition 1: *information fragmentation leads to higher lead times of MSCs due to non-value-adding activities to the process.*

Answer to sub-question 4
Since the information fragmentation perspective of this study addresses information fragmentation as a problem for lead times in MSCs, a problem-solving dimension is added to the perspective. The fourth sub-question concerns this problem-solving dimension; the question is formulated as follows: *what is the expected effect of boundary objects on information fragmentation in MSCs, based on the literature on boundary objects in SCs?* Generally, three main conclusions are drawn.

Firstly, boundary objects can theoretically reduce process information fragmentation. From a literature study, it becomes clear that process information must be extracted from the different sources as a structured overview in an interpretable format (C1). Consequently, this structured process information must be aligned into an integrated overview (C2) to reduce process information fragmentation (Van der Aa et al., 2015). Concerning the definition of Star (1989), boundary objects are both plastic enough to adapt local needs of actors but robust enough to maintain one common identity. Process information fragmentation can be reduced when boundary objects integrate structured process information in an interpretable format.

Secondly, the effect of boundary objects on information sharing in SCs and SC performance measures, including SC lead times, is significant. The performed literature study shows that the effect of boundary objects on information sharing in SCs and SC performance is significant in all five publications. All articles show a positive relationship between boundary objects and information sharing. Furthermore, all articles show a significant effect of information sharing on different SC performance measures. Specifically, Xu et al. (2016) determined that boundary objects contribute to improved SC processing time and reduced costs.

Lastly, considering the first two points, the expected effect of boundary objects on information fragmentation is negative for MSCs. I.e., when implementing a boundary object in an MSC process, the expectation is that this can reduce information fragmentation. This relationship is presented as proposition 2: *boundary objects reduce information fragmentation in MSCs if structured overviews of the information are extracted, in an interpretable format, and aligned into an integrated overview.*

Answer to sub-question 5
The literature supports the two propositions derived from the information fragmentation perspective. However, to support the existence of these effects in practice, empirical evidence is needed. Therefore, the next sub-question relates to the case study performed in this research, formulated as *what current problem in the invoice case relates to information fragmentation and lead times?* This sub-question analyses the first proposition in the invoice case of MoD. Four main conclusions are retrieved.

Firstly, the empirical data show that missing performance declarations are a significant problem in terms of lead times of the invoice process at MoD. The lead times of the invoice process of MoD are not in compliance with national legislation. Specifically, missing performance declarations are identified as a cause for the higher lead times by causing non-value-adding activities and waiting time for the proper formal process in practice information, resulting in the correct performance declaration.

Secondly, the invoice case shows formal process design information fragmentation, resulting in missing performance declarations. The formal process design information is stored in different systems with different representation formats and standards. Subsequently, the accessibility to the information is limited. Furthermore, the multi-actor context contributes to formal process design information fragmentation. Since the process design is partly incomplete, incorrect, and limited accessible, the current processes in the invoice case result in missing performance declarations. Furthermore, preventing missing performance declarations by improving the process design is challenging due to formal process design information fragmentation.

Subsequently, the invoice case shows fragmentation of formal process in practice information, resulting in missing performance declarations. The formal process in practice information is spread out through the multi-actor system. Furthermore, different systems and applications are used to execute the process

steps and different representation formats, and standards are used to present the process in practice information. Generally, the formal process in practice information is limited accessible and often incomplete and incorrect. This results in the occurrence of missing performance declarations. Furthermore, when a missing performance declaration occurs, non-value-adding activities are needed to obtain the relevant information, which results in additional waiting time.

Lastly, considering the previous three conclusions, it can be concluded that the empirical data support the expectation that process information fragmentation results in higher lead times for the invoice process. The empirical findings support proposition 1 for the invoice case. However, the empirical data on problem-solving interventions does not quantify this effect. Nevertheless, the empirical data show the significance of the missing performance declaration problem for the lead times of the invoice case with different sources (documents, quantitative data, interviews and the focus group).

Answer to sub-question 6
Additional empirical evidence is needed to confirm the applicability of the second proposition in practice. The sixth sub-question analyses the second proposition derived from the information fragmentation in the invoice case of MoD. The sixth sub-question is formulated as follows: *how to integrate formal information in the invoice case to reduce information fragmentation?* Addressing this research results in three main conclusions.

Firstly, a preventive intervention can reduce formal process design information by integrating this information into one overview shared by all stakeholders and covering all related processes. Specifically, an integrated process design overview, integrating formal process design information, can reduce lead times of MSCs by enabling optimisation and the identification of improvements. Besides this, making the process design overview will involve relevant stakeholders sharing their perceptions, experiences, and problems. This boundary object integrates parts of the process designs into one shared perspective towards the process, which is likely, based on the empirical data, to contribute to reducing the lead times of all MSC processes.

Secondly, the corrective intervention reduces formal process in practice information by recording the information in more detail and integrating the information in a track and trace system. Furthermore, a track and trace system can integrate the formal process in practice information, reducing lead times of MSCs by enabling faster problem solving and a more detailed record of formal process in practice information. Based on the empirical data, improving the information facility with a track and trace system will likely reduce the lead times of MSCs. However, the trade-off between the time taken for recording and the time gained from the recording must be considered carefully. Theoretically, the two interventions are supported to contribute to lead time reduction via the reduction of formal process information fragmentation.

Lastly, considering the previous two conclusions, it can be concluded that the empirical data generally support the expectation that boundary objects integrate formal process information and reduce process information fragmentation in the invoice case. The empirical findings support proposition 2 for the invoice case. However, the empirical data obtained related to problem-solving interventions is primitive. Nevertheless, no crucial deficiencies or disadvantages of the two problem-solving interventions have been detected during the focus group and using the empirical data. Thus, the practical data support - so far - the potential of the two interventions.

Answer to the main research question
The main research question for this research is formulated as follows: *how to reduce information fragmentation in order to reduce lead times in MSCs?* The conclusions described above, related to the six sub-questions, contribute to the conclusion of this main research question. The main research can be answered theoretically and with the empirical insights obtained in the case study. Since the case study is related to one specific MSC process, the question arises whether the conclusions to the sub-questions can be generalised in order to answer the main research question.

Based on the performed research, it can be stated that boundary objects can theoretically result in reduced information fragmentation in order to reduce lead times in MSCs. More specifically, the reduction of formal process information fragmentation contributes to improved formal information sharing, which results in a decrease in non-value-adding activities in MSC processes.

The development of an information fragmentation perspective shows the relevance of integrated process information for the lead times of MSC processes. Furthermore, the information fragmentation perspective gives four indicators for information fragmentation (Table 7). When these indicators occur in an MSC problem, information fragmentation is plausible. When the same problem also results in non-value-adding activities influencing the lead times of the MSC process, the effect of information fragmentation increasing MSCs' lead times (proposition 1) is substantiated. Consequently, information fragmentation is considered a problem for MSC lead times. Therefore, the information fragmentation perspective also includes a problem-solving dimension, which identifies a second proposition. This proposition consists of the expected effect of boundary objects on information fragmentation for SCs. According to Star's (1989) definition of boundary objects, these are plastic enough to adapt to stakeholder needs and robust enough to create an integrated, shared identity. Therefore, boundary objects can overcome the challenges of reducing process information fragmentation determined by Van der Aa et al. (2015). Because boundary objects can extract a structured overview of process information in an interpretable format (C1) and align this structured process information (C2) for process information fragmentation reduction.

From the empirical data, it becomes clear that the high lead times in the invoice case of MoD are related to missing performance declarations. The problem of missing performance declarations significantly influences the lead times of the invoice process by adding non-value-adding activities, which results in higher lead times. Furthermore, in the problem situation of MoD, the information fragmentation indicators are present. The effect of information fragmentation on the occurrence of missing performance declarations and resulting in non-value-adding activities is supported by the empirical data. Thus, information fragmentation is supported to be a problem in terms of lead times of MSCs based on the case study. This conclusion confirms the applicability of the first proposition in practice.

Consequently, two interventions (a corrective and a preventive) are developed specifically for the invoice case of the MoD to reduce process information fragmentation and to approach the problem related to missing performance declarations. Both boundary objects are likely to reduce formal process information fragmentation because they present the formal process information in one system, accessible to each actor, in a standard format. When combining this conclusion with the applicability of the first proposition in the invoice case, these boundary objects are likely to reduce the lead times of the invoice process. However, the boundary objects must be designed in more detail; a technical feasibility study and additional research are needed to analyse the effect of the interventions on lead times in more detail and to support the functioning of the interventions in practice.

Since supportive processes are essential for the functioning of MSC and external relations relevant to the flexibility of SCs, the lead times reduction of the invoice process is beneficial for primary MSC processes. Furthermore, reducing the lead times of the invoice process with the two proposed boundary objects can reduce costs and increases legislative compliance.

Information fragmentation is a problem that is likely to occur in other MSC processes for multiple reasons. Firstly, the multi-actor environment generally dominates the MSC systems. Secondly, task specificity is a characteristic throughout the whole military organisation, which likely results in the use of different representation formats, standards, and systems. Moreover, multiple employees at MoD indicate the slowness of processes, problem-solving and innovation, and the challenges of IM within the whole military organisation. Thus, information fragmentation – from the perspective of this research – is likely to occur in other MSC processes within MoD and other military organisations.

The generalisability of the problem-solving interventions for improving information fragmentation to reduce lead times in other MSCs is limited solely based on these research outcomes. However, the

proposed boundary objects for the invoice case to address the information fragmentation problem are not restricted to the application for the invoice process. The integrated process design overview and the track and trace system also apply to other MSC processes. Recommendations are made to increase the generalisability of the research outcomes, which are discussed in paragraph 8.3.

To conclude, information fragmentation of formal process information causes non-value-adding activities in MSC processes. Furthermore, boundary objects, which integrate formal process information, are likely to reduce information fragmentation; thereby, boundary objects can reduce lead times in MSCs.

This research contributes conclusions related to the specified problem statement. Military organisations, especially the MoD, require MSC flexibility due to rising threats and international developments. Lead time reduction of the MSC process contributes to MSC flexibility; therefore, this research focuses on lead time reduction. The conclusions of this research offer a new scientific perspective to achieve lead time reduction in MSCs. The effect of information fragmentation on lead times of MSC was not examined before, nor addressed a direction for solutions from an information fragmentation perspective towards MSC lead time reduction by reducing its non-value-adding activities. An information fragmentation is developed and applied, which delivered valuable outcomes for the MoD's invoice case and eventually as a first step to the achievement of lead time reduction in MSCs generally.

8.2. Scientific relevance

This paragraph discusses the scientific relevance based on the answers to the research questions, the knowledge gaps, and the implications of the research findings. Chapter 1 introduced two knowledge gaps as starting point for the research. This section describes how the research addresses these knowledge gaps. Moreover, this study contributes to the scientific knowledge base, especially by combining the two knowledge gaps. The main scientific contribution of this research is the development of a new information fragmentation perspective towards lead time reduction in MSCs. Furthermore, this perspective is applied to a case, which provides empirical insights into the applicability and value of using the perspective in practice.

When resuming the starting point of this research, the scientific contribution is related to the knowledge gaps. Accordingly, the knowledge gaps are formulated as follows:

Gap 1: lack of scientific research related to the reduction of lead times in MSCs.
Gap 2: lack of empirical research on (formal) information sharing as a contribution to the improvement of SCM.

This study provides empirical research related to the formal information sharing in MSCs, specifically associated with the invoice process of the MoD. Applying the information fragmentation perspective in practice resulted in empirical insights. Before the scientific contribution of the empirical insights is discussed, the scientific relevance of the information fragmentation perspective is further clarified.

From the second knowledge gap, the focus on information sharing for lead time reduction in MSCs is argued. Information sharing is considered a relevant focus concerning problems regarding the lead times in MSCs. Problems regarding lead times result from non-value-adding activities related to lacking information sharing. Combining these problems with the two knowledge gaps resulted in identifying a more specific deficiency of the current literature: an information fragmentation perspective towards lead time reduction in MSCs was missing.

The information fragmentation perspective developed in this research fills this specific gap. Existing literature already addressed different aspects, e.g., Lai and Yang (2017) specify formal information sharing, Marshall (2015) and Wieland et al. (2016) in which information sharing is linked to SCM, Acero et al. (2020) operationalising SCM to reduce lead times of MSCs, Dong et al. (2017), Im and Rai (2008), Malhotra et al. (2007), Wei et al. (2013), Xu et al. (2016) who analyse the effect of boundary objects on information sharing in SCs and different SC performance indicators. Compared this literature

the information fragmentation perspective combines these relevant aspects to create a better understanding of MSC lead time reduction by the reduction of formal information fragmentation making use of boundary objects.

Returning to the empirical research's relevance, applying the information fragmentation perspective on the invoice case provides insights and contributes to the scientific relevance. The study identified the missing performance declaration problem related to formal process information fragmentation in the invoice case of MoD. Furthermore, the obtained empirical data are used to substantiate two specific problem-solving interventions contributing to improved supply chain management. However, these problem-solving interventions can be analysed further to improve SCM regarding information sharing to reduce non-value-adding activities in the invoice case.

Furthermore, the information fragmentation perspective is applied to the invoice case to support its applicability in practice. Based on the research results, the relevance of the information fragmentation perspective can be supported. This research contributes with a perspective to the reduction of lead times in MSCs (gap 1) which is valuable due to the focus on information fragmentation and boundary objects and its application on the invoice case of MoD providing empirical insights (gap 2).

8.3. Further research

This section provides multiple recommendations based on the research implications, outcomes, limitations, and scientific relevance. Future research should reinforce the obtained research outcomes and enhance the feasibility of actual change. As described in chapter 7, this study involves several limitations. Primarily due to the chosen research setup, including its methodology, the research is explorative in nature. Therefore, several suggestions for further research are presented below.

First, because the research was performed in close collaboration with the MoD, there was a dependence for data extraction on the external organisation. It is suggested to analyse the lead times of the case in more detail to improve the scientific problem analysis; this is also a practical recommendation for the MoD since it would be beneficial for the organisation to record lead times in more detail. This recommendation is also covered in this research's corrective intervention of a track and trace system.

Besides this, additional cases can be analysed to determine further issues related to formal information fragmentation, which influences the lead times of MSC processes by adding non-value-adding activities. Additional empirical evidence from applying the information fragmentation perspective and analysing the two propositions in practice should strengthen the applicability and value of the information fragmentation perspective.

Furthermore, this study contributes an explorative analysis of the effect of formal process information fragmentation on lead times. It is recommended to study this relation quantitatively by modelling the formal information sharing between supply chain stakeholders and its effect on lead times. Besides this, the impact of informal information sharing behaviour can be incorporated to generate a more realistic computational model.

Moreover, the boundary objects can be further designed to complete problem-solving interventions so that these boundary objects can be implemented with a pilot study to test the improvement actions. Rukanova et al. (2017) determined that the governance structure can be critical for the success of measures to reduce information fragmentation in SCs. Thus, careful consideration of governance structures, adaptions and consequences is recommended. Subsequently, a scientific and organisational recommendation is to measure the current state of invoice process lead times and compare this with the lead times after implementing a track and trace system. Practically it is recommended to improve the IM related to lead times by the more detailed recording and saving of these data. These measurements would deliver empirical evidence and support for implementing a track and trace system as boundary objects.

8.4. Relevance for practitioners

Different practical implications can be discussed when reflecting on the relevance of this research. Generally, this research contributes with a perspective on lead time reduction in MSCs focusing on information fragmentation. Furthermore, problem-solving interventions are identified for the MoD invoice case using the information fragmentation perspective, and these interventions are explored. The propositions designed in this research can be used to analyse and approach issues regarding lead times in MSCs by addressing them from an information fragmentation perspective. It is recommended to develop the two boundary objects further to reduce information fragmentation in MSCs.

More specifically, a key recommendation for the MoD is to explore the possibilities of more detailed reporting of process in practice information to facilitate improved IM. As a report by Profource (2021) indicates, IM should still be improved by increasing reporting quality and consistency. Especially, unambiguous and consistent reporting of lead times in the invoice process should increase the ability to analyse the data. Furthermore, opportunities with S/4HANA should be checked. Improving IM of process in practice information would also benefit the development of a track and trace system. Further exploration of more detailed reporting of process in practice information will be a first step for implementing a track and trace system with the proposed advantages discussed in this thesis.

Furthermore, the focus group session turned out to be valuable. Enabling stakeholders involved in SC processes to meet each other helps to identify issues, understand the different perspectives and explore possible improvements. Based on the experiences during the focus group of this study, it is recommended to involve employees from all involved departments and external suppliers in further discussions. For the MoD project 'Blijvend Beter Betaalketen' in particular, it is recommended to involve not only managers and department directors but also practitioners of specific process steps. Besides this, it is also recommended to involve external suppliers in this project. Furthermore, ARIS is considered a valuable opportunity to facilitate the creation of an integrated process design overview at the MoD.

The results of this study are valuable for the MoD and other military organisations aiming to reduce MSC lead times. In the end, society benefits from improvements in MSC flexibility and performance. International safety and security cannot be taken for granted with the instability of the (global) situation and the rising threats. Practitioners in the field of military SCM are enabled to examine lead time reduction of MSC processes differently by focusing on reducing information fragmentation to improve MSC flexibility and performance.

8.5. Closing remarks

This thesis contributes an additional perspective towards MSC problems related to information fragmentation of formal information and lead times. Furthermore, for this thesis, explorative research is performed at the MoD with a case study related to invoicing. The critical attitude towards the current problems and process in practice was necessary to identify and characterise issues in the case. However, it should also be mentioned that the MoD has currently initiated some major innovative programmes after years of budget cuts. Partly because of the available budget but also because of the increased importance of well-functioning armed forces for national and international security and freedom, it is expected that improvements will be undertaken in the coming years.

Furthermore, innovation is likely to contribute further to process development. Primarily due to the characteristics of military organisations, it is increasingly essential to progress with integrating information sharing in MSC processes. Conclusively, to improve formal information sharing within a large and complex organisation like the MoD, the first step may be easier than thought; engage with each other within the specific department and, in particular, across the value chain.

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Reference list to internal MoD data

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Export 30.11.2022

MSWord document analysis MatlogCo's 100 oldest outstanding invoices (performed on 18-10-2022):
Analyse 100 oudste openstaande facturen 18.docx

PDF document Sitrap week 49 2020 (performed on 14-12-2022):
Sitrap week 49 2022 gedraaid op 2022-12-14.pdf

Appendices

Appendix A. Structured literature study lead times in military SCs

This appendix provides an overview of the performed literature study on the subject 'lead times in MSCs'. Since the concept of 'supply chain' is related to 'logistics', this search term is also used in the literature study. This study aimed to obtain a background of existing literature about MSCs concerning (the reduction of) lead times. The study was performed on 23rd November 2022 using Scopus as facilitating database. In Figure A. 1, a flow diagram presents the selection process. In total, 17 articles were selected; those publications are shown in Table A. 1.

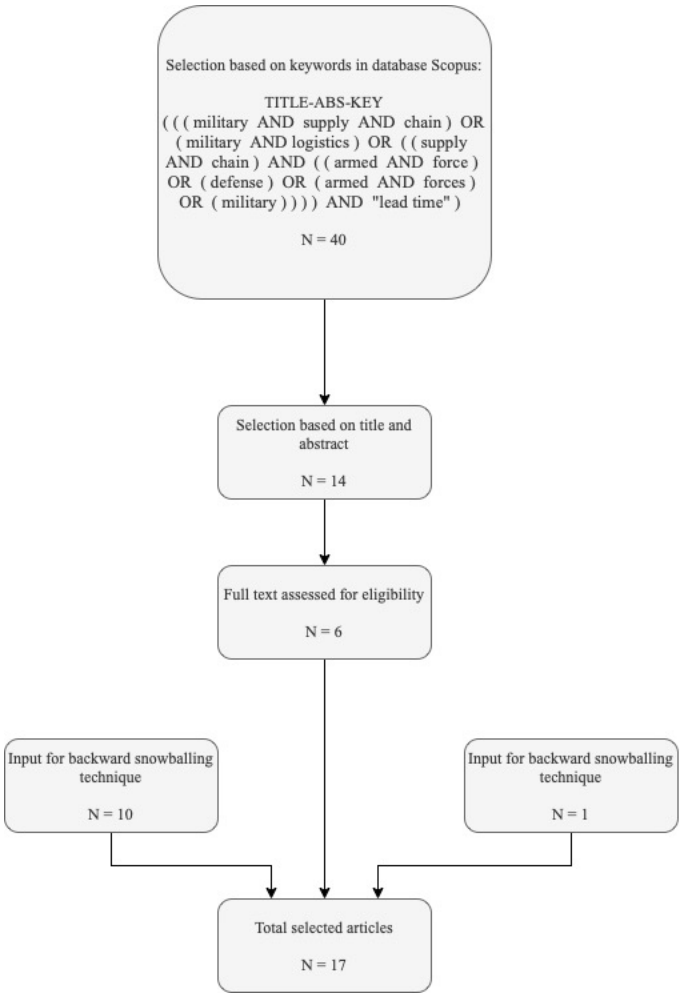


Figure A. 1. Literature study flow diagram: lead times in military supply chains

Table A. 1. Selected articles literature study lead times in military logistics

Title	Author	Year of publication
Value stream analysis in military logistics: The improvement in order processing procedure	Acero et al.	2020
Order processing improvement in military logistics by Value Stream Analysis lean methodology	Acero et al.	2019
Measuring supply chain performance	Beamon	1999
Quantifying variability impacts upon supply chain performance	Castilho et al.	2015
Simulation Based Decision Support for Supply Chain Logistics	Ganapathy et al.	2003
Advanced Technology in Navy Logistics Support	Houts	1990
Supply chain resilience in the global financial crisis: An empirical study	Jüttner and Maklan	2011
Measuring and Managing Army Supply Chain Risk: A Quantitative Approach by Item Number and Commercial Entity Code	Loredo et al.	2015
The Five Principles of Supply Chain Management: An Innovative Approach to Managing Uncertainty	Muckstadt et al.	2003
Joint Vision 2020: America's Military Preparing for Tomorrow	National Defense University	2000
Designing a Robust Supply Chain for Military operations A Multi-Agent Simulation approach considering Platooning	Reinders	2019
Strategies for Achieving Pre-emptive Resilience in Military Supply Chains	Sani et al.	2022
Military supply chain flexibility measures	Sokri	2014
Continuous Process Improvements and the Use of Quality Control Methodologies in the Data Item Description Process	Stanley and Wilson	1993
Flexibility from a supply chain perspective: Definition and review	Stevenson and Spring	2007
Supply flexibility strategies in Spanish firms: Results from a survey	Tachizawa and Gimenez	2010
Accelerate logistics: streamlining the army's supply chain	Wang	2000

Appendix B. Research flow diagram

Figure B. 1 presents a research flow diagram of this study. This research flow diagram shows the different chapters related to the research questions. Furthermore, the deliverables and research topics are indicated.

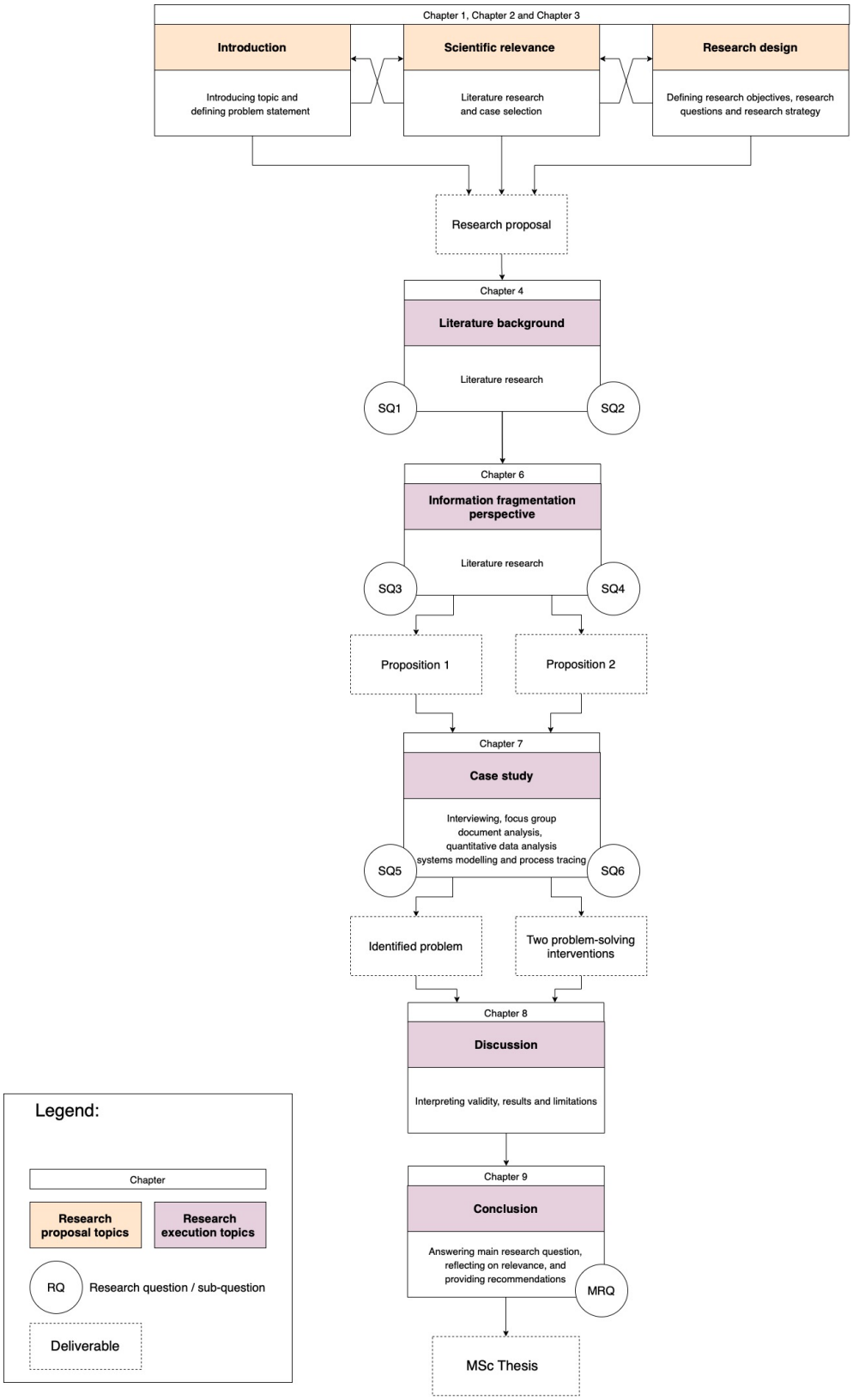


Figure B. 1. Research flow diagram

Appendix C. Methods

C.1. Methods and tools

Figure C. 1. presents an overview of the main methods and tools used for the research execution.

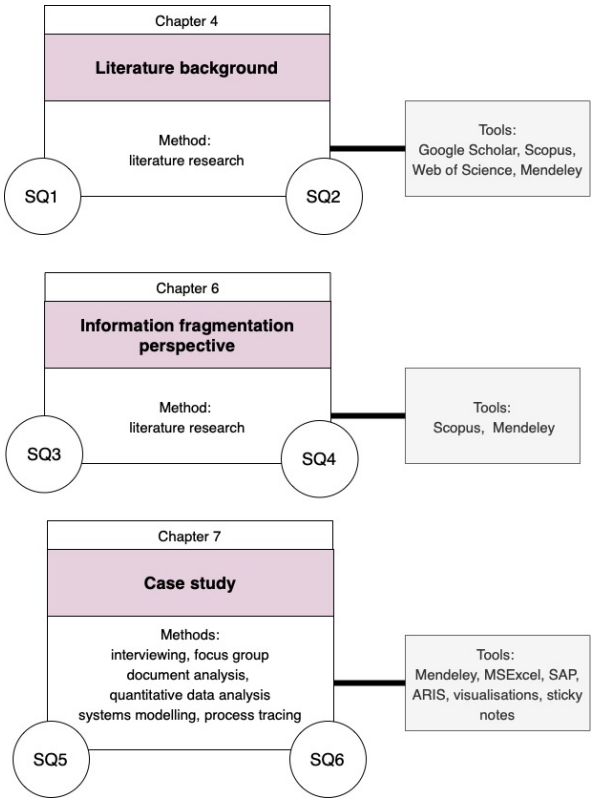


Figure C. 1. Methods and tools

C.2. Tools related to Lean Six Sigma

Several tools related to Lean Six Sigma and the DMAIC approach are used in the study. An overview of these tools can be found in table. Acero et al. (2019) argue for applying Lean Six Sigma methodologies to achieve lead time reduction in MSCs. The article presents an overview of the benefits of using the DMAIC problem-solving methodology and, specifically, the application of value stream mapping. Acero et al. (2020) determined that there is a lack of scientific research on applying Lean methods to MSCs. The article shows a performed case study on military material ordering procedures. It concludes: "*the demanding flexibility can only be achieved by improving supply chain management (SCM) to minimize lead times*" (p.1). Acero et al. (2020) suggest further research on applying Lean methodologies like VSM to other military processes.

Table C. 1. LSS tools in this study

DMAIC phase	LSS Tool	Reference
Define	Process map	Chiarini (2013); De Koning and De Mast (2006); Uluskan (2019)
	Stakeholder analysis	Chiarini (2013)
Measure	Data collection	Uluskan (2019)
	Process map	Chiarini (2013); De Koning and De Mast (2006a); Uluskan (2019)
Analyse	Cause-effect diagram/fishbone diagram	Chiarini (2013); De Koning and De Mast (2006b)
	Value stream mapping	De Koning and De Mast (2006)
Improve	Brainstorming	Chiarini (2013); De Koning and De Mast (2006)

Cause-effect diagrams (also named Ishikawa or Fishbone diagrams) are created to overview and summarise the root causes for high lead times during the explorative research.

Value stream mapping
More specifically than systems modelling generally is Value Stream Mapping (VSM). This lean tool focuses on the reduction of non-value-adding activities; this is relevant to this research in terms of lead times (Acero et al., 2020; Chowdhury et al., 2016). Applying VSM includes the identification of tasks and information flow by creating a detailed map of processes. The duration of technological operations is indicated, and the most important information is presented. Consequently, points for improvement are indicated and analysed (Żywiołek, 2016). Non-value-adding activities negatively influence the process lead times and imply points for improvement.

According to de Souza Pinto et al. (2017), VSM provides reliable quantitative analysis. Scientifically it is relevant to use VSM in the analysis of MSCs (Acero et al., 2020), but also concerning the objective to reduce lead times of MSCs by reducing its non-value-adding activities. VSM is often integrated with DMAIC in order to approach problems (Guo et al., 2019). According to McHenry and Will (n.d.), the most readily apparent benefit of using VSM is the identification of bottlenecks.

VSM is applied in earlier research to SCs. Suarez et al. (2016) determined three relevant flows for VSM related to SCs: material flow, information flow and cash flow. These three flows make the following indicators relevant for VSM in SCs: consistent quality as required, on-time delivery and a balance between volume and cost (Suarez et al., 2016). Acero et al. applied the VSM tool to a specific military logistic process and suggested further research of VSM in other military logistic operations.

VSM in this research is applied to the invoice process. In chapter 2 and 3, it is described that the invoice process is not part of the primary flow of MSCs but a supportive process. Consequently, the material flow receives little attention in the VSM of this research compared to the information and cash flow. However, the invoice process is related to the material flow of the MSC, therefore the material flow is considered.

Brainstorming is used to identify and explore two problem-solving interventions to reduce information fragmentation in order to reduce the lead times of the invoice process.

Appendix D. Interviews

This appendix provides information on the performed interviews at the MoD. The interviews have been coded to guarantee the respondents' privacy. In the table below, the references to the meetings are presented (Table D. 1).

Table D. 1. Coding explorative meetings

Code	Date	Time
MoD01	22-09-2022	09:00-12:15
MoD02	27-10-2022	14:00-15:00
MoD03	11-11-2022	10:30-12:45
MoD04	15-11-2022	09:15-11:15
MoD05	15-11-2022	11:15-12:00
MoD06	22-11-2022	09:00-11:15
MoD07	29-11-2022	11:00-12:05
MoD08	02-12-2022	08:00-09:05
MoD09	05-12-2022	10:00-10:45
MoD10	07-12-2022	09:00-09:50
MoD11	19-12-2022	10:00 -12:00

Appendix E. Focus group

This appendix provides an overview of the references to the respondents of the focus group and the focus group outcomes.

E1. Respondents
The respondents have been coded in order to guarantee the respondents' privacy. In the table below, the references to the respondent are presented (Table E. 1).

Table E. 1. Coding focus group respondents

Code	Department
MoD12	MatlogCo
MoD13	MatlogCo
MoD14	MatlogCo
MoD15	FABK
MoD16	FABK
MoD17	OTCO
MoD18	OTCO

E2. Outcomes
The answers to the questions on paper during the focus group and the output of the brainstorming session were coded to facilitate reference to the text. The answers to the questions belong to a specific respondent (MoD**), and the brainstorming session output belongs to the group (01 or 02). Table E. 2 provides an overview of the coding used for the focus group output.

Table E. 2. Coding focus group output

Code	Description
QR01-MoD**	Response to question 1 by the respondent from the MoD**
QR02-MoD**	Response to question 2 by the respondent from the MoD**
QR03-MoD**	Response to question 3 by the respondent from the MoD**
QR04-MoD**	Response to question 4 by the respondent from the MoD**
QR05-MoD**	Response to question 5 by the respondent from the MoD**
QR06-MoD**	Response to question 6 by the respondent from the MoD**
QR07-MoD**	Response to question 7 by the respondent from the MoD**
BO01	Brainstorm output group 1 focusing on the preventive intervention: process overview
BO02	Brainstorm output group 2 focusing on the corrective intervention: track and trace system

During the focus group, field notes and observations evaluate the discussions. The codes presented in Appendix E1 are used to refer to the contribution to the verbal discussion by the focus group participants.

Appendix F. Structured literature study information fragmentation

This appendix provides an overview of the performed literature study on 'information fragmentation'. This study aimed to obtain a background of existing literature using *information fragmentation* in an organisational or multi-actor context. The analysis was performed on 22nd December 2022 using Scopus as facilitating database. In Figure F. 1, a flow diagram presents the selection process. In total, 17 articles were selected; those publications are shown in Table F. 1. Table F. 2 shows the context or focus of the publications. Besides a summary of one of the papers is presented in this Appendix (F2).

F1. Structured literature study selection

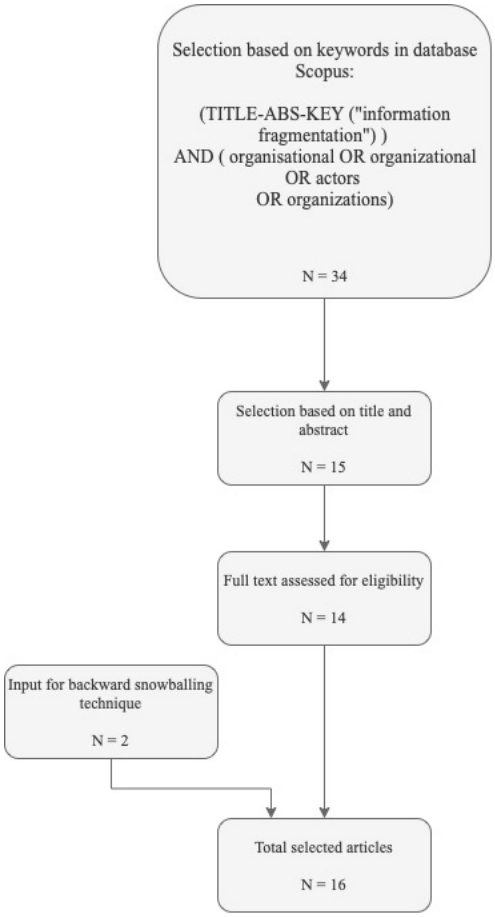


Figure F. 1. Literature study flow diagram: information fragmentation

Table F. 1. Selected articles literature study information fragmentation

Title	Author	Year of publication
An approach to spatial visualizing method for information structure to enhance remember to look	Lee and Shin	2015
Integrating BIM with ERP Systems Towards an Integrated Multi-user Interactive Database: Reverse-BIM Approach	Khan	2023
The Anatomy of Digital Trade Infrastructures	Rukanova et al.	2017
The impact of electronic health records on collaborative work routines: A narrative network analysis	Chao	2016
On the Fragmentation of Process Information: Challenges, Solutions, and Outlook	Van der Aa et al.	2015
Keeping found things found: Challenges and usefulness of personal information management among academicians	Warraich et al.	2018
Contextinator: Addressing Information Fragmentation with a Web-Based Project Manager	Hanrahan et al.	2014
An empirical study of long-term personal project information management	Copic Pucihar et al.	2016
Towards a Conceptual Framework and Metamodel for Context-Aware Personal Cross-Media Information Management Systems	Trullemans and Signer	2014
ActivitySpace: A remembrance framework to support interapplication information needs	Bao et al.	2016
All in pieces: A new media installation about information fragmentation	Huo	2015
Multimedia Health Records: User-centered design approach for a multimedia uploading service	Plazzotta et al.	2015
Information workers and their personal information management: A literature review	van Helvoort	2011
A Services Management System for Small and Disadvantaged Communities	Corradini et al.	2007
Fundamentals of Business Process Management	Dumas et al.	2013
Classification framework for context data from business processes	Möhring et al.	2015

Table F. 2. Focus or context of information fragmentation

Author	Year of publication	Focus/context
Lee and Shin	2015	Different applications
Khan	2023	ERP system to overcome information fragmentation and information loss
Rukanova et al.	2017	Digital trade infrastructures to reduce information fragmentation
Chao	2016	Electronic health records
Van der Aa et al.	2015	Fragmentation of process information
Warraich et al.	2018	Personal information management
Hanrahan et al.	2014	Web-based project manager addresses personal information fragmentation
Copic Pucihar et al.	2016	Personal project information management
Trullemans and Signer	2014	Personal information management
Bao et al.	2016	The use of different applications in software development
Huo	2015	Addressing information fragmentation with a new media installation: "All in Pieces"
Plazzotta et al.	2015	Electronic health records
van Helvoort	2011	Personal information management a literature review
Corradini et al.	2007	Services Management System for E-government
Dumas et al.	2013	Business processes (additional reference)
Möhring et al.	2015	Data in the context of business processes (additional reference)

F2. Summary Rukanova et al. (2017)

Rukanova et al. (2017) analysed four cases of initiatives, including Digital Trade Infrastructures (DTIs), where each initiative proposes to optimise information sharing between businesses and relevant governmental parties (all in the field of international trading). The insights from the case studies and the literature resulted in the development of a DTI framework including three dimensions: architecture, process and governance. The architecture dimension includes the categories level (e.g., national or international), actors (e.g., business (B), government (G), or intermedial), interactions (e.g., B2G or G2G) and specifically the DTI type of the initiative. The process dimension includes the development phase of the initiative (initiation, operation, etc.). The governance dimension consists of the "infrastructure" (formal or informal) and values about decision rights related to the initiative. The framework helps to address the initiatives and achieve a better understanding of the complexities and problems occurring.

Appendix G. Structured literature study boundary objects related to information sharing in SCs

This appendix provides an overview of the performed structured literature study on the subject boundary objects related to information sharing in SCs. This study aims to obtain a background of the scientific literature about the application of the concept of boundary objects related to information sharing in combination with SC literature. The study was performed on 20th December 2022 using Scopus as facilitating database. In Figure G. 1, a flow diagram presents the selection process. Five articles were found addressing boundary objects in SCs; those publications are shown in Table G. 1. A summary of the main effects presented in the articles is presented in Table G. 2 (Appendix G2). Appendix G3 provides insights obtained from the structured literature study on boundary objects.

G1. Structured literature study selection

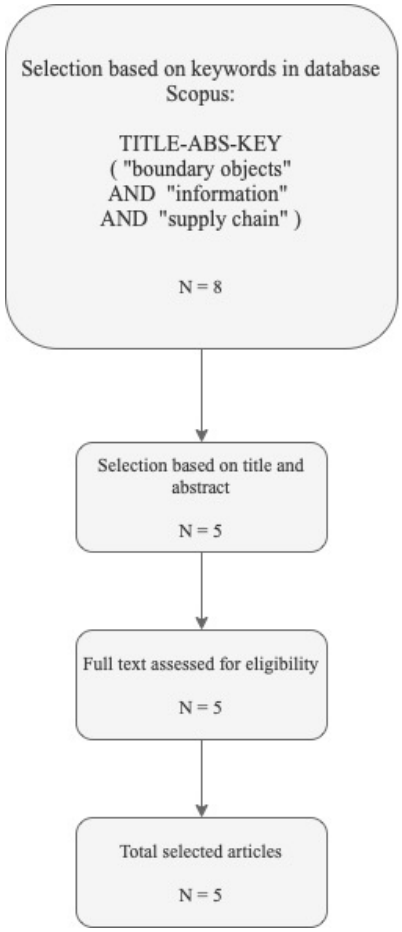


Figure G. 1. Literature study flow diagram: boundary objects

Table G. 1. Selected articles literature study boundary objects

Title	Author	Year of publication
The impact of institutional distance on the joint performance of collaborating firms: The role of adaptive interorganizational systems	Dong et al.	2017
Improving supply chain performance through industry standards use and community socialization: A perspective of standards consortia: Improving supply chain performance	Xu et al.	2016
Supply chain exploitation, exploration, and firm performance: Effects of top management and information technology capabilities	Wei et al.	2013
Knowledge sharing ambidexterity in long-term interorganizational relationships	Im and Rai	2008
Leveraging standard electronic business interfaces to enable adaptive supply chain partnerships	Malhotra et al.	2007

G2. Summary of main effects

Table G. 2. Summary of main effects boundary objects in literature

Publication	Summary of main effects
Dong et al. 2017)	Institutional distance (including the concern of formal rules and information) focus is inter-organisational and not on institutional distance within an organisation. The negative effect of regulative distance on the impact of IOS-enabled information sharing is **not supported**. The positive influence of IOS adaptability - as boundary objects - to IOS-enabled information sharing is supported, positively influencings the joint performance of two SC partners (supported).
Xu et al. (2016)	VIS systems (vertical information systems) - as boundary objects -including formal agreements between operating firms as a collaborative mechanism, contribute to more effective inter-organisational knowledge sharing (supported). Furthermore, inter-organisational knowledge sharing increases operational SC performance (supported). Operational SC performance includes, for example, improved processing time and reduced cost.
Wei et al. (2013)	The effect of external IT linkages - as boundary objects - on SC exploration and exploitation on the inter-organisational level and, ultimately, on financial and operational performance is supported. SC exploitation contributes to a more considerable extent to financial and organisational performance than SC exploration.
Im and Rai (2008)	The effect of ontological commitment on exploitative and explorative knowledge sharing and its impact on relational performance is supported. For the customer, these effects were supported. For vendors, only the related effects to exploitative knowledge sharing effects were significant; the hypotheses of the effects related to explorative knowledge sharing were **not supported.**
Malhotra et al. (2007)	The effect of standard electronic business interfaces (SEBIs) - as boundary objects - on collaborative information exchange and the effect of collaborative information exchange on mutual adaption and adaptive knowledge creation is supported.

G3. Insights literature study boundary objects

An overview of the research models of the publications, including their relevant variables and effects, is presented in the following figure (Figure G. 2). This figure summarises only the primary research details and outcomes pertinent to this research. For instance, some variables are not shown (e.g., environmental performance addressed by Wei et al. (2013). Besides this, multiple studies make a

distinction between different sub-variables or different groups. Only for Im and Rai (2008), the different groups are presented (customers and vendors) because this was needed to show the signification of the analysed effects. This figure shows the differences between boundary objects studied and their effects on information sharing and performance, specifically for the SC context. Four things are interesting to point out for the development of the theoretical framework and the main study.

1. Many different boundary objects related to the SC context are introduced in the scientific literature. Examples are external IT linkages, vertical information systems and standard electronic business interfaces.
2. All selected articles analyse the effect of their specific boundary object on information sharing, whereas all publications only focus on inter-organisational information sharing between supply chain partners. The effects of boundary objects on inter-organisational sharing are all significant for SC exploitation. Besides this, all improved (SC exploitation) inter-organisational sharing positively influences SC performance significantly. Based on this, boundary objects do indeed have a positive impact on SC performance via improved information sharing between SC players.
3. Different performance measures are selected to analyse. Xu et al. (2016) specifically mentioned the aspects of improved processing and cycle time for operational performance. In the main study, the important performance indicator is lead time; however, other performance indicators are still relevant to incorporate when assessing a potential action, like implementing a boundary object.
4. Dong et al. (2017) specifically addressed the influence of institutional distance on IOS-enabled knowledge sharing and its effect on the joint performance of SC partners. Specifically, the variable of regulative distance is interesting for this research since the focus is on formal information exchange. Regulative distance is defined in the publication as the difference between formal information (regulation) applied and enforced during the activities between SC partners. The publication concludes that there are no significant effects of regulative distance on the abovementioned variables. The authors do find these results surprising but try to explain the results. They argue that regulative distance would be easier to overcome since it is more tangible than the normative or cognitive distances, which are embedded in the "deep structure". Regulative differences considered before the implementation of IOS.

Thus, mainly the diversity of terminology and perspectives is large compared to the number of articles found in the study. However, since no snowballing techniques or additional investigation are executed, likely, the articles selected in this study are not an inexhaustible collection. Since the goal of this study is not to obtain a complete overview of all existing literature and the selected papers give a good view of possible applications and the diversity of existing research, the literature study is not extended with additional research related to these concepts.

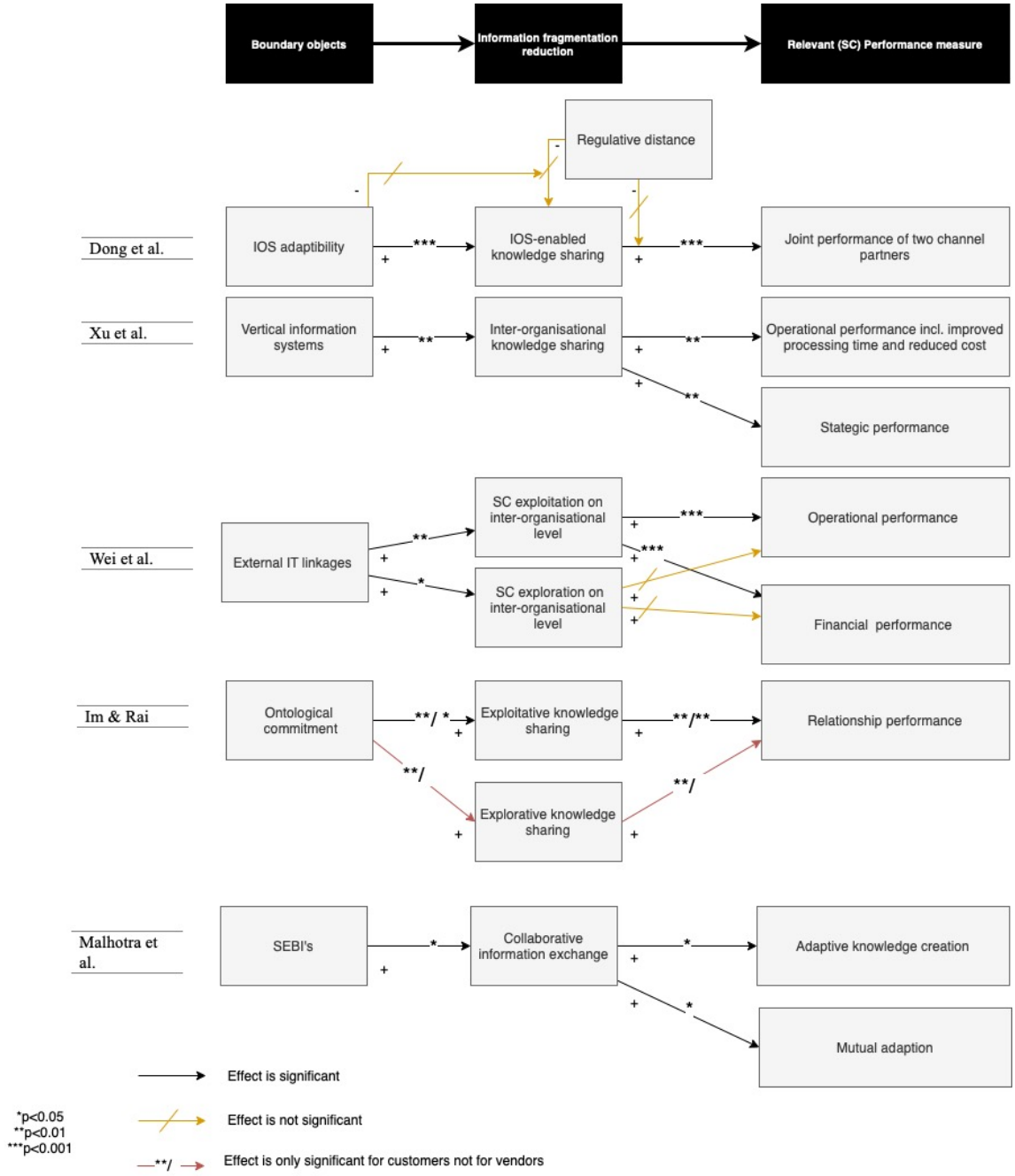


Figure G. 2. Summary of main effects

Appendix H. Case study

This appendix provides additional data obtained in the case study at MoD. Firstly, the starting point of the case study is presented related to the initial case description. Secondly, the multi-actor context of the case is described. Furthermore, rules and regulations related to the invoice case are presented. Appendix H4 gives an introduction to ARIS which is used as meta-model for process modelling within the MoD. Furthermore, the process in practice information, including conceptualisations and quantitative data, is presented.

H1. Starting point

The problem perception of MatlogCo was taken as a starting point for the case study. Furthermore, the case description is validated by MatlogCo (Ministerie van Defensie, 2022a) and a first interview (MoD01). The description of the initial case in the following text box.

> *"A relatively new method of funding invoices has recently come into use at Defence: e-invoicing. The automatic processing of invoices through e-invoices has several advantages, such as faster payments, security and reduced errors* (Rijksoverheid, n.d.)*. Nevertheless, using this method currently poses problems in several places in the logistics process. As invoices are paid before the desired items are properly delivered, problems are recognised in the registration of products. Sometimes the invoice is linked to the wrong order. In addition, prices in purchase orders are sometimes incorrect. A proforma invoice is used to adjust prices later in the purchase order. This makes the purchase order correct relative to the invoice when it arrives. If the purchase order is not in line with the invoice, it cannot be paid, and orders remain open. This makes the application requirements proposition (ATB) remain open, and the supply chain cannot be closed. Among other things, this creates open financial obligations in the supply chain. How do these delays affect process performance and reliability? Because e-invoicing has not been introduced for a long time, little research has been done on how it works within the organisation. This increases the relevance of the research."* (Ministerie van Defensie, 2022a)

Early in the research, it became clear that the problem statement from MatLogCo was considerably less specific than initially thought. MatLogCo's observation was that many of the problems they received related to outstanding invoices were related to electronic invoicing. The initial case description included the question of why e-invoicing causes many problems in the invoices process (from the perspective of MatLogCo). During the explorative research, while incorporating the perceptive of multiple players at MoD, many other factors arose that seem to impact the lead times of the invoice process and the problem perception of employees at MatLogCo. The difficulty in defining the problem substantiates the importance of an extensive problem-identification phase.

Implementing e-invoicing could have advantages like reduced environmental impact, cost savings and improved financial performance of organisations (Lagzian & Naderi, 2015). Moreover, EU and national policy enforces e-invoicing for governmental organisations. A policy prescribes that all national invoicing (with some exceptions) should be executed using e-factoring (Ministerie van Defensie, 2022b). The implementation of e-invoicing at MoD is part of the context of the invoice process. Whether this innovative way of invoicing is currently improving the financial performance of the defence organisation and whether the e-invoicing process results in cost savings is not evident. However, since the focus of this study is not to compare e-factoring with other types of invoicing, e-factoring is included as part of the context. E-invoicing is incorporated into the Dutch national policy, which is considered a guiding principle. For the MoD, it is interesting to analyse how to improve the invoicing process, with the fundamental principle that e-invoicing will be the standard.

.

H2. Multi-actor context

Currently, many of the operational responsibilities fall under the Chief of Defence (CDS). In addition, the policy department (DGB) primarily has responsibilities for policy making[17]. Only for the processes in the financial domain is HDFC responsible for policymaking.

For the problems regarding invoice processes at the MoD, multiple (sub-)organisations within the Ministry have influence and/or interests. For this research, the case study related to invoicing was initiated by the Army Material Logistics Command (MatLogCo). The structure of this command is illustrated in chapter 1.

Perspectives on the problem differ between actors within MatLogCo, and other departments related to the invoice process appear to be relevant. Parties within MatlogCo relevant to the invoice process are related to the order process. Still, the actors who control and manage the processes also have different tasks, roles, and perspectives. Outside MatLogCo, relevant parties for the invoicing process are the HDFC, DGB and the FABK (introduced in the previous section) as part of the Joint Support Command (DOSCO) and the external supplier. The actors are outlined below.

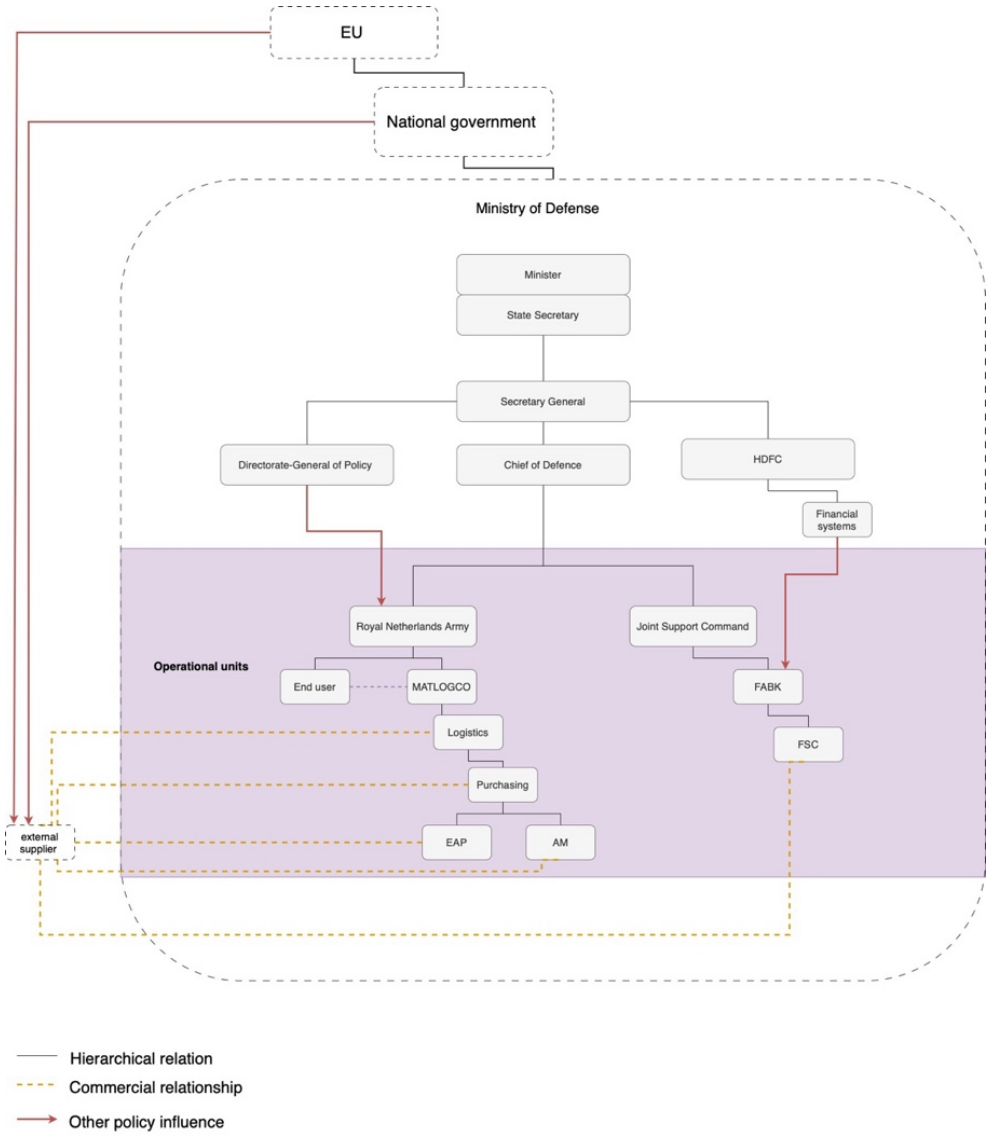


Figure H. 1. Formal Chart

[17] Except for some additional specific processes of RNLM and Intelligence and Security Service (MIVD) and the financial domain

H3. Rules and regulations
Formal process design information largely determines the process design. The governance model Besturen bij Defensie (BBD) can be seen as one of the most high-level steering conventions of the organisation (Ministerie van Defensie, 2021c).

Besides the BBD, national and international institutions determine the operation of the organisation externally. Other internal institutions influence the organisation. Internal policy documents (Dutch: aanwijzingen) and prescriptions are created by the DGB and HDFC (Principal Directorate of Finance and Control). In addition, work instructions (Dutch: werkinstructies) direct the operational level. Generally, the policy document 'HDBV-002' addresses the aspects of process, definition, and data management (Ministerie van Defensie, 2015a). The document presents the guidelines for players to comply with when performing process, definition, or data management tasks.

Many subject-specific institutions of the MoD, both internally and externally, influence the case's problem situation. No exhaustive overview, but a selection of pertinent information found during the explorative research is presented below. Generally, HDFC is responsible for the policy in the financial domain within the MoD. The HDFC-001 contains internal regulations related to the invoice process (MoD09; (Ministerie van Defensie, 2018a). The HDFC-001 delineates the general invoice process.

- *"In order to pay an invoice, a contract/order or other verifiable agreement between the MoD and a supplier is required. The presence of a framework contract is not sufficient; then it concerns the call on this framework contract;*
- *In order to pay an invoice, the creditor must be matched with the supplier name, bank number and the Chamber of Commerce number. This removes the check on address details to be allowed to pay the invoice;*
- *within ADR's checks on FI invoices, checking the combination of supplier name & bank account number is an essential part. With ERP M&F, a link is established with the purchase order (Dutch: bestelorder), and the supplier of the invoice cannot differ from the supplier linked to the purchase order;*
- *the supplier name registered in SAP is the statutory name, as registered at the Chamber of Commerce;*
- *in order to reclaim VAT, the invoice must meet the following requirements:*
    - *valid CoC number appearing in the trade register;*
    - *valid VAT number appearing on the EU site European Commission/Taxation and Customs Union/VIES;*
- *When paying an invoice, the purchase order and receipt (Dutch: goederenontvangst) must be checked in the case of services, a service entry. This is called the three-way-match. There will be no waiting for an inspection to take place unless this is explicitly indicated for this item/service;*
- *the purchase order may differ from the invoice (e.g., in case of subsequent calculation). In this case, the purchase order must be adjusted by the purchaser."*

Translated based on principles in "Aanwijzing HDFC-001" (Ministerie van Defensie, 2018) (p.41-42)

Besides this, national policy and regulation must be incorporated. Some key external institutions for the invoice process are the Compatibiliteitswet**,** the Dutch legal payment term and the governmental payment standard. MoD09 substantiates the relevance of these documents for the invoice case.

Compatibiliteitswet. This law contains the management of the state budget and the control and accountability of the state (Ministerie van Financiën, n.d.-b)

Dutch legal payment term. Article 119b of Book 6 of the Dutch Civil Law includes the legal payment term. This article is based on Directive 2011/7/EU of the European Parliament.

"If no expiry date (deadline) for payment has been agreed, then statutory interest shall be due by operation of law:

a. As of 30 days after the start of the day following the one on which the debtor has received the invoice …."

Article 6:119b. (Dutch Civil Law, n.d.)

Governmental payment standard. The Dutch government has a payment standard. The government-wide target of 95% for paying invoices to suppliers within 30 days was, for example, not met by the MoD in 2018 (Ministerie van Financiën, n.d.-a).

Furthermore, specifically for the invoice case of the MoD two work instructions (WI) were retrieved in the document analysis. These instructions address the technical operation to be performed within the ERP system (SAP).

WI-05.02-05: Service afroep bedrijfsmiddelen d.m.v. SAP (Ministerie van Defensie, 2016a). This work instruction describes how to place an order, how to adapt the order and how to enter the Service Entry in SAP. This document describes that the proforma invoice has to be added in SAP while entering the Service Entry in SAP. The work instruction is addressed to the following:

- the maintenance notifier to create the notification;
- the caller (Dutch 'afroeper') of the maintenance to convert the notification into a work order (Dutch: werkorder) and to create the order;
- the assessor of the corrective maintenance to create the 'DIR' with the proforma invoice.

WI-05.02-06: Storneren van een Service Entry d.m.v. SAP (Ministerie van Defensie, 2016). This work instruction describes how to enter the Service Entry in SAP. The work instruction is addressed to the following:

- the caller of the maintenance to complete the order;
- the assessor of the corrective maintenance (possibly).

H4. ARIS

An introduction to ARIS is presented below. Furthermore, the results related to ARIS obtained for the invoice case study are presented.

H4.1. Introduction to ARIS

The Architecture of Integrated Information Systems (ARIS) is an Enterprise Management System and contains different modules, all integrated as a meta-model for process modelling. ARIS is used at MoD for Process Model Management (PMM) which includes: the measures for obtaining and maintaining insights into all processes, including the management of information to control the processes. The use of PMM enables justification of the extent to which pre-set objectives have been achieved. The objective is the continuous improvement of the execution of processes to contribute to organisational objectives (Ministerie van Defensie, 2022c). ARIS incorporates multiple functionalities subject to different modelling types related to a different perspective on the organisation (Figure H. 2).

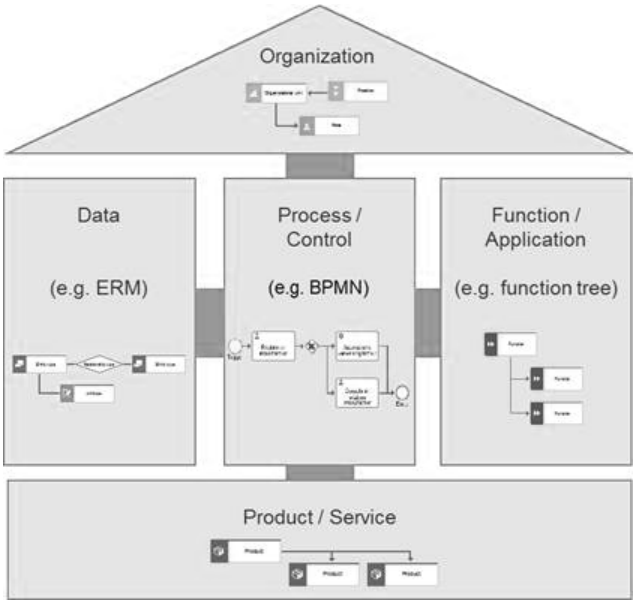


Figure H. 2. Coherence between functionalities (Ministerie van Defensie, 2022c)

Within the MoD, a process definition is elaborated, which is in line with the definitions of the Dutch Government Reference Architecture (NORA). The chain processes contain one or multiple business processes. Each business process contains one or multiple work processes. These processes are application independent. While a process step or action is application-dependent, e.g., for the MoD, process steps are mainly depending on the application SAP, which is the ERP system. An overview of the process definition is presented in Figure H. 3.

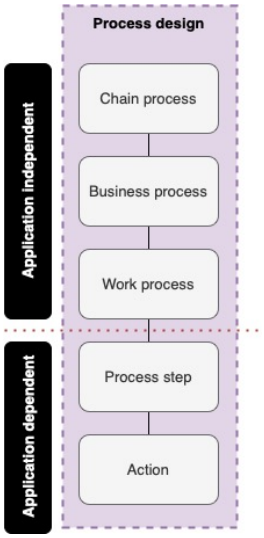


Figure H. 3. Process design MoD

BPMN models represent the business and work processes in ARIS. The processes are linked to other organisational aspects, namely the organisation structure, functions, products and services and data. Processes in ARIS relate to SAP transaction codes on the level of actions. As part of the programme Roger[18], the Defence Enterprise Design is currently being created in ARIS (MoD04, MoD06). In order to change the business processes and support the transition to S/4HANA[19], the current business processes must be identified and modelled in ARIS.

[18] Roger: Roger facilitates the implementation of S/4HANA within MoD
[19] S/4HANA: the new version of the used ERP system SAP

H4.2. ARIS invoice case

During an interview with an employee of FABK (MoD04), general information about the invoice process is obtained. Based on this information, a sketch of a simplified invoice process is created, where the starting point is receiving the invoice at MoD and the end of the payment of the invoice (Figure H. 4). In this figure, no distinction is made between e-invoicing and other types of invoices. Based on the document analysis, multiple work processes (WP) and business processes (BP) in ARIS were found. Validating the accuracy of these process designs was important, as it turned out that the process descriptions (WP and BP) were incomplete and outdated (MoD04). Table H. 1 provides information about the process steps of the invoice process.

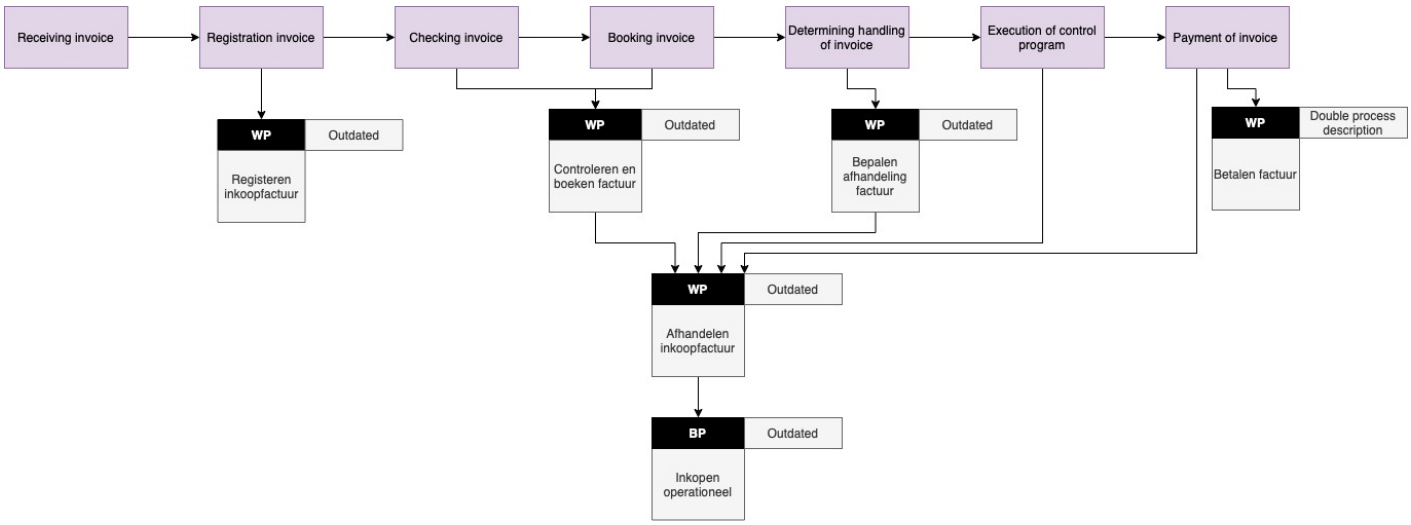


Figure H. 4. Simplification of the invoice process including process design documentation (ARIS)

Table H. 1. Explanation process steps in invoice process

Process step	Explanation
Receiving	Receiving invoices at the MoD. Some invoices are received by e-mail (pdf), on paper or electronic invoices (e-invoices).
Registration	Registration for e-invoices is immediately performed. Pdf or paper invoices must be implemented in SAP manually.
Checking	In this process step, the invoices are checked. When no PV is created in SAP, 14 days after the invoice registration, a Request for Information (RFI) is sent to the person who placed the order in SAP. In this step, mistakes in invoices are registered. The step adds value to the process because a wrong invoice should not be paid.
Booking	When the checking is not completed, an invoice cannot be booked but will stick here in the process. Many repair steps must be taken to get the invoice back on track. These non-value-adding activities should be prevented.
Determining handling	This step determines which follow-up steps will be taken, as it depends on the type of invoice.
Execution of control programme	In this step, a sample of the invoices is verified. These steps add value to the process regarding safety and costs. When an invoice is selected for verification, additional steps will be taken to analyse the correctness of the information.
Payment	A released (Dutch: vrijgegeven) invoice will go through a number of steps to perform the payment to the external supplier. This step ends with the authorisation of the payment order.

Based on the interviews, it becomes clear that the transition to a complete ARIS business model is not so simple. All advisors do have their operating procedures. However, the thought is that the outcome would be the same (MoD04). The transition phase creates confusion about which models are correct and which are obsolete (MoD04). No estimate can be made of when the process models will be ready (MoD04). Sometimes a bottom-up modelling strategy is used where the work processes are modelled first and, thereafter, the business processes (MoD04, MoD06). The processes are modelled based on how the processes in practice are going (MoD04, MoD06). Thus, there is a chance that the modelled processes are not in line with the rules and regulations. ADR (Audit Dienst Rijk) does carry out inspections, and sometimes, observations that certain processes are not in line with the regulation do occur at MoD (MoD06 and [20]).

H5. Process in practice conceptualisation
The first interview with an employee of MatLogCo was the starting point of the process tracing (MoD01). This meeting has succeeded in getting a global overview of the experienced problems at the logistics department of MatLogCo. For MatLogCo, the aim is to decrease the total amount related to invoicing, not only e-invoices. Based on the information obtained in this first meeting, an initial overview of the invoice process was made (MoD01).

In the second interview with an employee of FABK (MoD02), some of the process steps executed at FABK were explained in more detail. This information is related to the invoice process generally and specifically for e-factoring. Based on this meeting, the difference between e-invoicing and invoice with a PDF format was outlined. An e-invoice is automatically registered at FABK, while a PDF invoice must be registered by hand (MoD02).

The process continued with the creation of a sketch of the global ATB process, which takes place before an invoice process is triggered. This sketch shows the simplification of a reparation process (Dutch: Loonbewerking). This process is selected based on the ability to address employees. Besides this, the expectation seemed to be that reparation processes cause more invoice problems (MoD01). The process of an external service or the purchase of goods is largely the same; however, the external service and the resulting invoice are less straightforward. Services deviating from the previously discussed order are more likely (MoD10).

To analyse this ATB process, a planner of reparation tasks provides information about the ordering process and the invoice process's relevance (MoD03). A sketch of the simplified reparation process is presented in Figure H.5. Two different work instructions are linked to the processes in the sketch.

[20] For example: “Steekproef ADR - AVPL 360 - Ontbreken getekende order in BO pos 10”

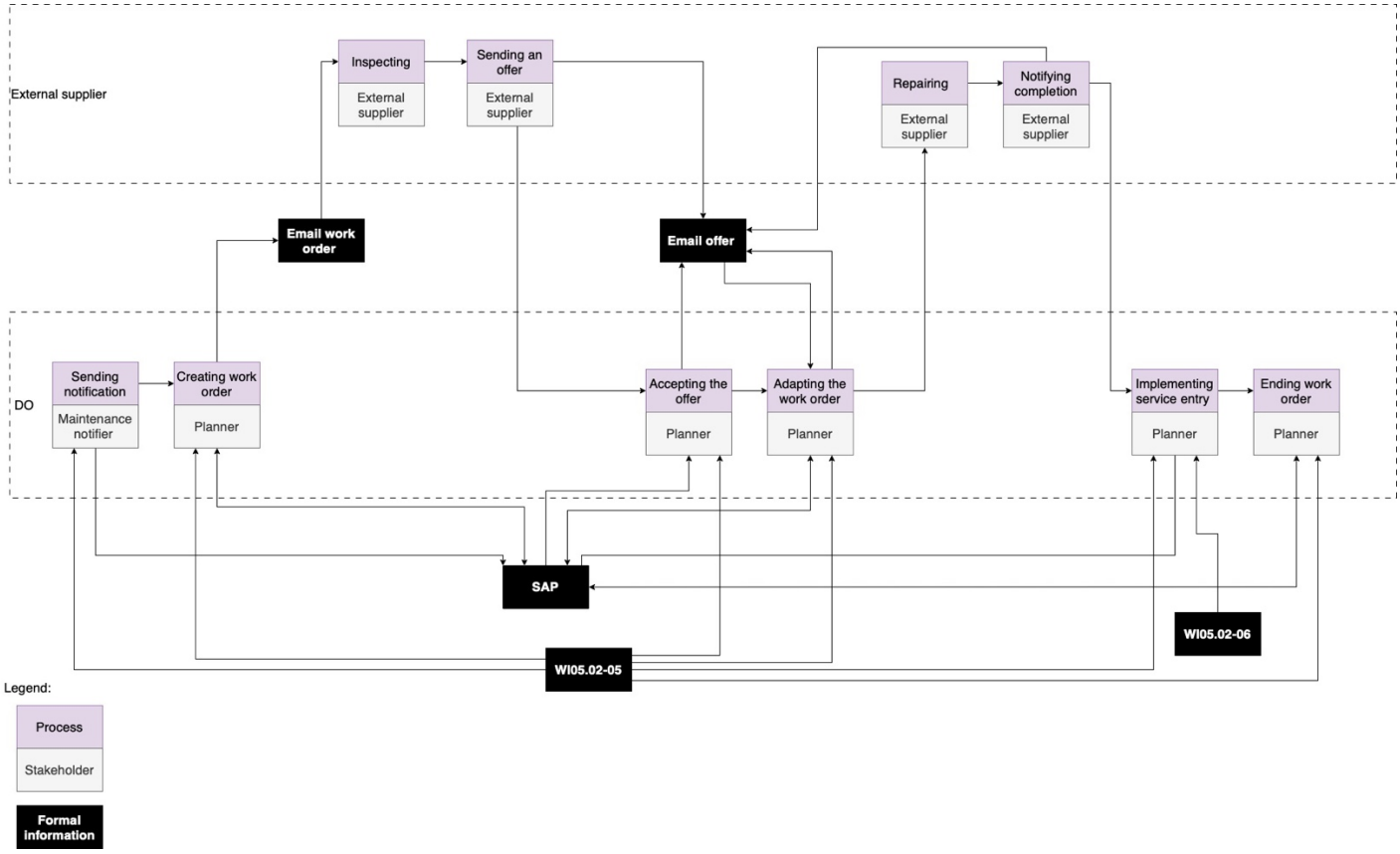


Figure H.5. Ordering process sketch

Based on the sketches, an initial BPMN model of the ordering process in combination with the invoice process is created. This initial BPMN is validated in a meeting with an employee of HDFC (MoD05). Since these processes are much more complex due to the variety of options in the process steps, this BPMN is aggregated and simplified towards the actual process. However, it still gives an impression of a happy flow in the process of invoicing. The BMPN is validated by MoD11 and presented in Figure H.6. A more simplified BPMN is presented in the main text (Figure 11).

Two general types can be distinguished: the ordering process of goods and services. The process for services is more complex due to the involvement of technical inspection (MoD11), and more often, the costs deviate from the initial order compared to the purchase of goods (MoD10). Thus, this BPMN is visualised for the ordering process of services. On this level, the process slightly differs for the purchase of goods.

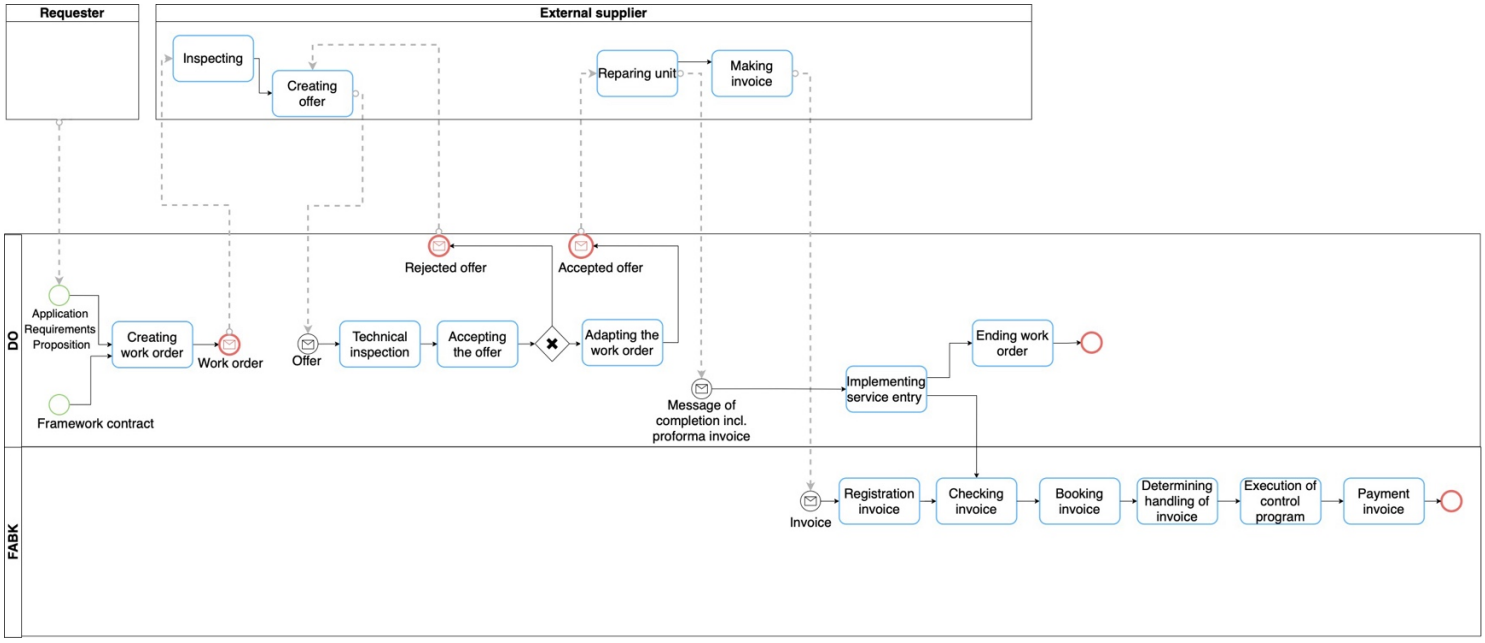


Figure H.6. BPMN

H6. Quantitative data of invoice case

The following paragraphs provide quantitative data retrieved for the invoice case study.

H6.1. Excel files 2A_Doorlooptijden GEREALISEERD_2022_WK**

From the MoD Excel files of week 20 to week 46[21], some statistics are retrieved. In these excel files, all the invoices paid in that specific week are included. The percentages of payment within the legal payment term of 30 days are presented in Figure H. 7 for the following categories:

- invoices paid for the entire MoD;
- invoices paid for Royal Netherlands Army (CLAS);
- e-invoices paid for the entire MoD;
- e-invoices paid for Royal Netherlands Army (CLAS).

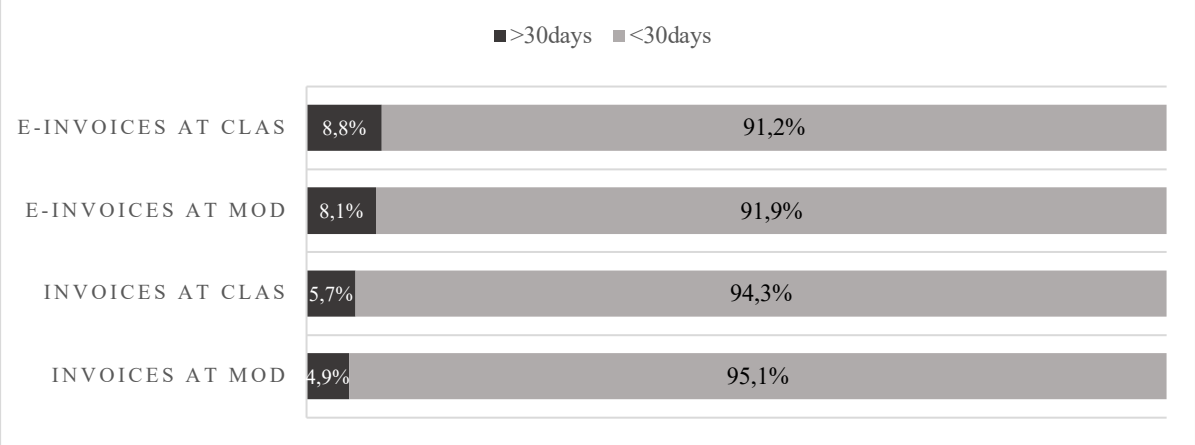


Figure H. 7. Average percentages payment within 30 days

H6.2. Monitor of outstanding invoices

Some statistics are retrieved based on the monitor of outstanding invoices ('Monitor Logistieke Facturen'). The data were retrieved on the 30th of November 2022 and included all open invoices at MoD (n = 14731). The data are presented in Table H. 2 must be interpreted carefully. Incorrect, double and credit invoices are also included because all open invoices are included in this monitor. Therefore, these statistics do not give an impression about the actual outstanding payment amount of MoD, only what is entered into the system. Since these data are automatically retrieved from SAP, these are only the data on how the invoices are registered in SAP.

Table H. 2. MLF statistics (data retrieved on the 30th of November 2022)

	Days booked	Days open
Average	18.41	20.56
Min	1	1
Max	576	587

[21] The weekly MS Excel overviews are internal MoD documentation entitled: "2A_Doorlooptijden GEREALISEERD_2022_WK**", where ** is respectively the week number.

H6.3. Excel file 2A_Doorlooptijden GEREALISEERD_2022_WK46

Based on the MoD Excel file of week 46, the following lead time averages are retrieved (Table H. 3). Lead times for e-invoices seem to be, on average higher for e-invoices except for the registration step. The data for this registration step make sense since e-invoices are automatically registered.

Table H. 3. Lead times averages (week 46)

	PDF invoice	E-invoice
Registration	2.126 days	0 days
Checking	5.541 days	7.851 days
Booking		
Determining handling	2.981 days	5.785 days
Execution of control program		
Payment		

H6.4. Monitor of outstanding invoices

Based on the dataset retrieved on the 30th of November 2022 from the MoD's monitor of outstanding invoices ('Monitor Logistieke Facturen'), all the outstanding invoices for longer than 30 days are selected (n = 2208). For 643 invoices, the indicated reason for outstanding payment is the absence of a declaration of performance; this is about 29% of the invoices. These results are presented in Table H. 4.

Table H. 4. Number of open invoices due to missing declaration of performance (MLF)

Number of invoices open > 30 days	Number of invoices open > 30 days AND missing performance declaration
2208	643

Appendix I. Focus group

This Appendix provides additional information about the focus group. The planning, slides and observation protocol are presented.

I1. Planning

Stage		**Topic**	**Work form**	**Time in min**	**Organisational format**	**Type**
Introduction	Introduction, objectives and planning	Planning, practical comments, anonymity and informed consent, introduction round	Introduction by B&I employee and researcher	5 min (9:00-9:30)	Plenary	Speaker oriented
Core session 1	Experience	Language is a challenge. Exercise associations	**Exercise with words and associations** Associations on paper	10 min (9:30-9:40)	Plenary	Assignment
	Reflection	Experience from respondents	**Questions (1 t/m 5)** Respondents answer on paper	30 min (9:40-10:15)	Individually/ Plenary	Assignment/ discussion
Break				15 min (10:15-10:30)		
Core session 2	Reflection	Experience from respondents	**Questions (6 + 7)** Respondents answer on paper	10 min (10:30 – 10:40)	Individually	Assignment
	Conceptualisation	Research introduction and results Preventive and corrective problem-solving strategies	**Presentation by the researcher** 2 strategies	15 min (10:40-11:10)	Plenary	Speaker oriented
	Application	Brainstorm including pros and cons for the presented strategies	Brainstorm, two groups: 1. Preventive 2. Corrective 3 collars sticky notes (idea, pros, and cons)	(11:15-11:50)	Group work	Explanation, Assignment and discussion
Wrap up	Closing remarks, feedback, questions	Closing remarks, feedback, questions	Closing remarks by B&I employee and researcher	10 min (11:50-12:00)	Plenary	Speaker oriented

Focusgroep betaalketen

14 februari 2023

1

Planning

- Introductie
- Korte oefening
- Introductievragen
- Pauze
- Presentatie oplossingsstrategieën
- Brainstormsessies oplossingsstrategieën

14/02/2023

2

Praktische zaken

1. Informed consent
2. Observatie aanwezig

Ministerie van Defensie

TU Delft

14/02/2023

3

Een blik op de betaalketen

Vandaag kijken we specifiek naar waar het bestelproces raakt aan het betaalproces

De prestatieverklaring als probleem voor snelle betaling

TU Delft

14/02/2023

4

Kennismaking

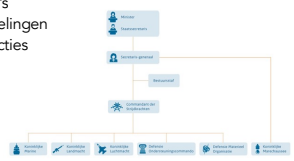
- Voorstelrondje

14/02/2023

5

Meerdere stakeholders betrokken

- Defensie intern / extern
- Verschillende DO's
- Verschillende afdelingen
- Verschillende functies



14/02/2023

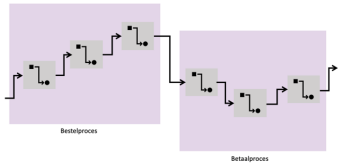
6

Vragen

Antwoorden op papier!

7

1. Waar zit je in de keten?



8

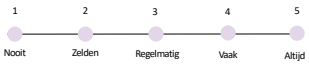
2. Van wie (welke functies) ben je afhankelijk?

9

3. Indien je afhankelijk bent van iemand anders in de keten wat doet dat met jou en je werk?

10

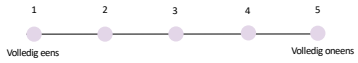
4. In welke mate ben op het juiste moment de juiste informatie om je werk te doen?



11

5. Stelling:

Ik herken de problematiek van informatie-uitwisseling voor het probleem van een missende PV



12

Pauze

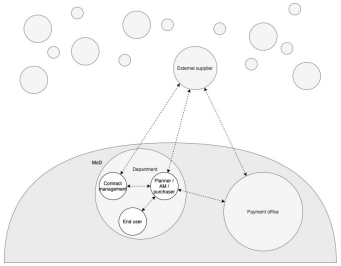
13

6. Wat zou helpen in het werk om missende prestatieverklaringen te voorkomen?

14

7. Wat zou helpen in het werk om als er eenmaal een missende prestatieverklaring is, dit sneller op te lossen?

15



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Twee mogelijke strategien voor doorlooptijdverlaging

1. Het sneller/beter kunnen omgaan met problemen (correctief)
2. Het voorkomen van problemen (preventief)

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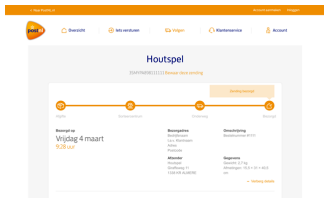
Track and trace PostNL

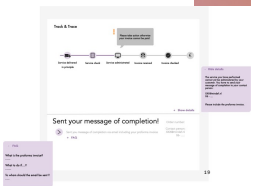


Geraadpleegd van: https://houtspel.nl/blog/nieuws/pakket-volgen-met-track-en-trace

18

1. Track and trace betaalketen (Correctief)

- Sneller missende PV oplossen
- Lessons learnt over een bepaalde periode



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2. Beter overzicht van het gehele proces en afhankelijkheden (Preventief)

- Upfront procesoptimalisatie

20

Brainstormsessie

- 2 groepen

Ideeën	Postieve punten / voordelen / kansen	Negatieve punten / nadelen / aandachtspunten

21

Dank voor jullie inzet!

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Protocol observanten:

Beste observant,

Op 14 februari 2023 zal je een focusgroep bijwonen als observant voor mijn onderzoek.
Om je voor te breiden op deze sessie stuur ik je hierbij wat informatie die belangrijk is voor de juiste en haalbare uitvoering van de observatie.
De focusgroep heeft twee doelen met betrekking tot het wetenschappelijke onderzoek:

1. *De validatie van 'informatie fragmentatie' als oorzaak voor problematiek in facturatieproces omtrent het missen van de PV bij Defensie*
2. *De verkenning van mogelijke oplossingsrichtingen op het gebied van 'boundary objects'*

Twee hypothesen worden bekeken in deze focusgroep:

- ***H1**. 'Informatie fragmentatie' wordt als oorzaak bevestigd voor de problematiek van het missen van de PV in het betaalproces*
- ***H2**. De gepresenteerde 'boundary objects' (die beide focussen op het aanpakken van informatie fragmentatie) dragen bij aan de verbetering van de huidige probleemsituatie omtrent informatie-uitwisseling binnen het betaalprocess gefocust op het missen van de PV.*

Om een goed beeld te krijgen van de perspectieven van de respondenten zal hen een aantal keer gevraagd worden om antwoorden op vragen op te schrijven en om met behulp van post-its informatie te noteren, dit zal dan ook de hoofduitkomst van de focusgroep zijn. Naast deze data, helpt het om een beter beeld te krijgen van de perspectieven van de respondenten door het noteren van uitspraken tijdens de discussie van de onderwerpen.

Indien een van de respondenten een (bevestigende/ontkrachtende) opmerking met betrekking tot (een van) de hypothesen genoemd hierboven vraag ik je deze letterlijke uitspraak te noteren. Hierbij is precieze verslaglegging vereist anders kan de desbetreffende respondent niet geciteerd worden in het onderzoek. Het is erg belangrijk om de naam (die staat op de naamkaart van de respondent) te noteren. Noteer ook de deelsessie van de focusgroep om te kunnen achterhalen op welk moment deze uitspraak gedaan is. Daarnaast is er ruimte om een indruk toe te voegen die je krijgt bij het doen van deze observatie. Onderstaande tabel zal je (vergroot) ontvangen om de observaties te kunnen noteren.

Wie:	***Deel van de sessie:***	***Letterlijke uitspraak***	***Hypothese***	***Eventueel indruk observant***
Naam van de naamkaart	*(Introductie, kernsessie 1, kernsessie 2, slot)*	*"….."*	*H1 of H2*	*…..*

De letterlijke uitspraken zullen enkel gebruikt worden in het stuk na goedkeuring van de desbetreffende respondent.
Indien er aanvullende vragen zijn hoor ik het graag.

Alvast enorm dank voor je inzet!

Aanvullende informatie

Missen van de PV (prestatieverklaring)
Voor het facturatieproces is het noodzakelijk dat er een prestatieverklaring is afgegeven door het defensieonderdeel zodat de factuur betaalbaar kan worden gesteld. Wanneer een factuur niet op tijd betaald is komt dit regelmatig door een missende prestatieverklaring. Het missen van de prestatieverklaring is een interessant probleem door de volgende kenmerken:

1. Er kunnen veel verschillende oorzaken zijn voor het missen van de PV
2. De impact op de doorlooptijden van het facturatieproces is aanzienlijk
3. De PV is precies de link tussen het betaalproces en het bestelproces
4. Er zijn veel verschillende partijen betrokken (denk aan de externe leverancier, mensen van het betaalkantoor, en verschillende mensen van het DO).
5. Relevantie informatie mist vaak en informatie-uitwisseling is een gemeenschappelijke factor voor de verschillende oorzaken van de missende PV

Informatie fragmentatie
Voor deze studie is informatie fragmentatie gedefineerd als: *the lack of an integrated overview of formal information relevant to the invoice process between different actors, including internal actors at MoD and external suppliers.*
Hierbij is 'formal information' de gestructureerde, traceerbare informatie.

Boundary objects
Star (1989) defineert boundary objects als: "*objects that are both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use, and become strongly structured in individual-site use.*" (p.46).

In dit onderzoek worden er twee strategieën bekeken:

1. Een correctieve manier die de problemen van een missende PV sneller wil verhelpen als de missende PV zich voor doet
2. Een preventieve manier die de problemen van een missende PV wil voorkomen

De twee strategieën zijn:

1. **Track and trace systeem**. Denk aan het systeem wat PostNL ook gebruikt om de pakketjes te bezorgen. Dit systeem geeft de relevante informatie weer voor elke partij op een andere manier. Het is hiervoor noodzakelijk om op een gedetailleerder niveau de locatie en

toestand in het proces vast te leggen. Hierdoor wordt het makkelijker om te identificeren waar het probleem ontstaat en kan er ook op langere termijn gekeken worden naar waar dit vaker plaatsvindt. Ook kan het systeem op actie aansturen bij de desbetreffende partij. Een koppeling met het SAP-systeem lijkt logisch.

2. **Gedeeld procesoverzicht.** Het hebben van een overzicht van een proces dat voor elke speler te begrijpen valt op detailniveau maar voor allen op globaal niveau is belangrijk voor het kunnen verbeteren van het proces up-front. Dit procesoverzicht kan helpen als eerste stap om het gesprek te voeren over verbeterpunten waarbij alle betrokken partijen aanwezig zijn.