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Technology Transfer within Related Offset Business

-From an Aircraft Production Perspective

Anna Malm

Division of Manufacturing Engineering
Department of Management and Engineering
Linköping University
581 83 Linköping
Sweden

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Department of Management and Engineering
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ABSTRACT

The aircraft industry is viewed as a prestigious industry by many countries. Emerging economies regard the establishment of aircraft production capabilities as contributing to their competitiveness and technological development. Therefore, in the defence aircraft industry, politics play a key role in competitiveness. Governments can strategically trade market access for technological development, often in the form of offset business. “Offset” is defined as an agreement in which a large system is bought and the seller assumes obligations that both benefit the buying nation and have long-term effects on the development of the buyer’s national industry. When the offset obligations are directly connected to the product or system sold, they are called “related offsets”. The realization of an offset agreement is in most cases including some form of technology transfer. Technology transfer is the transfer of technology from a sending company to a receiving company, where it is implemented and adapted to use.

The empirical data presented in this thesis were gathered through six in-depth studies performed at the unit for aircraft production at the Swedish company Saab. The findings from the studies are presented in six appended papers. The objective of this thesis is to extend the current understanding of technology transfer realization connected to related offsets within the defence aircraft industry. The research objective is fulfilled through the addressing of two research questions. The first research question aims to identify factors that can have a major effect on technology transfer realization in the research context. As an answer to the first research question. Following factors were identified: Capability gaps, Knowledge transfer, The purpose of related offset business, Seller’s fulfilment of offset obligations before contract termination, Related offset business include hierarchical levels, Related offset work package identification to meet the buyer’s request, and Assessment of the receiver in two steps, and finally Cultural and communication challenges.

These factors set the basis for research question two. The second research question addresses how to manage future related offset technology transfer realization connected to aircraft production. As an answer to the second research question, a structured related offset process and facilitation tools for managing capability gaps between the sending and the receiving company was presented. The purpose of the suggested structure is to maintain the link between the negotiated related offset agreements and the employees, working to achieve the agreement within the realization of the technology transfer.

Keywords: related offset, technology transfer, capability growth, capability gap, knowledge transfer, production transfer, aircraft industry

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Without the financial support for the research from Saab and the Swedish Innovation Agency, Vinnova through NFFP (Swedish national aeronautics research program), this research would not have been possible. Thank you.

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Linköping, October 2016

Anna Malm

LIST OF APPENDED PAPERS

Paper I

Fredriksson, A., **Malm**, A. and Johansen K. (20XX) What are the differences between related offset and outsourcing? -A case study of a related offset business at Saab. Accepted for publication in *International Journal of Technology Transfer and Commercialisation*.

Contribution: Fredriksson was the leading author. Malm and Fredriksson initiated the paper. Malm, with some assistance from Fredriksson and Johansen, collected data. Fredriksson and Malm wrote the paper, Johansen contributed by improving the structure and readability of the paper.

Paper II

Malm A., Björkman M., Johansen K. (2011). Cross-cultural communication challenges within international transfer of aircraft production. Presented at the International Symposium on the Management of Industrial and Corporate Knowledge (ISMICK) in Lausanne, Switzerland, June 2011.

Contribution: Malm was the leading author and initiated the paper. Malm collected the data, conducted the analysis and wrote the paper. Johansen and Björkman contributed by refining the analysis and improving the structure and readability of the paper.

Paper III

Malm A., Johansen K. (2014) Exchange of tacit knowledge within advanced production with small batch sizes. Accepted as a chapter in *Organizational Processes and Received Wisdom*, a volume in the Research in Organizational Sciences, edited by D.J. Svyantek and K.T. Mahoney, Auburn University, Auburn, AL.

Contribution: Malm was the lead author. Malm and Johansen contributed equally.

Paper IV

Malm A. (2012) Model based definition within relocation of aircraft production. Presented at 28th International Congress of the Aeronautical Sciences (ICAS 2012), 23–28 September 2012, Brisbane, Australia.

Contribution: Malm was the sole author. Malm initiated the paper, collected data and wrote the paper.

Paper V **Malm** A., Andersson, H. (2014). A change process: transition from 2D to 3D by Model Based Definition. Proceedings of the 6th Swedish Production Symposium (SPS), Gothenburg, Sweden. September 2014.

Contribution: Malm was the leading author and initiated the paper. Malm collected the data, conducted the analysis and wrote the paper. Andersson contributed by refining the analysis and improving the structure and readability of the paper.

Paper VI **Malm**, A. Fredriksson, A. and Johansen K. (2016). Bridging capability gaps in technology transfers within related offsets. *Journal of Manufacturing Technology Management*, Vol.27, No.5. pp. 640-661.

Contribution: Malm was the leading author. Malm and Fredriksson initiated the paper. Malm, with assistance from Fredriksson and Johansen, collected data. Malm and Fredriksson wrote the paper. Johansen contributed by improving the structure and readability of the paper.

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1 INTRODUCTION

The first chapter of this thesis introduces the research by presenting the background, research objective including the research questions, scope, delimitations and finally the structure of the thesis.

1.1 BACKGROUND

The aircraft industry is an example of a global industry; several companies with high geographical spread can design and/or manufacture different parts for the same aircraft (Aerostrategy, 2009; Porter, 1990; Yip, 1992). The aircraft industry is often viewed as a prestige industry. Countries with an industrial base therefore want to be players in it (Wessner, 1999). Establishing aircraft production capabilities is seen as a contributing factor for competitiveness, and for technological development for emerging economies (Goldstein, 2006; Eriksson, 2007). In the defence aircraft industry, politics play a key role in competitiveness (Ahlström, 2000). Countries can strategically trade market access in exchange for technology development, often in the form of an offset business (Eriksson and Steenhuis, 2015). Here, inspired by Ahlström (2000) and (Hennart, 1989) offset is defined as:

> An agreement in which a large system is bought and where the seller has obligations that benefit the buying nation and have long-term effects on the development of the buyer's national industry.

'Buyer' refers to the government purchasing the defence equipment (Ahlström, 2000). The main reason to engage in offsets is the opportunity to secure a sale (Wessner and Wolff, 1997). Offset can be divided into different types; the two most often discussed types are related and unrelated offset (Ahlström, 1991). When the offset obligations are directly connected to the product or system sold, they are called related offsets and can take the form of co-production, subcontracting, licensed production, and technology transfer, among other forms (Brask and Jonsson, 2002). A related offset process can be described as the activities occurring from negotiation of the main offset contract to the realization of that contract through a company-specific contract between the receiver and seller. The technology transfer then follows upon this (Ahlström, 2000). In this research, with inspiration from Robinson (1988) technology transfer is defined as:

> Technology transfer from a sending context where it is developed and/or in use, to a receiving context where it is implemented and adapted to use.

Much of the knowledge needed in order to apply the technology to be transferred goes beyond written instructions. This knowledge is often not evident in its original context; it is embedded in its surrounding. When technology is transferred to a new context, new problems often will occur; information not needed earlier is suddenly requested. This knowledge transfer is of high importance for technology transfer. The transfer of machines, requirements and basic training, often referred to as production transfer, is a part of the technology transfer (Grönhaug and Kaufman, 1988). Technology transfer in the context of related offset is illustrated in Figure 1.1.

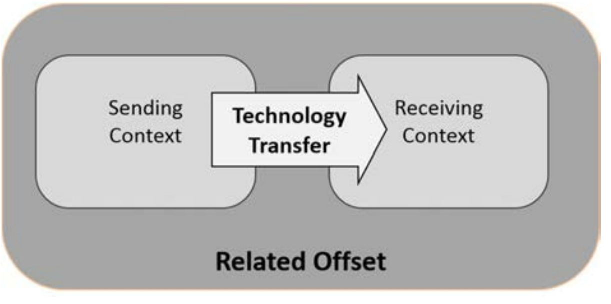

Figure 1.1: The two main areas included in the research objective: technology transfer and related offset.

The studies in this thesis have been performed at the aircraft production unit at the Swedish company, Saab. Saab serves the global market with products, services and solutions from military defence to civil security. Saab has advanced aviation technology in-house. For example, the Gripen fighter aircraft is presently the main product developed and manufactured at Saab. Saab also is an established partner and subcontractor to the commercial aircraft industry for structural parts such as aircraft doors and ailerons, parts that give flight control to aircrafts (Saab, 2016). Within related offset business at Saab, an order is accompanied by an offset agreement including long-term industrial cooperation and a significant technology transfer to industry connected to the buying country.

1.2 Research objective and research questions

It is not possible to have only one solution for all technology transfers, the inclusion of components and the complexity can vary greatly (Porter, 1986; Yip, 1992; and Wipro council, 2013). The related offset agreements are unique from time to time depending on the requests from the buyer, and that countries have different policies and legislation. When the offset agreements are unique, so are the agreed upon technology transfer following the signed agreement (Ahlström 2000).

The overall objective of this thesis is:

> To extend the current understanding of technology transfer realization connected to related offset within the defence aircraft industry.

The ability to perform a successful technology transfer within a related offset business context is challenging. This can be exemplified by the offset deal between Saab and Brazil. A large order worth approximately EUR 4 billion from Brazil was closed at Saab in 2015. It was accompanied by an offset agreement including technology transfer to the Brazilian industry. The technology transfer commitment from Saab to Brazil includes development, production and maintenance of parts of the Gripen aircraft (Kleja, 2015). A citation from Göran Almquist, deputy program manager for Gripen, regarding the purpose of the technology transfer indicates the complexity of the technology transfer:

> *"The main aim for the technology transfer is to train Brazil's own industry so that it will eventually be able to maintain its own fleet of Gripen aircraft and also develop its own future technology."*
>
> Göran Almquist (deputy program manager for the Gripen fighter)

The citation implies that the technology transfer to Brazil must include complements to Brazil's existing aircraft industry. The complements should strengthen the areas that the Brazilian government has pointed out. And stretching the aim to include support in development further increases the complexity of the technology transfer. It is a trend in offset business to include more and more development and production capabilities in the technology transfers (Ellingsen and Weibull, 2006). Such changes make the transfer more challenging. Activities connected to product development are explorative in nature, and therefore it is difficult to know exactly what knowledge to transfer before an actual development project begins (Cummings and Teng, 2003). Saab has observed these new challenges, to include more development and production capabilities in the technology transfers, and the company seeks solutions of how to manage them. Nassimbeni et al. (2014) emphasized that the industrial implications and industry specific research are lacking within related offset.

Today, Saab does not have a standardized way of working in relation to technology transfers within related offsets. A lot of experience and knowledge exists but it is spread on different individuals in the organisation. It has not been compiled, structured and documented. According to Ahlström (2000), research into related offsets has omitted how decision-making and negotiation early in the related offset process affects the realization (i.e., the technology transfer) of the offset business.

This thesis addresses two research questions. The first research question aims to identify factors that can have a major effect on technology transfer realization within related offset within aircraft production.

RQ1: What factors can have a major effect on the realization of technology transfer within related offset connected to aircraft production?

The second research question has a more normative approach, seeking facilitating tools to manage future related offset technology transfer realizations connected to aircraft production.

RQ2: How can future related offset technology transfer realizations connected to aircraft production be managed?

1.3 Scope

The definition of technology transfer can coincide with the definition of production transfer. In literature, the two concepts are not always easy to distinguish from each other (Bozeman, 2000). In this thesis, technology transfer is seen as more general, and production transfer as a part of a technology transfer.

In the research objective, the scope is the realization of the technology transfer connected to related offset within the defence aircraft industry. The activities in technology transfer before and after the realization has been studied. However, the focus has been to investigate the effect on the realization phase of technology transfer.

Much of the earlier research and literature does not differentiate offset from countertrade, or offset from related offset, and the concepts are applied synonymously in various contexts. Furthermore, in business practice, offsets can be referred to as industrial participation, industrial collaboration, business value development, governmental procurement, countertrade etc. (Ahlström, 2000; Stephen, 2014; Nassimbeni et al., 2014). Offsets are unavoidable for some companies and a fact of life for others and for some a good marketing tool (Wessner and Wolf, 1997). These differences provide several perspectives on the input to the theoretical background, and at times, it is difficult to see from which perspective studied material is presented.

There is a lack of research and accessible empirical data concerning technology transfer in related offset business. Only limited research has been conducted. The number of actors within the aircraft industry is very limited, especially when focus lies on the defence side. Saab is for example the only Swedish company producing fighter aircraft. There are other producers of defence aircraft around the world, but they are most often competitors with Saab. Hence, they are in all probability not willing to share their knowledge and experience. Due to low amounts of accessible data from the defence aircraft industry, the commercial aircraft industry will at times provide a theoretical and empirical example within this study. Furthermore, the literature review includes reference areas from beyond the offset business and the aircraft industry.

1.4 DELIMITATIONS

The decision-making and contract negotiation early in a related offset process are of high importance. However, the focus in this thesis is placed on the effects of decision-making and contract negotiation on the realization of the technology transfer. Focus is not at the decision-making and contract negotiation processes.

The thesis does not base the knowledge discussions from a Human Resources Management perspective. Knowledge is viewed from the perspective of technology transfer and aircraft production. Furthermore, the economic effects of technology transfer within offset business is not in main focus of the thesis. However, economic effects in general are taken into consideration. The main motivation for all type of offsets is economically driven.

1.5 STRUCTURE OF THE THESIS

Chapter 1 introduces the research by presenting the background, research objective including the research questions, scope, delimitations and finally the structure of the thesis.

Chapter 2 provides an overview of the researched context. The content in this chapter is a mix of theory and information connected to the investigated company: Saab. This chapter will give insight into areas connected to Saab and the research objective by describing the research context.

Chapter 3 presents the theoretical framework for the research within this thesis. It outlines areas connected to transfer of defence aircraft production within related offset business. Within the framework, the two main areas are described: technology transfer and offset business. More references will be found throughout the thesis to clarify or strengthen the empirical results and discussion.

Chapter 4 describes the research methodology. This chapter presents research design, research process, literature study, and data collection for the conducted research. After that, the research quality is discussed.

Chapter 5 presents the four industrial cases included in the research. The industrial cases involve technology transfers from Saab to South Africa, Czech Republic and India, as well as in-house production at Saab. The industrial cases are both retrospective and ongoing.

Chapter 6 summaries the six appended papers and presents their purpose and main findings.

Chapter 7 elaborates on the results from the appended papers in relation to the research questions.

Chapter 8 include discussion of the research contributions, including how the research objective was fulfilled through answering the research questions. Finally, directions for future research are discussed.

2 AIRCRAFT INDUSTRY AND OFFSET

The content in this chapter is a mix of theory and information connected to the investigated company: Saab. This chapter will give insight into areas connected to Saab and the research objective by describing the research context.

2.1 THE AIRCRAFT INDUSTRY

The defence aircraft industry tends to be seen by industrial and industrializing countries as a key industry for several reasons. It is closely connected to a nation's security, and the aircraft industry generally accounts for the largest share of defence equipment. This industry is seen as a technology driver in manufacturing techniques, electronics, advanced materials, sensors, etc. (Wessner, 1999). The aircraft industry is characterized by highly complex, high-technology products produced in relatively low production volumes (Rasheed and Manarvi, 2008; Wessner, 1999). The high-technology requirements necessitate a high level of R&D (Research and Development). In no other industry is there more inter-dependence and cross-fertilisation of advanced technology (Eriksson and Steenhuis, 2015, Hagedoorn, 2002).

The aircraft industry is dedicated to quality thinking, as failures in an aircraft may have severe consequences. The industry is regulated by strict national and international standards, and much focus is placed on security, safety and reliability requirements, which are necessary to always maintain traceability (Armbrust and Masafumi, 2009; Rasheed and Manarvi, 2008).

2.1.1 AIRCRAFT PRODUCTION

The defence aircraft industry is driven by the economy of scale, particularly due to the large development costs and quite small production volumes. Fixed production and tooling cost add to economic of scale. The more you produce, the cheaper the production process becomes, because you learn how to perform it better. With low production volumes, as in the defence aircraft industry, development and production costs cannot be spread across the production life cycle (Wessner, 1999). In general, aircraft production can be referred to as craft production. Special skills are required by the blue-collar workers to achieve aircraft quality and design requirements (Balaji et al., 2014).

2.1.2 Saab, Gripen fighter and Model Based Definition

Saab is a Swedish aircraft and defence company with over 14.000 employees in 100 countries. Saab was funded in 1937 after discussions held by the Swedish government, which wanted a national manufacturer to secure fighter planes for the Swedish armed forces. During its almost 80 years as a company, Saab has developed civil and military aircrafts, unmanned aerial aircrafts, defence systems and missiles (Saab, 2014). Saab is divided into six business units, one of which has the overall responsibility for the Gripen fighter aircraft and its related support systems. This responsibility includes sales, marketing support, contracting and implementation of all Gripen deals. The campaigns to sell Gripen are organised by the unit and led by steering committees (Saab, 2014).

Gripen is a fighter, it is developed in different versions, the versions currently in production, Gripen C (single seater) and Gripen D (two seater) is a NATO (North Atlantic Treaty Organization) adopted version of the original Gripen A and B versions. The upcoming Gripen E is, like its precursors, a multi-role fighter applied for fight, ground attack and reconnaissance. The performance improvement from Gripen C/D to E are found primarily on the inside, with a more powerful engine, increased internal fuel capacity, an upgraded cockpit display system and more advanced avionics (aviation electronics). Gripen A to D is powered by the Volvo RM12, and has a top speed of Mach 2. Military aircrafts are very complex products, which demands a lot manual skills in production of them. Therefore, the production of a military aircraft, such as Gripen include long lead-time. The Gripen fighter consists of four metal fuselage sections and two wing sections, consisting of about 11.000 parts and 125.000 fasteners. There are 300m of pipes and 700 welded assemblies. The electrical parts are fitted in 145 harnesses with a total of 1800 connectors and includes about 35 km of wiring. Figure 2.1 shows a production sequence from Gripen E. The production of Gripen at Saab is further described in Chapter 5.1, and in Study 1 (Appendix I).

Figure 2.1: A production sequence of the Gripen E (Kustvik, saabgroup.com, 2016).

MODEL BASED DEFINITION (MBD) AT SAAB

In aircraft production at Saab, the batch sizes are small, and the assembly lines have long and complex work sequences and the repeatability in time for the work operations is longer, compared to many other industries. Therefore, the blue-collar workers are dependent on the drawings and the assembly instructions. Historically, the use of 2D drawings has been required to see details. Thanks to methods like Model Based Definition (MBD), engineering information is now virtually accessible and reusable in 3D (Alemanni et al., 2011). MBD is a way of managing engineering and business processes by applying 3D models as sources of information for the overall product life cycle. Hence, the 3D models within MBD are sources of information for design, production, technical documentation, and services (Alemanni et al., 2011; Nestor and Unroth, 2013). With MBD, the 3D model can be combined with Product and Manufacturing Information (PMI) (Lokay, 2016). Within production at Saab, the 3D model communicates the PMI, including data such as geometric dimensions and tolerances and 3D annotation. At Saab the PMI in 3D, is referred to as 'production documentation in 3D', and henceforth applied here. MBD as a method, and the implementation of MBD at Saab, is further described in Chapter 5.1, and in Paper V.

2.2 OFFSET AND EUROPEAN LEGISLATION

A defence procurement directive, Directive 2009/81/EC, placed offset arrangements under stricter legislation. The directive entered into force on August 21, 2009 and concerns European Union (EU) law and defence procurement. It aims to increase transparency to help companies' access to defence and security markets in other EU countries. The directive covers specific security and defence procurement contracts for defence equipment and related works and services. It addresses the tendering part (European Parliament, 2009).

The directive does not explicitly address offsets. However, procurement practices which conflict with the principles of openness, transparency and non-discrimination are incompatible with the directive, whether explicitly mentioned in the directive or not (Šváb and Hanzalik, 2013). The directive, through Article 346 TFEU, presents opportunities for setting specific capability requirements for securing the national security of supply. In general terms, security of supply can be defined as ensuring that there is enough capacity and/or capability to meet future demand (Vázquez et al., 2002), so that armed forces receive deliveries in time, particularly in times of crisis or armed conflict (European Parliament, 2009).

2.2.1 OFFSET AT SAAB

Offset business is an essential part of Saab's way of working. Within business practise, offset business can have various names: industrial participation, industrial collaboration, business value development, governmental procurement, security of supply, etc. (Ahlström, 2000; Stephen, 2014). Similar vocabulary is used at Saab; the wording 'offset' is not primarily used within Saab. Saab must comply with the defence procurement directive. Directive 2009/81/EC does not change the situation for defence trade with non-EU countries, which are governed by World Trade Organization (WTO) rules and, in particular, the Government Procurement Agreement (GPA). The directive does not affect the performed case studies within this research; some are technology transfers outside of Europe or initiated before the directive came into force. However, future deals at Saab within Europe will comply with the directive.

3 THEORETICAL FRAMEWORK

This chapter presents the theoretical framework for the research within this thesis. It outlines areas connected to transfer of defence aircraft production within related offset business. Within the framework, the two main areas are described: technology transfer and offset business. More references will be found throughout the thesis to clarify or strengthen the empirical results and discussion.

3.1 OFFSET BUSINESS

Offset can be seen as one branch of countertrade, the other branch being traditional countertrade, as illustrated in Figure 3.1. Traditional countertrade refers to arrangements where the bought products are financed in the form of buy-back agreements, switch accounts, barter or counter purchase.

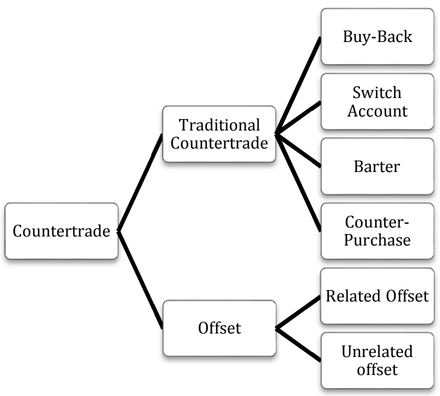

Figure 3.1: Countertrade and related concepts (Adapted from Ahlström, 2000).

Offset business includes an agreement between the seller and buyer, where the seller has obligations that benefit the buying nation and have long-term effects on the development of the buyer's industry (Ahlström, 2000; Hennart, 1989). Here, 'buyer' refers to the government purchasing the defence equipment. Offset business often exists in the context of few buyers and few sellers, large contracts and technically advanced products or systems (Ahlström, 2000). In several countries, such as Sweden, the United States, China, and Russia, the offset industry is an important part of the economy (Hartley, 2014). Ahlström (2000) noted that governments always have procured defence material to achieve or maintain a level of security for their countries, and without technical exchange, it is difficult to be independent from the seller. For national independence, the buyer wants to produce, improve or develop the bought system themselves (Ahlström, 2000). In offsets, the buyer can request different levels of involvement, from off-the-shelf purchase with limited development or production transfer, and all the way to high industrial involvement with mutual development and a convincing share of production technology transfer. An off-the-shelf purchase will not develop the purchaser's capability nor its technology assimilation (Martin, 2007; Misra, 2012).

3.1.1 OFFSET AGREEMENTS AND MULTIPLIERS

There is no universal solution to create an offset agreement; each country must evolve its own policy (Mitra, 2009). Within offset, the competition is getting harder and the offset ratios are increasing. An offset agreement often contains 100% or more of the value of the main contract; the percentage is measured in offset credits. The offset credit value is calculated using offset multipliers, and these multipliers are set based on an agreement between the buyer and seller (Kirchwehm, 2014). This means that, $100 in offset credits is not equal to $100 of actual work; the value of the work could be much less, based on multipliers used by the buyer. If the buyers request a specific technology or if they need economic development of a selected geographical area, such requests will have a higher multiplier. For example, a buying government will negotiate a multiplier for work placed in a certain segment, in a high unemployment area or for a requested technology. The negotiated multiplier (for example 5) will be implemented in the cost calculations to calculate a credit value. The credit value for the offset obligations, is not the value in money, it is the value that express the buyers interest in the offset. By applying multipliers, the buyer can control what they want the seller to propose (Kirchwehm, 2014; Wessner and Wolff, 1997). Multipliers are further presented in appended Paper I.

Different nations and companies prefer their own definitions and wording for the use of 'multiplier'. The wording 'multipliers' is applied at Saab and sometimes in the literature, so henceforth applied here.

3.1.2 THE PURPOSE OF OFFSETS

One driver of offsets, especially related offset, is the desire to create job opportunities and to obtain or maintain a high technological level. Subsequently, the local companies in the buying country are more or less dependent on technology transfer (Ahlström, 2000; Axelson and Lundmark, 2009; Paukatong and Paul, 2006). New technology often is requested, as the buyer wants to assimilate new technologies into the domestic economy where they can diffuse and stimulate growth (Stephen, 2014). Through technological development, the economic development can be improved (Sharif, 1986; Roessner et al., 1992). Within related offset, it is often the buyers that propose what technology should be included in the agreement. The seller and buyer develop an offset agreement taking into account the unique capabilities of participating industries, special requirements, the extent of resources, and the level of economic development. The offset agreement should be based on assessment of the buying country's capabilities to absorb the requested technology (Mitra, 2009). Stimulation of capability growth can be achieved through, for example, establishing a local plant. The receiving companies in the buying country then must invest or redirect to be able to produce the offset work packages. This can enhance both capability and economic growth; however, there can be negative side effects. The adaption of the receiving companies will involve large costs and a risk is that the company will only be specialized in production of the specific work package. This can reduce the company's chances of attracting other customers outside the offset (Axelson and Lundmark, 2009; Mitra, 2009).

3.1.3 EARLIER RESEARCH WITHIN OFFSETS

It is important to note that much conducted research has not differentiated offset from countertrade, or offset from related offset; moreover, as mentioned earlier, offset can go by various names (Ahlström, 2000; Stephen, 2014; Nassimbeni et al., 2014). The literature review by Nassimbeni et al. (2014) showed many contributions on general aspects of countertrade, such as motivation, obstacles, size etc. Nassimbeni et al. (2014) highlight that research has left out managerial implications, which may not be as important in some types of countertrade. However, managerial implications become crucial in more complex agreement such as offsets (Nassimbeni et al., 2014). Hence, research efforts are needed within organizational and managerial implications of the offset agreements. Nassimbeni et al. (2014) also lack research within the fulfilment of offset obligations and country- and industry-specific influences (Nassimbeni et al., 2014). Ahlström´s study (2000) indicated that the background and intentions of offset agreements and the agreements themselves have been studied. The interaction between seller and buyer during negotiations and the realization or fulfilment of the agreements have been identified as in need of research (Ahlström, 2000). In response to this, Brask and Jonsson (2002) and Ahlström (2000) have concentrated on the relationship and motives between seller and buyer in related offset business (i.e., buyer–seller interaction, primarily in the negotiation phase).

Research into related offsets has not yet considered how decision-making and negotiation early in the related offset process relates to and affects the realization of the offset decision (Ahlström, 2000). Realization of an offset agreement can be exemplified by a technology transfer. Instead, the focus has been on the effect and outcome of the offset (Axelson and Lundmark, 2009; Batchelor and Dunne, 2000). In a process view, the related offset starts with negotiation, a buyer-seller interaction, and ends up with outcome and industrial effects. The realization and fulfilment of the agreement, the interval between negotiation and outcome, is less researched (as shown in Figure 3.2). Nassimbeni et al. (2014) emphasized that the managerial implications and industry specific research are still lacking. After 2000, King and Nowack (2003) have covered some aspects of the fulfilment of offset agreements by considering technology transfer within offset from a learning perspective.

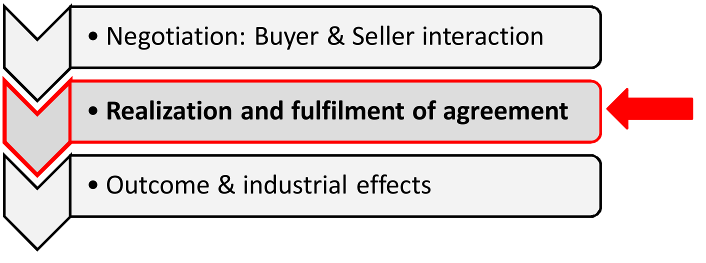

Figure 3.2: The realization and fulfilment of the offset agreement is less researched.

Earlier research conducted on countertrade and offsets have been placed by the author into three categories: countertrade and offset in general (motivation, success factors and effects), buyer and seller (interaction and negotiation), and outcome and industrial effects of offsets.

COUNTERTRADE AND OFFSET IN GENERAL: MOTIVATION, SUCCESS FACTORS AND EFFECTS

Countertrade is a research area that comprises many studies published in the 20th century (Aggarwal, 1989; Sarkis, 1984; Menzler-Hokkanen, 1989; Fletcher, 1998, Paun, 1997; Camino and Cardone, 1997). Most of these studies define ways to map activities included within countertrade.

Eriksson (2007), Mitra (2009), and Kirchwehm (2014) have conducted research into the offset phenomenon at a general level, covering the background to, intentions for, and results of offsets. Taylor's (2003) work analyses offset agreements and demonstrates that offset deals are selected not only according to economic rationales (price, quality, etc.), but are also guided by political economy drivers (e.g., national security and unemployment reduction). The economic considerations underlying offsets as a phenomenon have been researched by, for example, Batchelor and Dunne (2000), Jang et al. (2007), and Mörk (2007). Research has been conducted with the seller's and/or buyer's motives in mind (Banks, 1983; Fletcher, 1998; Forker, 1992; Hennart, 1990; Hennart and Anderson, 1993; Lecraw, 1989; Mirus and Yeung, 1986; Paun, 1997). Another research field is risks and problems (Al-Suwaidi, 1993; Erridge and Zhabykenov, 1998; Fletcher, 1996; Nassimbeni et al., 2012; Neale and Shipley, 1988; Pearson and Forker, 1995). A central topic within countertrade research concerns legal aspects. The characteristics of these agreements have been studied (Rajski, 1986), as have the country specificities and national laws regulating countertrade (Al-Suwaidi, 1993).

Wessner and Wolff (1997) wrote about policy issues in aerospace offsets in a report of a workshop. This report, in combination with that of Wessner (1999) involving trends and challenges in aerospace offset, provide a good background for offsets in the aircraft industry. However, the focus was on the US industry and, since it was a workshop, more questions were raised than answers given (Wessner and Wolff, 1997; Wessner, 1999).

NEGOTIATION: A BUYER AND SELLER INTERACTION

Research efforts have been placed on the offset agreement negotiations (Sarkis, 1984; Jang et.al, 2007). The offset negotiation process is long, and the longer such negotiations last, the greater the influence of politics. A study demonstrates that this competitive and protracted bidding can lead to unrealistic and complex offset agreements (Ellingsen and Weibull, 2006). Research into offset relationships demonstrates that offset business creates unique setups with long-term industrial commitments typically lasting for more than ten years (Axelson and Lundmark, 2009). As an effect of these long-term commitments, the seller will often establish partnerships within the buying country and close cooperation with suppliers there (Kirchwehm, 2014).

OUTCOME AND INDUSTRIAL EFFECTS OF OFFSETS

Hoyt (2011), King and Nowack (2003), Axelson and Lundmark (2009), and Batchelor and Dunne (2000) have studied the industrial effects and outcomes of related offsets on a national or company concern level. These factors are also studied through the lenses of local offset policies (Hoyt, 2011; King and Nowack, 2003). There are rarely any cost evaluations of offset business or processes, or any estimates of the benefits, such as the success of the technology transferred or the number of jobs generated (Stephen, 2014). It is virtually impossible to evaluate employment, technological, or competitive effects of offsets with the available public data. Such data are highly aggregated and cannot be linked to individual firms, product lines or individual offset agreements (Wessner, 1999, p.104). Even if data that are more detailed were available, it is difficult to reach definite answers; it is hard to isolate the effect of offset from the general trends in the globalization (exchange rates, defence spending, business cycle etc.) of sourcing and employment (Wessner and Wolff, 1997; Wessner, 1999). Regarding related offset cost estimation, the buyer tends to focus on the value while the seller focuses on the cost (Jang et al., 2007).

3.2 TECHNOLOGY TRANSFER

The definition of technology transfer differs substantially from one discipline to another (Bozeman, 2000; Zhao and Reisman, 1992). Bozeman (2000) is cited below on his view of the complexity in describing technology transfer.

> *"In the study of technology transfer, the neophyte and the veteran researcher are easily distinguished. The neophyte is the one who is not confused. Anyone studying technology transfer understands just how complicated it can be. First, putting a boundary on 'the technology' is not easy. Second, outlining the technology transfer process is virtually impossible because there are so many concurrent processes."*
>
> Bozeman (2000, pp. 627)

From the range of all technology transfers, Minshall (1999) has defined some common elements. A technology transfer involves a sender and a receiver of the technology. There is some form of link or agreement between the sender and the receiver and an agreed time schedule for the completion of the transfer. Later comes the actual transfer of machines, equipment, requirements and knowledge, a phase that varies depending on the context (Minshall, 1999). Robinson (1988) inspired to the definition for technology transfer in this thesis: Technology transfer from a sending context where it is developed and/or in use, to a receiving context where it is implemented and adapted to use.

In theory, the definition of technology transfer can coincide with the definition of production transfer; the two concepts are not always easy to distinguish from each other (Bozeman, 2000). International production transfer can involve everything from the production of a standardised part to the production capability of a complete factory (Minshall, 1999).

3.2.1 CAPABILITY

Capability gaps are relatively common within all types of technology transfers (Ferdows, 2006; Grant and Gregory, 1997). If the capability gap is small, the individuals at the receiver and the sender have highly overlapping knowledge (Reagans and McEvily, 2003). This is often not the case within related offset (Ahlström, 2000), the context of related offset adds difficulties that require a different approach for transfer in comparison to, for example, outsourcing. In related offset, the receiver is often chosen by the buyer based on aspects other than its capability (Ahlström, 2000). The need of a different approach within related offset business can be explained by the purposes of offset business; to enhance long-term economic development in the buying country (Ahlström, 2000). There are previous processes developed to decrease the capability gap between sender and receiver (Ferdows, 2006; Grant and Gregory, 1997; Minshall, 1999). However, these models have a strong focus on the adaption of production processes to fit with the receiver's capability, and identification of suitable processes for transfer after a supplier is selected based on performance and what to outsource.

Vincent (2008) defines a capability as the ability to perform or achieve certain activities that also can be developed and improved. Oppat (2008) and Winter (2000) highlight in their definitions that capability should give competitive advantage. That is, it should be reflected in an activity that produces outputs that clearly matter to the organization's survival and prosperity. When there is a small capability gap, the individuals on each side of the transfer possess highly overlapping knowledge (Reagans and McEvily, 2003).

In this thesis, inspired by Vincent (2008), Oppat (2008) and Winter (2000) capability is defined as:

> The ability to perform certain activities so that when the activities are transferred they can be developed and improved by the sender and give competitive advantage.

The buyers in the related offset agreements often desires capabilities and 'know-how' in design, development and production techniques connected to the bought product to expand their national industry. The offset agreements are a financing package as well as long-term bi-lateral collaboration between the governments (Global security, 2015).

3.2.2 KNOWLEDGE TRANSFER

The transferability of an activity can be linked to the properties of the knowledge, different dimensions of knowledge relates to the replication and application in the receiving unit (Ferdows, 2006; Stock and Tatikonda, 2000; van Wijk et al., 2008).

Knowledge can be divided into two dimensions: explicit and tacit (Lundvall and Johnson, 1994). Explicit knowledge refers to knowledge about facts and can often be divided into smaller pieces and be documented (Johnson et al., 2002). Explicit knowledge can be exemplified by documented product requirements, production and quality control manuals, product specifications and written policies and procedures (Ernst and Kim, 2002). Madsen (2009) state that improved production documentation can be an important support to increase the knowledge transfer (Madsen, 2009). In 2010, Cheng et al. emphasized the need of research within transfer of production know-how on the shop floor. Know-how and tacit knowledge refer to skills. Much engineering knowledge – such as experience, intuition, and professional judgment, is tacit (Backlund, 2006). If knowledge holders do not have sufficient ability to transfer needed knowledge to the recipient, or if the knowledge is of a tacit nature, the success of the knowledge transfer will be reduced (Tang et al., 2010). Tacit knowledge is not a static stock of knowledge; it is continuously being updated. The stock of tacit knowledge is continually growing through accumulated learning but erodes through loss of staff, forgetting or through other companies' attempt to capture similar knowledge. Often, tacit knowledge resides at an individual level, and can easily leave the company. The degree of tacitness can vary; the less explicit and codified the knowledge is, the more difficult for individuals and organizations to assimilate (Howells, 1996).

Companies need to continually regenerate and capture their tacit knowledge. Tacit knowledge complicates the process of selecting, moving and applying knowledge (Grant, 1996; Hansen et al., 1999; Kogut and Zander, 1992; Simonin 1999). If tacit knowledge from experienced employees is not transferred, the company will lose its level of competence in the concerned area. Therefore, the ability of employees to learn from each other and to adapt are critical to technology development and long-term success of organizations (Argote and Miron-Spektor, 2011). The theoretical framework for tacit knowledge is described in detail in appended Paper III.

SENDER AND RECEIVER

To achieve a smooth transfer, it is important to consider the knowledge transfer context and the experience of transfers, at both the sender and receiver (van Wijk, et al., 2008; Lyles and Salk, 1996; Ferdows, 2006). There are various ways for the sender and the receiver to impact the knowledge transfer, as seen in Figure 3.3.

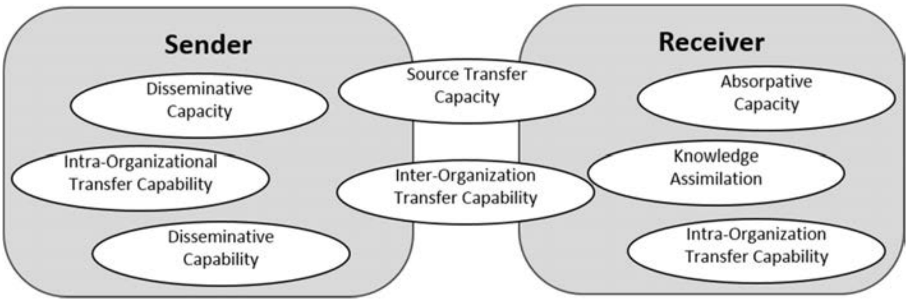

Figure 3.3: Different ways for the sender or the receiver to impact on knowledge transfer (adapted from Oppat, 2008).

Oppat (2008) focuses on the sender's perspective, and investigates the *disseminative capabilities*, the capacity of knowledge at the sender end that produces activities, which influence the success of knowledge transfer (Oppat, 2008). Tang et al. (2010) state that the senders' *disseminative capacity* – that is, the ability of knowledge holders to efficiently, effectively, and convincingly frame knowledge in a way that other people can understand accurately and put into practice is important. They conclude that both the disseminative capacity of knowledge senders and the absorptive capacity of knowledge receivers are important within knowledge transfers (Tang et al., 2010).

Easterby-Smith et al. (2008) introduce the importance that organizations need to be well equipped to diffuse the knowledge within its own boundary, their *intra-organizational transfer capability*. Intra-organizational transfer capability, is important at both the sender and the receiver, see Figure 3.3. Martin and Salomon (2002) introduce *source transfer capacity* as the ability to articulate its own knowledge, assess the needs and the capabilities of the potential receiver thereof, and transmit knowledge so that it can be used in another location, which is closely related to *inter-organisation transfer capability* (Martin and Salomon, 2002). Knudsen and Madsen (2014) also point out the specific ability to prepare and send knowledge between manufacturing facilities.

From the receiver's perspective, *absorptive capacity* is a key factor for successful knowledge transfer. The absorptive capacity can be described by the ability to recognize, to assimilate and to use that knowledge at the receiver, hence related to the receiver's existing skills and knowledge (Cohen and Leventhal, 1990; Lyles and Salk, 1996; Minbaeva, 2007; Szulanski, 1996; Ferdows, 2006). Madsen (2009) and Szulanski (1996) focus on how to capture knowledge at the sender and the *knowledge assimilation,* how the knowledge or production process transferred needs to be adapted to fit within the context of the receiver. Their research within knowledge transfers emphasizes the importance of knowing what knowledge should be transferred from the sending site and who possesses it (Zhu et al., 2001).

3.2.3 CONTEXTUAL DIFFERENCES

Geographical distance will often challenge suppliers and manufacturers with contextual differences, such as political, financial, cultural and practical differences. Financial differences can be exemplified by different currencies and payment systems, which can delay the transfer. Practical differences can involve for example different time zones. All of these factors can diminish the effectiveness of business processes. Different languages can make communication a challenge; in many cases, the mutual language is none of the parties' mother tongue.

An important part of the context is the culture of the sender and receiver (Steenhuis and de Bruijn, 2007); different cultural settings can affect many aspects of a project, since culture follows people (Zeng and Rossetti, 2003; Fraering and Prasad, 1999; Fawcett and Birou, 1992; Levy, 1995; Johansen et al., 2005). Hofstede and Hofstede (2005) define culture as "the collective programming of the mind that distinguishes the members of one category of people from another". Culture is something you learn; it comes from our social surroundings rather than our genes and it is specific for the group or category (Hofstede and Hofstede, 2005). Hofstede's model is probably the dominant explanation of behavioural differences between nations (Williamson, 2001). However, Hofstede's model has not been without criticism; some of this comes from Smith (2002), who states that the mean scores of some attribute will tell us nothing about variability within each nation, or whether the particular individuals are typical or atypical of that culture (Smith, 2002). As cultures are difficult to change, it is often more advantageous to increase the sender's and the receiver's awareness of their cultural differences (Najafbagy, 2008). The theoretical framework for national culture is described in detail in appended Paper II.

3.2.4 TRANSFER PROCESSES

A process or framework for transfer can help companies determine why, what, to whom, and how to transfer. The first question – why? – concerns the drivers of the transfer. The second – what? – concerns what is possible or profitable to transfer. The third – to whom? -– concerns who best can assume responsibility and become a supplier (receiver). And the fourth – how? – concerns how the structure and coordination between the sending and the receiving context should be established and managed (Fredriksson, 2011). Much research has been done in transfer processes. Some authors have studied how the transferred knowledge or production process could be adapted. They see solutions in conceptual models showing how knowledge can be assessed and how knowledge can be included in the transfer process (Ferdows, 2006; Grant and Gregory, 1997). Minshall (1999) developed a guide for manufacturing mobility that takes into account knowledge gaps between the sender and receiver. The guide has similarities with the model that Grant and Gregory (1997) developed. These models have a strong focus on the adaption of production processes and these processes' suitability for transfer when a supplier is selected based on performance, and the work package to transfer is based on what the sending company prioritizes to outsource. Other researchers have a less hands-on approach, and focus more on the knowledge transformations that transfer of complex knowledge requires reconstruction and adaptation (Lillrank, 1995; Attewell, 1992; Kogut and Zander, 1992). For example, Lillrank (1995) noted, that the greater the social and cultural distance, the greater the change during the transfer and, hence, the greater the abstraction and application needed.

4 RESEARCH METHODOLOGY

This chapter presents research design, research process, literature study, and data collection for the conducted research. After that, the research quality is discussed.

4.1 RESEARCH DESIGN

The purpose when developing the research design was to steer and plan the research, and the choice of the research methods (Williamson, 2002). The research in this thesis was conducted in cooperation with the industry and its starting point was an industrial challenge. Research close to the industry can share similarities with development; one main difference is the methodology, research always apply a structured methodology, to gather and analyse empirical data (Leedy, 1997; Williamson, 2002). The research method applied within this thesis was interactive research with support of case-based research.

4.1.1 INTERACTIVE RESEARCH

When applying interactive research, the objective was to evolve the way of working with technology transfer at Saab. Interactive research means that the researcher and participant (person at the investigated company) must come close enough that they can participate in the same change process (Trägårdh, 2003). The interactive research has a double purpose: to provide both theoretical insights and practical usable knowledge. The main research assignment is to provide understanding in the moment of the action, not to find general answers and finalized solutions. In dialogue with the participant, the researcher can support a mutual reflection (Argyris et al., 1985; Svensson et al., 2002; Schön, 1983). When performing interactive research it is important to establish a close and trustful relation with the participants (Barret, 2001; Davies, 1999; Ribbens and Edwards, 1998). Within interactive research, the focus is to develop knowledge mutually between the researcher and the practitioners (Svensson et al., 2002). However, in this research, it was difficult to have mutual knowledge building between the author and the participants. The author wanted to see correlations in the studied situation and relate that to earlier research. The participant most often desired a solution to implement as soon as possible. Therefore, in this research, a parallel knowledge building is more relevant (Trägårdh et al., 2003). One of the largest challenges in interactive research was the difference in time horizon for the knowledge building. To keep interest of the participant, the learning process and the feedback had to be fast. The reflections have to appear before the studies are finalized, this is in line with Trägårdh et al. (2003).

4.1.2 Case based research

Case based research was applied to support the author in the interactive approach. A good structure and design can help to ensure reliability and validity (Williamson, 2002; Yin, 2003). With the help of the structure applied within case-based research, the description and understanding of the studied phenomena was improved. Case research requires time and commitment from the organization studied (Voss et al., 2002); this was however not a problem in this case since the author was employed as an industrial PhD student at the studied company.

Several researchers discuss the benefits of using case-study research (McCutcheon and Meredith, 1993; Patton, 1990; Yin, 2003; Leonard–Barton, 1990; Williamson, 2002). In this thesis, the choice of a case study approach was based on the following reasons:

- The studies were mostly explorative
- The studies were most suitable for a qualitative analysis of each single experience and situation
- Related offset businesses are typically shrouded in secrecy, which made the use of other more quantitative methods difficult
- The understanding of the context was important
- The phenomenon to be studied was dynamic.

As noted in the first bullet, the case study method is a powerful method when the researching is more explorative (Eisenhardt, 1989; Swanborn, 2010). In this research, it was identified that research into the realization of a related offset technology transfer was lacking. This research gap is emphasized by (Nassimbeni et al., 2014; and Ahlström, 2000).

4.2 Research process

The research started in June 2010, as the author received an employment as an industrial PhD student at Saab. Before the PhD studies the author had been employed 5 years at Saab in other positions. Hence, the personal network within the company is large. The research project had a steering group and a reference group (including both industry and academia) to support the author. The reference group was flexible in its participants depending on the needs from the author. The author also has a good connection to the university with three supervisors at Linköping University.

The research process can be described from the perspective of the performed studies and the appended Papers, as illustrated in Figure 4.1. The research began in the middle of 2010 and finalized during 2016. During the research, six studies were conducted.

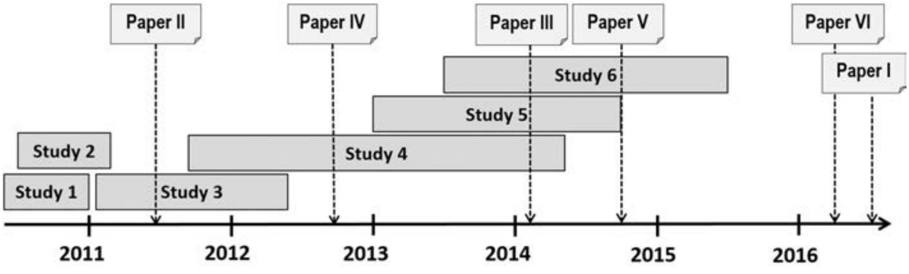

Figure 4.1: The studies and the appended papers.

First in 4.2.1, the studies are presented, after that is a short introduction to the appended papers are presented in 4.2.2, a longer summary of the appended papers are presented in Chapter 6. Empirical data used in the studies were collected from four industrial cases within Saab, these are introduced in 4.2.3.

4.2.1 THE STUDIES

Study 1, included a risk analysis performed at Saab in 2010, the purpose was to identify the largest risks in transfer of production connected to aircraft production. To complement the risk analysis, a mapping of Saab's production processes was conducted to map challenges connected to a transfer. The result of the risk analysis and the mapping were compared with the result from a conducted literature study. Based on study 1, areas to research more in-depth were framed, as shown in Figure 4.2. Focus was initially placed on the research areas Culture and communication (Study 2), Knowledge transfer (Study 3), and Model Based Definition (Study 4). Based on these initial four studies, two more studies were conducted, Related offset (Study 5) and Capability gap (Study 6). A complete description of the risk analysis, the mapping of the production process and its challenges related to transfer, and the literature study are included in Appendix I. Appendix I is a part of the earlier published Licentiate thesis by the author (Malm, 2013).

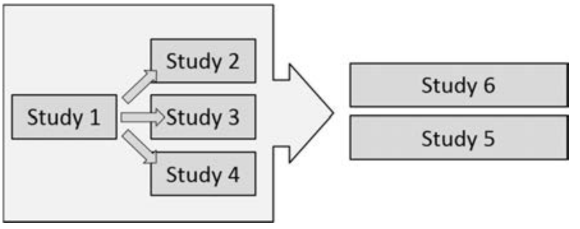

Figure 4.2: The relation between the performed studies.

Study 2, Culture and communication, aims to explore cultural differences within the transfer of aircraft production from Saab, a Swedish company. One part identifies possible ways to reduce the negative effects of the difficulties that cultural challenges may induce on the technology transfers from Saab.

Study 3, Knowledge transfer, the main purpose of the study, was to see how Saab transfer tacit knowledge between employees within the company. The following questions provided a guideline for the study:

- How is knowledge transferred today?
- How are tacit and explicit knowledge described/documented within Saab?

Study 4, Model Based Definition (MBD) were implemented at Saab before and during the time of this research. Within MBD, 3D models are used as sources of information for technical documentation; hence, the work instructions for the blue-collar workers are in 3D instead of paper format. MBD was seen as an enabler to reduce many of the identified risks (in Study 1) connected to the interface between product development and production. MBD aims to explore the largest challenges placed in an implementation and/or relocation of MBD, and how MBD can affect exchange of tacit knowledge. The focus of this study was to investigate the effects of MBD, not the technique used within the method.

The results from Studies 1, 2, 3 and 4 were published in the Licentiate thesis by the author (Malm, 2013). In the Licentiate thesis, the purpose of the research was to find and explore challenges within transfer of advanced production within offset business. After the Licentiate thesis, the purpose of the research was expanded to include the effect of the strategic decisions taken early on in the offset deals. Therefore, the offset context, and in particular the effects that related offset business have on the technology transfer realisation was identified as important to study. Based on this *Study 5* focused Related offset.

In *Study 6,* Capability gap, the focus included how to identify capability gaps connected to technology transfers within related offset and how to manage these gaps. Study 6 was based on the factors identified in the earlier studies, and was conducted in parallel with Study 5, as shown in Figure 4.2.

The performed six studies and their connection to the industrial cases is illustrated in Figure 4.3. The industrial cases are introduced in 4.2.3 and further presented in Chapter 5.

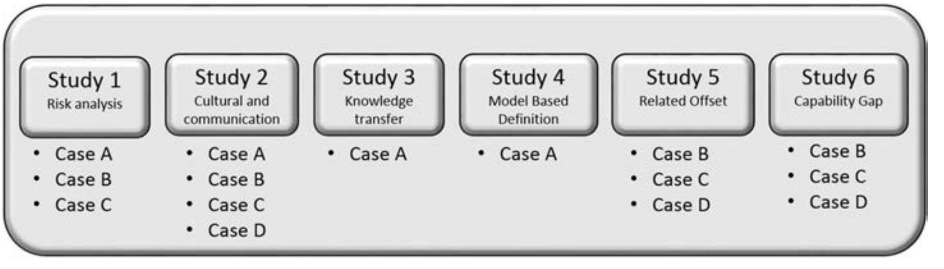

Figure 4.3: The performed studies and their connection to the industrial cases.

4.2.2 THE APPENDED PAPERS

In Table 4.1, the studies connected to the papers are presented. And a short introduction to the appended papers is presented as follows.

Paper I concerns related offset and how such context affects technology transfer realisation within the aircraft industry. Paper I is presented first in the thesis to provide an understanding of the context of related offset. The research of Paper I is more normative. In other words, the author explains the past and predicts the future (Badersten, 2006). *Paper II* involves cultural challenges connected to aircraft production transfers. *Paper III* concerns tacit knowledge among blue-collar workers. *Papers IV* and *V* identifies future challenges when transferring MBD (Model Based Definition) or the way of working with 3D models, and describes the implementation of MBD at Saab. *Paper VI* focus on how capability gaps can be identified and how these gaps can be managed in technology transfers in future related offset businesses.

Table 4.1: The relation between the performed studies and the appended papers.

Performed Studies	Appended Papers
Study 1: Risk analysis	Paper I, Paper II, Paper IV
Study 2: Culture and communication	Paper II
Study 3: Knowledge transfer	Paper III
Study 4: Model Based Definition	Paper IV, Paper V
Study 5: Related offset	Paper I
Study 6: Capability gap	Paper VI

4.2.3 INDUSTRIAL CASES

The industrial cases are both retrospective and longitudinal. Retrospective industrial cases provide a possibility to analyse an outcome (Voss et al., 2002). A particular problem with retrospective studies is post-rationalisation, that events can be interpreted differently now than what they might have been when the event actually occurred (Leonard-Barton, 1990). Longitudinal studies are often characterised by active participation in collecting data and information. Longitudinal research offers the possibility of observing relations between cause and effect (Voss et al., 2002). The longitudinal studies enabled to apply interactive research discussed in 4.1.1. The industrial cases are summarized in Table 4.2, and more in-depth described in Chapter 5.

Table 4.2: Summary of industrial cases

Industrial case	Description	Time span Industrial case	Type of Agreement
A	Saab, internal production	Longitudinal, ongoing	NA
B	Saab to South Africa	Retro 1997 to 2013	Related Offset
C	Saab to Czech Republic	Retro & Longitudinal, 2007 to 2013	Related Offset
D	Saab to India	Longitudinal, 2009 and ongoing	Commercial (Strategic)

Industrial Case A involves in-house production at Saab and industrialization of the Gripen fighter. Industrial cases B and C are within the defence segment, and defined within related offset. Industrial Case D is from the commercial industry.

However, the prerequisites for the business studied within Case D have several similarities with offset: the choice of the supplier was partly steered by the customer, and the work package included complex production processes.

4.3 LITERATURE STUDY

During each performed study, presented in 4.2.1, separate literature studies have been performed. This provided the author with an understanding of the existing research within the area. The literature study also helped to identify earlier research within the area, and to identify possible research gaps. The literature studies have been iterated in parallel to the performed studies. Further, the interview templates applied within the semi-structured interviews were created based on the literature studies.

Literature search was performed in databases such as Science Direct and Google Scholar, the first search began with the search phrase 'transfer of advanced production' and 'related offset'. These phrases were include in the scope defined for in the start of the research journey back in 2010. In the start, limited amount of literature was identified. This can be explained by the fact that within offset, much data is sensitive (Grandetti et al., 2009; Nassimbeni and Sartor, 2005; Stephen, 2014). It is often connected to national research institutes and related studies are published in popular science journals and on company and governmental websites (e.g., the Institute for Defence Studies and Analyses, or IDSA; Development Southern Africa; Swedish Defence Research Agency, or FOI; Defense Institute of Security Assistance Management, or DISAM; and *DISAM Journal*).

Another explanation to the limited amount of identified literature were the narrow search phrases applied in the databases. To increase the amount of literature, the search was conducted with the search phrases 'transfer of advanced production' and 'related offset' in different combinations, and individually. This way of searching led the author to several similar concepts, such as: technology transfer, knowledge transfer, tacit knowledge, technology assimilation, codified knowledge, explicit knowledge, new product introduction, production relocation, industrialization and strategic outsourcing. The same approach with the literature search was applied with 'related offset'. This led the search into similar concepts such as industrial participation, industrial collaboration, business value development, governmental procurement, local policies, countertrade, and counter-purchase. These different identified expressions were then combined with each other to identify interesting literature connected to the research context.

4.4 DATA COLLECTION

This section describes the data collection. In Table 4.3, a summary of the data collection within the conducted studies is presented. In study 5 and study 6, some data collection was input to both studies, see Table 4.3.

It is important to be aware of the difference in passive and active data, and how that can affect the results in the research. Passive data is that which the researcher is searching for; active data is connected to discovery through, for example, observation or open-ended interviews (Dubois and Gadde, 2002). This research includes a lot of active data, and such data is difficult to find without an interactive approach. Too much active data and too little reflection can mislead the researcher to miss the research objective. Hence, reflection and documentation has been an important part of the research process. A risk with too much passive data is that the researcher presents a too specific version of the reality (Bryman, 2008).

A central part of the data collection in the research was the use of *focus groups* as a means to gather empirical data. Focus groups are group interviews where small groups of people meet, and, on a researcher's request, discuss a given subject with each other (Wibeck, 2011). A mix of snowball selection and strategic selection recruited the people within the focus groups performed at Saab. Snowball selection is that the researcher chooses people, and then they pass on an invitation to other people that might contribute to the subject of the focus group (Wibeck, 2011). The purpose with focus group in this research was that the chosen group members would encourage each other to speak about the chosen subject. The moderator of the focus group should not affect the members' opinions. Before the focus group meeting, the group members received general information about the subject. Too detailed information can limit the group members in the discussion (Wibeck, 2011). The interview questions for the focus group were planned in a way that the moderator, if needed, could enhance the conversation. In this research a total of six focus groups were held, see summary in Table 4.3.

Interviews have been involved in all the studies, see summary in Table 4.3, with a focus on interviewing project managers, production managers, blue-collar workers and project members. Follow-up interviews were often performed, often based on perceived overlooked information. In addition, follow-up interviews were conducted to validate results over time. In agreement with Leonard-Barton (1990), the focus was placed on seeking multiple viewpoints to help limit subjectivity and bias. Mainly semi-structured interviews were applied, an interview guide were created to provide the structure. However, at times, the author deviated from the planned questions. From 2011 on, all scheduled interviews were recorded. The length of the interviews varied from 30 minutes to three hours. Interview templates are stored in a database at Saab. During 2010, the first year of the research, not all interviews were recorded. However, there were notes taken and filed during and after the interviews.

Direct observation was often used to collect data in this research, and was input to all studies; see some notations in Table 4.3. Within direct observation, the studied events are in the present time and within the studied context. The author attended to weekly meetings in transfer of production projects, both connected to outsourcing and related offset. The author has been positioned within the production organization at Saab from 2010 to 2016. Hence, observations have been conducted in the production environment at Saab longitudinally. For example, the direct observation helped the author to observe that much of the daily work in production was performed based on experience and not solely on the production documentation. That example was important for the progress of the research. The need to map or identify such tacit knowledge was a milestone in the research and, henceforth, more interaction between the author and the blue-collar workers or project managers was needed.

Informal conversation between employees happens all the time; these conversations differ in tone from more formal interviews. Conversations are not planned and the people participating in the conversations have not been prepared to address a special subject or seen any questions beforehand. Informal conversations are an important type of observation. In interactive research, much data are informal data and are therefore difficult to document.

Much data has been gathered through *interaction* within different projects and programs at the studied company. The author was positioned within different project or program roles at the company. In Case B, the author was a risk manager for the in-sourcing of production from South Africa. And, the author has been positioned to develop, a Saab specific transfer process, and a Saab specific industrialization process. These are summarized in Table 4.3. This provided the author with unique possibilities to gather data within the research area. However, much of the information is informal, and it was not possible to record the meetings or to have public files from the meetings. Meetings were held once or twice a month, from 2014 and the meeting are still running, to further develop the processes.

Table 4.3: Summary of the data collection within the conducted studies.

Studies	Study 1	Study 2	Study 3	Study 4	Study 5	Study 6
No of Focus Group	3 (2010)		1 (2011)		2 (2013)	
Focus group members	Managers Project managers		Blue collar workers Production team leaders		Project managers Managers representing all industrial cases Experts	
Number of interviews	22	8	10	12	12 specific for Study 5 15 specific for study 6 5 for study 5 and 6 1 deep interview outside Saab	
Position of the interviewee	Production managers Project managers Production team leaders Blue-collar workers Project members	Production Managers Engineers Project managers Blue-collar workers	Production managers Experts Production team leaders Blue-collar workers	Managers production and development Experts (MBD) Production engineers Project managers	Project managers Production managers Sourcing and supply managers Development managers Project members Blue-collar workers Project manager at a company working with strategic outsourcing	
Documents from Saab	Company specific Lessons learned	Company specific Lessons learned	Company specific	Company specific	Company specific	Company specific
Authors position				Positioned 1 year at the MBD department	Risk manager, 4 risk meetings and 4 lessons learn meetings Process developer	
Observation	Internship at 7 production units, 1 day each			Daily work Weekly meetings	Weekly project meetings	

4.5 RESEARCH QUALITY

Research quality can be described as the extent to which a concept or conclusion corresponds to reality (Yin, 2003). Research quality can be determined by discussing four areas (Yin, 2003): Construct Validity, Internal validity, External validity, and Reliability. Internal validity is used to establish casual relationships. According to Yin (2003), internal validity only concerns explanatory research, proving underlying characteristics found in the study (Hellevik, 1984). Consequently, internal validity is not further discussed here.

4.5.1 CONSTRUCT VALIDITY

Construct validity can be described as the extent to which the concept to be measured was actually measured (Yin, 2003). The author is an industrial PhD student and was employed at the Saab from 2006, so the author's network at Saab is extensive. This background increases the risk of author's bias, that the researcher influences the data collection and the evaluation based on their personal experiences (Williamson, 2002). Bias can decrease the validity (Yin, 2003).

To increase the validity Yin (2003), recommend to use multiple source of evidence when collecting data. In this research were triangulation applied. Triangulation can be to apply two or more methods or techniques to investigate the same research question. Triangulation can also be to collect information from several sources to one study (Hittleman et al., 1997). For the research herein, two methods were applied, interactive research and case based research. Several data collection techniques were used, as shown in 4.4. The empirical data were collected from employees at Saab through focus groups, interviews, observation, and literature from journals, and books. Some of these are exemplified as follows.

To increase the validity, focus groups were applied, for example, two of the focus groups were conducted in parallel, these focus groups was input to both study 5 and 6. The participants of the focus groups were project leaders and managers representing all industrial cases.

Interviews were often used as a tool to gather empirical data. Most often were semi-structured interviews applied, and interview guides were based on the performed literature studies. Several interviews were performed connected to each study, see table 4.3. Follow-up interviews were often performed to validate results over time, and almost all scheduled interviews from 2011, were recorded. Those interviewed always had the chance to review their contribution before publication to ensure the validity of the research. The analyses of the results in the studies were performed in communication and cooperation with the reference group at the company and with academia through co-authors and the supervisors.

The author was an industrial PhD student, hence employed at the company. The author was positioned within different project or program roles at the company. One of these responsibilities included to develop a transfer of production process at the company. When developing that process, reoccurring meeting were set. The people invited to the meetings represented all the studied industrial cases. Setting aside the result that the industry requested, these meeting helped validate the research. These meetings were used as a feedback method, to test results derived from literature or from the studies. The meetings can be seen as key informant reviews. According to Yin (2003), such meetings can increase the external validity. These type of interactive meetings also contributed with a high correctness of the empirical data. With an interactive approach, the iteration decrease the amount of misunderstanding between the author and the people at the meeting.

During the research process, the author saved notes on a weekly basis in a research diary. The notes consist of daily observations, motivations for decisions or changes in the research process, and other informal information. These notes have been a good tool to link the identified ideas and solutions to their origin and thereafter conduct interviews or other activities. The diary has also been a tool for reflection and a database used to keep the chain of evidence.

4.5.2 EXTERNAL VALIDITY

External validity can be explained by the generalisability of the results (Yin, 2003). In this research, that is case based, an analytical generalisation is appropriate (Yin, 2003). Analytical generalization refers to the ability to abstract the generated case specific knowledge to be applicable and relevant in other contexts (Fishman, 1999).

The research herein is based on four industrial cases from one company. The research was conducted in a context of related offset business and the aircraft industry. Not much research has earlier been conducted by other within the research objective. It can be a strength to explore and analyse specific situations or phenomenon; the uniqueness can be highlighted (Yin, 2003). However, the generalisability is decreased. According to Yin (2002), a way to increase the external validity is through validate with relevant literature. In this research, the performed studies all include separate literature studies. Another way to increase the external validity in the research was to present and discuss the research results outside the investigated context. This was performed with the results from the first four studies, both at international conferences and at conferences within Sweden.

4.5.3 Reliability

Reliability can be described as the ability to repeat the research and get the same result (Merriam, 1994; Sekaran and Bougie, 2013). In interactive research, reproducibility of the result is difficult; hence, a thorough description of the research process will provide better understanding and increase the possibility of conducting similar research (Westlander, 1999). The author has created a database that maintains all the research data, such as interview templates, interviews focus groups, research reports, protocols, notes from meetings etc. This database could help to reconstruct similar set-ups for research in related areas. However, it is not possible to reconstruct the research, and get the same empirical data. The context change, there are new projects, new people, new business deals etc.

5 INDUSTRIAL CASES

Within this chapter, industrial cases are presented; they involve technology transfers from Saab to South Africa, Czech Republic and India, as well as in-house production at Saab. The industrial cases are both retrospective and ongoing.

5.1 INDUSTRIAL CASE A, SAAB GRIPEN

Industrial Case A involves production of the fighter Gripen, Model Based Definition (MBD) and production documentation in 3D, and finally industrialization of the fighter aircraft Gripen at Saab is described.

5.1.1 PRODUCTION OF GRIPEN

Saab production of Gripen has two main production processes: parts manufacture and assembly. Parts manufacture consists of 'composite', 'machining', and 'sheet metal', as shown in Figure 5.1. Support processes are surface treatment, including painting. Assembly consists of sub-assembly (tube and welding, and harness and panel), structural assembly and final assembly. All these processes are illustrated in the flowchart in Figure 5.1.

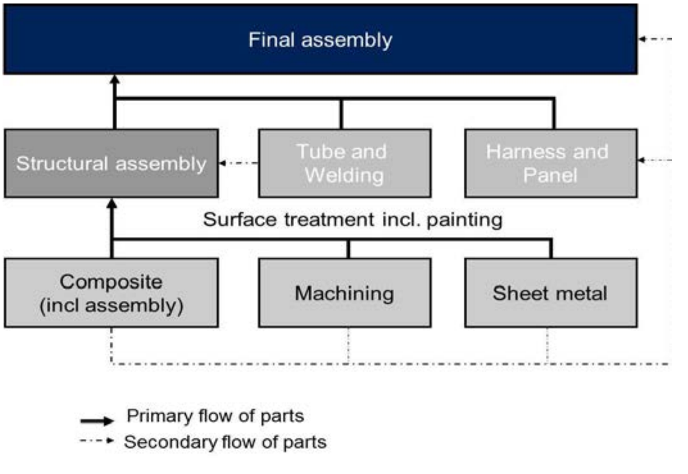

Figure 5.1: A flowchart of the production processes of Gripen at Saab in Case A.

PARTS MANUFACTURE

Parts manufacture within Gripen production at Saab consists of composite, sheet metal, and machining. Approximately 20% of the total structural weight in Gripen aircraft is carbon composite. Composite production is a complex process, with a large amount of manual work; this demands a certain skill in order to reach the quality demands. Within the production of sheet metal, the level of automation is very low, the blue-collar workers have to feel and see how the material is affected. Within sheet metal, the production documentation mainly consists of a 2D drawing and short guidelines. This type of documentation is remarkably brief for such a complex process, due to the difficulty of describing skills. The level of automation within 'machined parts' is much higher than in other segments within Gripen production. Some machines are fully automated, supervised by a blue-collar worker. However, most of the machines are semi-automated.

ASSEMBLY

Sub-assembly includes manual work with the aid of some power tools or other machines. Sub-assembly consists of several sub-processes: tube bending, welding, harness, panel and mechanical and electrical sub-units to final assembly. The level of automation is low and the machines and tools are used as aids. The main structural parts such as wings, fuselages and tail cones are assembled in structure assembly and later delivered to final assembly. The overall level of automation within structure assembly is very low.

Final assembly can be described as a giant 3D puzzle built by several persons at the same time, with all 'pieces' dependent on each other. The assembly is mainly manual and complex, and the level of automation is low, close to none. The production is rate-based, but the rates are very low if compared to, for example, the automobile industry. Figure 5.2 illustrates a typical assembly situation for blue-collar workers performing final assembly. There are several blue-collar workers working at the same station at the same time. They have to work in parallel without disturbing each other. The working positions can be very uncomfortable and the assembly operations are often performed in inaccessible places. The blue-collar workers apply special assembly tools and mirrors to reach these inaccessible places. The creation of production documentation is difficult. If the documentation lacks information, it is hard for the blue-collar workers to perform the tasks correctly. If the production documentation is too detailed, it is difficult for the blue-collar workers to identify which information in the documentation is critical. See more information about Gripen production in Appendix I, However, this Case description are based on the same information as Appendix I (from the authors licentiate thesis), hence there are similarities.

Figure 5.2: A typical installation situation at final assembly.

5.1.2 Model Based Definition and production documentation in 3D

Saab has been working with Model Based Definition (MBD) for a long time. The main motivation for Saab was to save time and money. MBD is a method to manage engineering and business processes by using 3D models as source of information (Alemanni et al., 2011). MBD can help Saab with their concurrent engineering work, and to improve their design for manufacturing. At Saab, the 3D model communicates the Product and Manufacturing Information (PMI), including data such as geometric dimensions and tolerances and 3D annotations. At Saab the PMI in 3D, is referred to as 'production documentation in 3D', and this wording is henceforth applied here. At Saab, production documentation in 3D enables better possibilities to improve the work instructions. In 2004, Saab had mostly text-based work instructions, including many abbreviations. When MBD was implemented, a team was formed to work with improvements of the production documentation (Paper V). Improvements in the existing documentation were necessary, in order to change it into digital format (i.e., adjust them for MBD). The role models for the visualisation of the 3D models were those that set an example for non-text based instructions like IKEA and LEGO. There is no text in IKEA's instructions and the company has a well-developed language with symbolic meaning for those in that organization. Today, experienced blue-collar workers and engineers make Saab's documentation. The documentation is not non-text based like IKEA's or LEGO's. However, the improved work instructions in 3D are inspired by IKEA's and LEGO's way of producing work instructions, with fewer abbreviations and more pictures.

5.1.3 INDUSTRIALIZATION AT SAAB

Saab's product realization process, as shown in Figure 5.3, includes three main steps: product development, industrialization, and manufacturing. Industrialization within the product realization process occurs in the interface between product development and manufacturing.

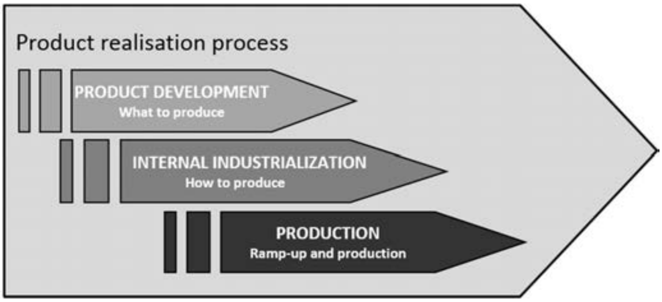

Figure 5.3: An illustration of the investigated company's product realization process in Case A.

The main purpose of industrialization at Saab is to make the product development and the production system match. The internal industrialization within the product realization process in the sending context occurs in the interface between product development and production. The output of the industrialization process at Saab is intended to provide the production unit with the ability to deliver ordered products on time, at the requested quality, and at the agreed-upon cost. Production of the first part always must be performed before a transfer can be initiated, in order to verify the product design to avoid new design changes.

5.2 INDUSTRIAL CASE B: TRANSFER TO SOUTH AFRICA

Case B describes the transfer between Saab (of Sweden), BAE Systems (of England), and Denel Aviation (of South Africa), shown in Figure 5.4. The campaign to sell the Gripen aircraft to South Africa started in 1997. Early in the sales campaign, Denel was suggested as a possible receiver of production by the South African government. Saab quoted the South African government a price for 28 Gripen aircraft; as part of this offer, Denel quoted Saab a price for Gripen modules. In late 1999, the South African government contracted Saab through BAE Systems for 28 Gripen aircraft. Related to the contract was an offset agreement worth USD 8.7 billion, of which USD 808 million constituted related defence offsets from Saab to South Africa. Saab's contract was part of a large order fulfilled jointly with BAE Systems (formerly British Aerospace), in which BAE manufactured structural parts for the Gripen aircraft. BAE had requested to adjust its participation in the joint venture at the same time as South Africa showed an increased interest in the Gripen aircraft, so it was decided to transfer the production from BAE instead of from Saab.

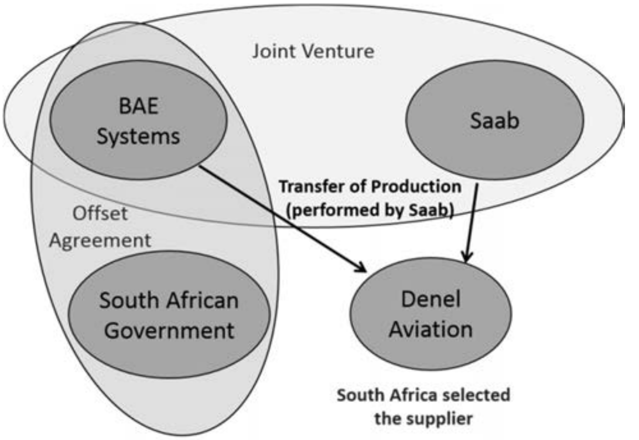

Figure 5.4: Illustration of the relations between Saab, BAE Systems, South African Government, and the receiver of the transfer: Denel Aviation (Case B).

The offset contract in the industrial case study was extensive, and Saab needed to ensure support, maintenance, and spare parts to South Africa for a long period. The agreement also included pilot training and integration of the aircraft with the South African defence organization. South Africa also requested the ability to introduce updates into the system themselves. The planned outcome of the agreement from the South African government's side was to restructure the South African defence industry and raise its competence. Furthermore, the South African government also wanted to offer employment opportunities to historically disadvantaged citizens in selected geographical areas. From Saab's point of view, South Africa was an important business case as it could set a good example in new negotiations with other countries.

The agreement to transfer parts assembly was signed in February 2001; the physical transfer occurred in the spring; and production started in the summer of 2001. The chosen parts had formerly been manufactured by BAE in England, so the transfer of production was from England (BAE) to South Africa (Denel). In 2013, the offset agreement was completed from the economic and strategic perspectives. Decreasing production volumes made continuation difficult, so the production was relocated back to Saab.

5.3 INDUSTRIAL CASE C: TRANSFER TO CZECH REPUBLIC

In Case C, Saab received a new order and the existing supplier could not achieve the required production volume, so a second source had to be found. Saab had the opportunity to influence the choice of supplier and therefore performed its own assessments of four suppliers in countries that were preferred from an offset perspective. The chosen supplier offered the most competitive performance at the most reasonable price of the four. See the relations within Case C in Figure 5.5.

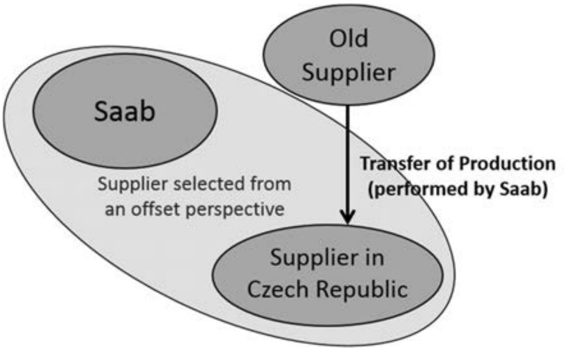

Figure 5.5: The relations between Saab, the former supplier, and the Czech Republic supplier (Case C).

The purpose of Saab's transfer project in Case C was to manufacture three different NATO (North Atlantic Treaty Organization) pylons for Gripen aircraft at a new supplier. Gripen NATO pylons are installed on the aircraft fuselage and wings to carry different kinds of payloads. The transfer project was responsible for industrializing the production at the receiver, that is, the work needed to establish serial production that met the requirements agreed to by the buyer. The transfer to the second supplier started in July 2008.

5.4 INDUSTRIAL CASE D: TRANSFER TO INDIA

This industrial Case D involves the transfer of manual composite production to India from Saab's commercial business area. In Case D, Saab was able to choose the supplier on its own, though the buyer had recommendations included in the agreement as to preferred regions and countries of origin. The recommendations from Saab's customer were in line with the recommendations from the Saab company group. Figure 5.6 illustrates the relations within Case D. The main incentive on Saab's side was to decrease costs; the incentive on the customer's side was to become established in a geographically preferred market and to reduce costs.

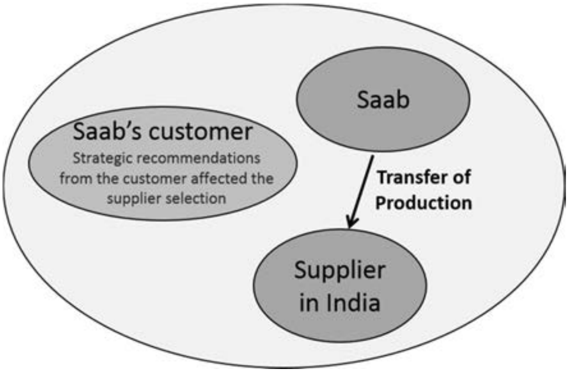

Figure 5.6: The relations between Saab, Saab's customer, and the receiver of the production transfer (the future supplier) in India (Case D).

In February 2009, a business agreement was signed between the Indian supplier and Saab. The agreement included the production of structural composite components, including the hand lay-up of prepreg (uncured composite material). Significant experience is required to perform the hand lay-up of prepreg to achieve approved results for the final product. Blue-collar workers who conduct such operations may have different ways of working, but they still must produce the same final result. In composite production, it is impossible to measure quality (in what Saab calls a "special process") until the product is finalized. The prepreg material is cured in an autoclave, so the process is irreversible. The cured product made of prepreg is monitored by means of non-destructive testing (NDT), a test method for examining a part without impairing its future usefulness. The composite production process required extensive and expensive qualification programs on the part of the supplier.

6 SUMMARY OF APPENDED PAPERS

Within this chapter, summaries of the six appended papers and their purpose and main findings are presented.

6.1 PAPER I: WHAT ARE THE DIFFERENCES BETWEEN RELATED OFFSET AND OUTSOURCING?

The purpose of Paper I is to study differences between outsourcing and related offset. The identified differences should serve as a starting point to develop a more general related offset process. Paper I is based on an in-depth case study of a related offset business at Saab, a Swedish military aircraft producer. The analysis compares the studied case with an existing outsourcing process identified in the literature. Paper I identifies five main differences between outsourcing and related offset:

- Different hierarchical levels are involved in the negotiation and the realization of a related offset business
- The related offset work package identification must meet the buyers' request.
- The use of multipliers within related offset.
- Supplier assessment in two steps.
- The seller's fulfilment of offset obligations have to be approved, before contract termination.

These differences are translated into activities to be included in a suggested related offset process. First of all, Paper I contributes by showing that there are differences between related offset and outsourcing. Further, it highlights the need for developing a process for related offset agreements. Paper I also contributes to offset research by providing an overview of the activities taking place during the entire related offset process. As a result, the involved people can better understand the course of events.

6.2 Paper II: Cross-cultural communication challenges within international transfer of aircraft production

Paper II aims to explore production-related cultural differences from a Swedish perspective; Sweden is a relatively small country with a strongly defined culture. The cultural challenges were linked to cross-cultural communication when conducting international aircraft production transfer. Furthermore, the need for specific types of cross-cultural training to reduce the difficulties that cultural challenges may induce is discussed.

Paper II shows that most of the differences appeared when the interviewees worked in India, South Africa, the Czech Republic and the United States. For that reason, many of the differences involve a comparison and discussion between these countries and Sweden. Compilation of empirical data indicated that many of the cultural differences that emerged could be divided into three main categories.

1) Organisational structure, hierarchy, and delegation of responsibility
2) Consensus behaviour and avoidance of conflicts
3) Individual motivational factors.

One key factor for successful industrial collaboration and transfer of production is improved understanding of cultural differences. This understanding would improve the chances of reducing the number of problems that occur.

The result indicates that it would be beneficial for Saab to apply organised cross-cultural training (in combination with technical training) to educate a project team before starting a production transfer. It is essential for Saab to organize a suitable type of cultural training and to adjust the training to match the culture in the sender and recipient countries. The research result in Paper II matched the theory well, according to both Lewis (2006), and Hofstede and Hofstede (2005). Therefore, it could be beneficial to use their theories in the workshops.

6.3 PAPER III: EXCHANGE OF TACIT KNOWLEDGE WITHIN ADVANCED PRODUCTION WITH SMALL BATCH SIZES

The research presented in the book chapter views similarities and differences between two industry segments - aircraft and wood furniture - in how they transfer tacit knowledge between employees. Here, focus is placed on Saab.

It is important to transfer tacit knowledge between individuals. Especially when transferring production between a sending and a receiving site. In Paper III, knowledge was mapped with a focus on the tacit component. The first half of the book chapter involves a description of the nature of the knowledge, specifically the shop floor knowledge at an individual level in the aircraft industry. The second half is more normative and asks for support to transfer the knowledge, the inter-organizational transfer capability.

Two production areas were chosen for the study: final assembly and sheet metal. Within final assembly, blue-collar workers often have extensive experience, and few have less than 10 years in the industry. They know the production documentation inside and out. Final assembly can be described as a giant 3D puzzle built by several people at the same time, where all pieces are dependent on each other. Small, undiscovered mistakes (within tolerances) that are made in earlier assembly or production steps can generate large consequences in final assembly. The production area of sheet metal has more in common with classic craftsmanship production than final assembly. Comprehensive experience is required to achieve an acceptable final result. The production area was chosen due to the high demands on the blue-collar workers' manual skills.

The unique qualities of the aircraft industry are emphasised, especially the craftsmanship of the blue-collar workers. Hence, a mapping of tacit knowledge on the shop floor is preformed and means to exchange tacit knowledge within Saab is discussed. Today there are several means to transfer tacit knowledge applied within the production segment of Gripen. Some of them are daily routines and schedules; improved production documentation; personnel movement; social networks and mentor-novice training. In this study, not one specific means has been identified to solve the problem of transfer of tacit knowledge.

6.4 Paper IV: Model Based Definition within relocation of aircraft production

The purpose of Paper IV was to explore how relocation of production can be affected when Model Based Definition (MBD) is applied. Production transfer from Saab has earlier mainly been performed with drawings and production documentation on paper not within 3D models. Paper IV was written from a viewpoint of production relocation; the focus was not on MBD as a method. The paper is based on a literature review combined with empirical data from an industrial study at the Swedish enterprise Saab.

An important subject of discussion in Paper IV was that an update or creation of 3D production documentation can decrease the amount of the sender's tacit knowledge of and facilitate the possibility of differentiating off-line learning from online learning, which can save both time and cost when transferring production. With production documentation in 3D, blue-collar workers are able to see the work package before it is possible to touch the products. This virtual off-line training will decrease the online time, the blue-collar workers will learn faster and the quality level will be kept more stable. Another advantage when transferring production and MBD is applied is that an online 3D model will guarantee the same revision level. The sender and the receiver will see the same model at the same time. However, the ability to manage Information Technology (IT) on a system level at the recipient is a decisive factor.

6.5 PAPER V: A CHANGE PROCESS: TRANSITION FROM 2D TO 3D BY MODEL BASED DEFINITION

The purpose of Paper V was to investigate factors that are important for the transition from 2D to 3D by Model Based Definition (MBD). Within MBD, 3D models are used as sources of information for design, production, distribution, technical documentation, services and the overall product life cycle. The introduction and development of MBD at Saab can be described in five transitions between large projects. The mapping illustrates how the knowledge enhancement between the projects and the linear organization has evolved.

The result in Paper V showed that the ability and efficiency of a project depend on driving forces during the project. Even though the projects in this study work with MBD, the identified motivation factors vary, for example, between internal driven and customer driven. A major factor for how the MBD methodology is applied and developed is the staff available and their experience level, especially during the initial phase. Another important factor involves the possibilities of choosing project members based on their experience and skill, which have been enabled thorough planning for education, method support, and further methodology development.

6.6 PAPER VI: BRIDGING CAPABILITY GAPS IN TECHNOLOGY TRANSFERS WITHIN RELATED OFFSETS

The purpose of Paper VI is to explore how capability gaps can be identified and how they can be dealt with in aircraft technology transfers in future offset deals. The study is based on lessons learned as identified from three case studies of technology transfers from Saab, a Swedish aircraft production company to South Africa, the Czech Republic, and India.

The main finding in Paper VI is that the capability gap between sender and receiver has to be dealt with on two levels: on an organizational level; and on an individual level, here individual level refers to the employees. It is proposed that the disseminative capacity constitutes the ability to assess the capability gap between the sender and receiver, and to convert this assessment to adaptations of the product and production process to include in an industrialization process. On the individual level, the capability-raising activities were connected to employees' knowledge, Personal Development Plans (PDPs) for the transfer of explicit knowledge, as well as on-the-job (OJT) training to facilitate the exchange of tacit knowledge, see Figure 6.1.

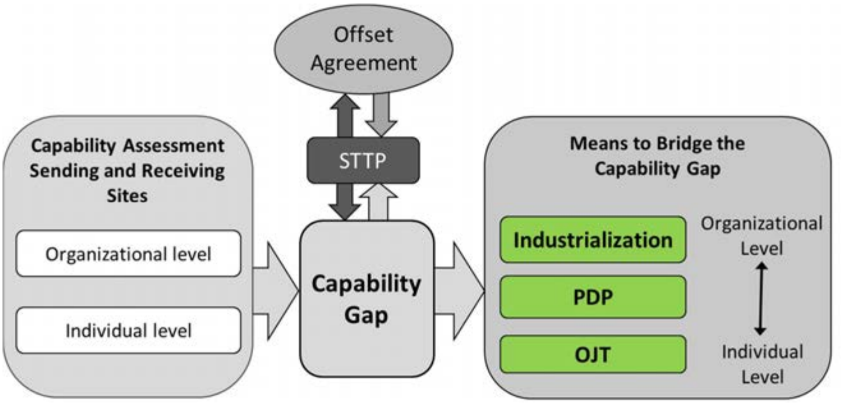

Figure 6.1: Illustration of bridging the capability gap between sending and receiving sites through Industrialization, Personal Development Plans (PDP), and On-the-Job Training (OJT).

The originality of Paper VI is the focus on the context of offset and reports on actual experiences from a capability perspective of technology transfers within the aircraft production area. It proposes a structured way of identifying and bridging the capability gap within such transfers.

7 RESEARCH RESULTS

This chapter elaborates on the results from the appended papers in relation to the research questions.

The objective of this thesis is: *"To extend the current understanding of technology transfer realization connected to related offset within the defence aircraft industry"*. To reach the objective, two research questions are addressed. The first research question aims to identify factors and their effect on the technology transfer realization within related offset connected to aircraft production. The second research question has a more normative approach: seeking facilitating tools to manage future related offset technology transfer connected to aircraft production. In this chapter, the research results are divided into two sections, one for each research question. The relation between the appended papers and the research questions is illustrated in Figure 7.1. A dotted line illustrate a weaker connection to the research question.

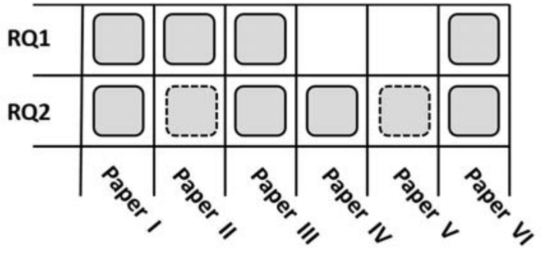

Figure 7.1: Relation between the research questions and the appended papers.

7.1 FACTORS AFFECTING TECHNOLOGY TRANSFER REALIZATION WITHIN RELATED OFFSET

In this chapter the results from the first research question is addressed:

RQ1: What factors can have a major effect on the realization of technology transfer within related offset connected to aircraft production?

Important aspects that affect the technology transfer realization within offset business are visualized in Figure 7.2. These aspects are:

- Activities to be transferred
- Related Offset Business
- Contextual Differences.

The identification of the aspects was based on the reasoning as follows.

The most important aspect in technology transfer realization is what is transferred, i.e. the activities to be transferred, see Figure 7.2. These activities are relocated from a sending company to a receiving company. To illustrate the relocation of the activities, they are in Figure 7.2 symbolized by an arrow. The related offset business, and in particular the offset agreement between the sending and receiving company affects the realization of the technology transfer, by defining the rules for how the transfer should be conducted and what it should include. In Figure 7.2, to represent the limitations that the related offset business sets, related offset business is illustrated as a tunnel. Furthermore, in addition to the importance of what is transferred and how the transfer should be conducted, the companies involved in the transfer are important, i.e. the sending and receiving companies. For the realization of a technology transfer within related offset, the contextual difference between these companies are especially important. The identification of the important aspects in realization of technology transfer is mainly based on Study 1 (Appendix I), the appended papers, and (Argote et al., 2003; Easterby-Smith et al., 2008; Minshall, 1999; Cummings and Teng, 2003; and Mu et al., 2010).

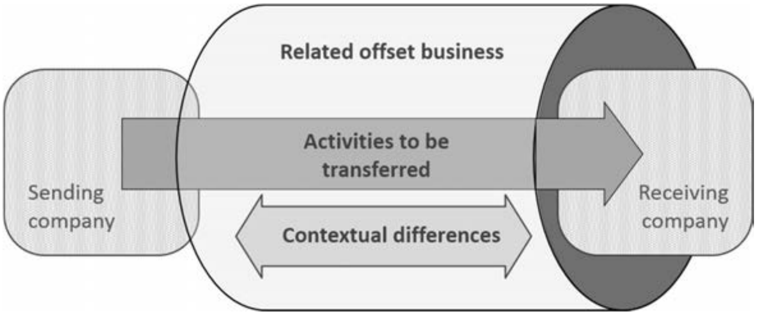

Figure 7.2: Important aspects affecting the realization of technology transfer within related offset business.

7.1.1 THE ACTIVITIES TO BE TRANSFERRED

The activities to be transferred, as shown in Figure 7.2, are based on the level of development that the buyer wants to reach. An example is described below from Paper I.

> *"The planned outcome of the offset contract for the South African government was the restructuring of the South African defence industry, from personnel intensive to personnel efficient (i.e., raising its competence). A further purpose was to provide employment opportunities for historically disadvantaged inhabitants in selected geographical areas".*
>
> Paper I

When raising competence and employment opportunities in selected geographical areas is requested, a technology transfer can contribute to capability growth (Jabar and Soosay, 2011; Steenhuis and Brujin, 2001). The activities to be transferred have to generate capability growth within the area that the buyer request in the offset agreement. Previous research has highlighted the need to identify and adapt the activities to be transferred to fit the receiver (Minshall, 1999). To adapt the identified activities, the difference or the gap between the sender and the receiver must be identified (Paper VI).

CAPABILITY GAPS

Within related offset, capability growth is often intended, and then the anticipated capability gap will be large, this was observed in Case B and Case C (Paper VI). An essential part of an effective technology transfer is to bridge capability gaps between the sender and the receiver (e.g., Lyles and Salk, 1996; Salomon and Martin, 2008; Galbraith, 1990). In Chapter 3.2.1 capability is defined as:

> The ability to perform certain activities so that when the activities are transferred they can be developed and improved by the sender and give competitive advantage.

A capability gap then becomes:

> The difference in the ability between the sender and the receiver in relation to performing an activity in such a way that it gives competitive advantage and can be improved and developed.

Within the closed offset deal between the Brazil government and Saab, the buyer requested capability growth within specific areas, and the extensive technology transfer included in the deal definitely contributed to a signed offset contract (Paper VI). On Saab's part, a prioritized business strategy in offset negotiations has been to emphasize the importance of capability growth to the buying part. One way to include capability growth in technology transfer from Saab can be exemplified by 'Build to Print' and 'Design to Build'.

Build to Print occurs when the receiving company receives technical specifications from the seller and then produces according to a predetermined design. Within Build to Print, the focus is normally on capacity transfer of standard parts, not activities such as final assembly. In the aircraft industry, capacity transfer involves relatively small volumes, high investments, long payback times and often poor profits for the receiver. Therefore, it is hard for the seller to fulfil the buyer's and receiver's often high expectations of production volumes. For the seller in an offset, when applying Build to Print, this can limit the number of potential buyers. This, since the total production volumes often are low, and the sold product do not have parts enough for transferring production to all potential buyers. In Build to Print deals, the buyer takes a risk. When the offset business is fulfilled and finalized, the seller has new markets to satisfy. The seller often relocate the Build to Print work package from the previous receiver, to a new buyer. However, it can be noted that Build to Print often also requires some type of capability transfer for the receiver to produce the part.

Design to Build occurs when the receiving company receives product requirements from the seller. Then the receiver develops and produces the part according to the given requirements. The extent of the development responsibility can vary, from redesigning a single part to creating a new design of a large section of the aircraft. The design change and the design responsibility depend on the size of the offset business deal, the capability of the buyer, and the development phase in which the aircraft is to sell. Requesting Design to Build can be a way for the buying country to enhance technology and capability growth within local industries. Through a

Design to Build business deal, the buyer undergoes a capability growth, learning to design and produce parts from a set of product requirements. When the offset business is fulfilled and finalized, the receiver can access new markets with their newly acquired capability. However, this example does not imply that capability growth only occurs with Design to Build work packages. Often certain activities, such as final assembly, are requested to provide capability growth. These activities do not need to be connected to a Build to Print or Design to Build work package; they are negotiated separately.

Knowledge Transfer

When capability growth is requested by the buyer (Ahlström, 2000), the activities to be transferred often are new activities for the receiver. The success of the knowledge transfer to learn the new activities between the sender and the receiver is important. To improve the knowledge transfer, the disseminative capacity at the sender and the absorptive capacity of the receiver have to be good (Tang et al., 2010; Minbaeva et al., 2010; Ferdows, 2006). Transfer of knowledge sets high requirements on intra- and inter-organizational transfer capability (Grant, 1996; Madsen, 2009; Minshall, 1999). The focus in this thesis is mainly from an intra-organizational point of view, mainly concerning how knowledge can be transferred on an individual level within the organisation. Intra-organizational transfer capability is defined by Easterby-Smith et al. (2008) as the capability to diffuse knowledge within the company's boundaries. If the intra-organizational transfer capability is good, it will help the inter-organizational transfer capability (Mu et al., 2010; Minbaeva et al., 2010).

Based on the results in Study 1 (in Appendix I), Paper VI and Paper III, it appears that on an individual level, capability-raising activities are often connected to the blue-collar worker's knowledge. Their 'know-how', is often connected to complex operations such as final assembly. Madsen et al. (2008) emphasize the importance of investigating how to deal with the tacit dimension of production operations. The transferability of an activity can be linked to the properties of the knowledge- that is, whether it is tacit or explicit (Ferdows, 2006; Stock and Tatikonda, 2000, van Wijk et al., 2008). Final assembly is a typical activity that can be requested by the buyer in related offset to raise the capability of the local industry (Ahlström, 2000). Within final assembly at production of Gripen, the production rate and the level of automation are low. Typical work assignments are complex manual assembly, conducting inspections, and troubleshooting of units and systems. A team leader describes final assembly as:

> *"Final assembly can be described as a giant 3D puzzle built by several persons at the same time and all pieces are dependent on each other."*
>
> Team leader at Saab

This research confirms the theory about managing knowledge transfer including tacit knowledge, especially in manual assembly. Most of the blue-collar workers, in the studies had at least 10 years of experience, and they were able to manage unexpected challenges, trouble-shooting, and adjustments and to act upon intuition. Final assembly often entails a large amount of 'know-how' and tacit knowledge (Paper III). The success of transfer of tacit knowledge connected to final assembly is important for a successful production transfer. In several of the studied cases, after the transfer of the production, the receiver perceived the documentation as insufficient. However, the exact inadequacies were difficult to pinpoint. This difficulty was probably related to the Saab's blue-collar workers' advanced know-how and considerable amount of tacit knowledge (Paper VI).

7.1.2 RELATED OFFSET BUSINESS

The context of related offset adds difficulties that can require a different approach for technology transfer realization in comparison to, for example, outsourcing. There are several frameworks that describe how to carry out an outsourcing process, from initiation to conclusion (e.g., Fredriksson and Johansson, 2009; Franceschini et al., 2003; McIvor, 2000; Momme and Hvolby, 2002; Zeng, 2003). To be able to develop a structured process for related offsets, the specifics for related offset have been identified and are presented below.

THE PURPOSE OF RELATED OFFSET BUSINESS

The difference in focus between technology transfers within related offsets business and other types of technology transfers, such as outsourcing, can be explained by the fundamental purpose of offset business, that is, to enhance long-term economic development in the buying country (Ahlström, 2000; Axelson and Lundmark, 2009). For example, the main reason for the technology transfer to South Africa in Case B was to facilitate economic development in the receiving country (Paper I). Through technological development, the economic development can be improved (Sharif, 1986; Roessner et al., 1992). Within related offset business, the receiver of the technology transfer often is selected by the buyer. And, the buyer often selects the receiver based upon where and how economic development is desired i.e., the technology development requested (Paper I and Paper VI). The receivers of the technology transfer have different levels of experience: from novice to very experienced (Paper I and Paper VI). If the receivers are novice, the capability gaps will increase (see 7.1.1). Large capability gaps are common within related offset due to the difficulty to influence supplier/technology receiver selection (Paper VI).

SELLER'S FULFILMENT OF OFFSET OBLIGATIONS BEFORE CONTRACT TERMINATION

A specific situation for related offset business is that the seller has to fulfil its obligations of the related offset before termination of the contract. When the seller has fulfilled its obligations, the offset contract can be terminated. However, if the receiver is competitive as a supplier, the offset contract will be terminated, but the business deal can continue as an outsourcing arrangement (Paper I).

RELATED OFFSET BUSINESS INCLUDE HIERARCHICAL LEVELS

In Paper I, it was observed that within the realization of the related offset, it was difficult for the sending company to accomplish a fast and cost-efficient transfer. In an interview presented in Paper I, the Saab project manager who managed the transfer from BAE to Denel said:

> *"The purpose of the technology transfer was to improve the competence of the receiver; a risk was to underestimate the effort required."*
>
> Project manager at Saab

It could be noted that two different purposes of the related offset are described, and that they can be contractionary. First, people at the sending company working with the realization of the technology transfer consider fast and cost-efficient transfer as main purposes. Second, people involved in the related offset negotiation consider capability growth and strategic benefits as the main purposes. As a result, it was noted that the decisions taken in the negotiation of the offset agreement have large effects on the technology transfer realization carried out at the operational level within the sending and receiving companies. To decrease negative effects of this, the purpose of the related offset business must be understood by the people involved in the technology transfer realization.

An important result is that the negotiation and the realization of the offset agreement are on different hierarchical levels. Figure 7.3 illustrates that offset business includes hierarchical levels. The hierarchies are divided into three levels: National level, Company level 'commercial', and Company level 'operations'. The governments in the selling and buying countries represent the national level. The commercial level involves sales and marketing at a company. The operational level, involve the development and production of the sold product. In Paper I, the offset agreement was negotiated between the selling company at a commercial level and the buying government, see Figure 7.3. Within related offsets in general (outside this research), government-to-government negotiations exists as well. Within the realization of the offset agreement in Paper I, the realization of the offset agreement (i.e. the technology transfer) was from the sending company at an operational level to the receiving company, also at an operational level (Figure 7.3).

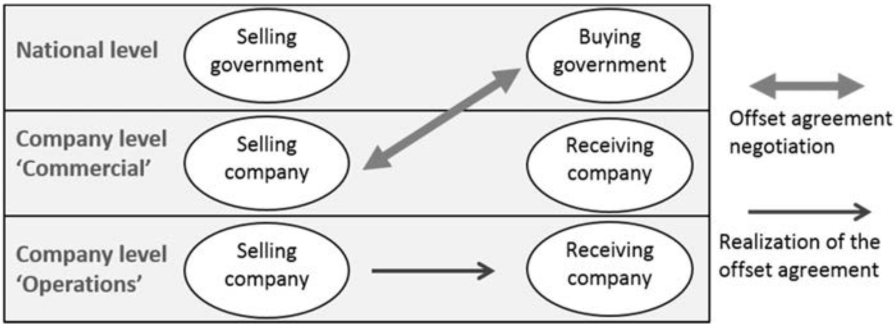

Figure 7.3: Different levels for offset negotiations of the offset agreement and realization of the offset agreement.

An observation is that in the hierarchical structure of the offset business, different agreements also are negotiated at different hierarchical levels. In Case B, the main offset agreement was established between Saab at a commercial level and at the level of the buying government (Figure 7.3). Then, sub-agreements were established between the parts involved in the offset. The structure of the sub-agreement varies from time to time. An example of a sub-agreement from Case B is the related offset agreement between Denel and Saab, both on a commercial level within the companies.

In agreement with Ahlström (2000) and Axelson and Lundmark (2009), Paper I observes that a related offset agreement also is long in duration. The process, extending from negotiation of the offset agreement to its realization, often takes up to ten years or more. This long horizon, in combination with the hierarchical structure visualized in Figure 7.3, makes it even harder for the people working in the realization phase to see the same purpose as the people in the early phases negotiated several years prior.

RELATED OFFSET WORK PACKAGE IDENTIFICATION TO MEET THE BUYER'S REQUEST

In Paper I, the contract negotiations followed the hierarchical structure described in Figure 7.3. The more strategic terms were negotiated early, before the main offset contract was signed between the seller (Saab) and the buyer (South Africa). The development of the work packages depended on the initial evaluation of possible receiver capabilities and what technology the buyer has requested. A work package includes products, processes, technologies or activities that is put together as an offer to meet the requests from the buyer. The work packages were identified by dividing the Gripen aircraft into possible modules suitable for transfer. Such modules have to match with the requests from the buyer. During the initiation of identifying the work package content, a negotiation of offset multipliers on a general level was included (Paper I). Within related offsets, a multiplier analysis is most often added to the cost calculation, the multiplier levels differ depending on the technology requested from the buyer (Paper I). If the buyer requests a specific technology, the multiplier will be high to express the importance and the value to the buyer. Negotiating with multipliers is unique and important for related offsets business (Jang et al., 2007; Kirchwehm, 2014). The buyer tends to focus on the value and the seller on the cost (Jang et al., 2007). Multipliers are further described in 3.1.1. The more operational terms in the main contract were negotiated after the offset multipliers were analyzed (Paper I).

ASSESSMENT OF THE RECEIVER IN TWO STEPS

Within related offsets, the assessment of the receiver follows the hierarchical structure in Figure 7.3. The assessment of the receiver is performed in two steps; the first is more general and the second as a gap analysis. The general assessment included a pre-screening of possible receivers of the technology transfer in the buying country (Paper I). The first assessment and the work included to identify work package to transfer were iterated to negotiate a solution that both the seller and the buyer were satisfied with. Then, the second assessment was performed through a gap analysis to prepare for the realization of the transfer. The gap analysis aims to compare the receiver's capabilities to the sender's (Saab) capabilities, not to identify the most suitable receiver. The assessment criteria in the gap analysis were based on the identified work packages to transfer (Paper I). The capability gap assessment provides in-put for the sender to structure and plan the realization of the capability growth at the receiver.

7.1.3 CONTEXTUAL DIFFERENCES

The contextual differences can include for example: type of relationship, type of communication, and type of culture (Argote et al., 2003; Szulanski, 1996; van Wijk et al., 2008; Cummings and Teng, 2003). Not all of these examples have been studied in this research. In study 1, cultural and communication challenges was identified as an important factor to in the research context, see Appendix I.

CULTURAL AND COMMUNICATION CHALLENGES

At Saab, several transfer projects have undergone delays due to misunderstandings that stemmed from cultural and communication issues (Paper II). However, these challenges differed in form between the cases, presumably because the receiving countries differed (Paper VI). Saab is located in Sweden, a relatively small country with a strongly defined culture. An important aspect highlighted in Paper II is that the cultural challenges were viewed from a Swedish perspective. Gesteland (1999) emphasizes that in international business, the seller is expected to adapt to the buyer, and that the visitor is expected to observe local customs (Gesteland, 1999). Nguyen and Nguyen (2015) add that it is important to be aware of the effects of differences in cultural values and to apply appropriate interfaces to decrease cultural differences.

Paper VI note that cultural challenges are not new notions, and scholars such as Hofstede and Hofstede (2005), Lewis (2006), and Najafbagy (2008) have reported on challenges caused by cultural differences during technology transfers. It was observed in Paper VI that culture differences in technology transfer realizations in related offset are enhanced by difficulties to influence supplier/receiver selection (the receiving company will be the supplier when producing parts to the aircraft). For example, in Case B, the South African government wanted to offer employment opportunities to historically disadvantaged citizens. This preference meant that Saab encountered major cultural, language and capability differences because of these citizens' lower education levels due to, historical oppression.

Paper II explored challenges linked to cross-cultural communication when conducting international aircraft production transfer. Saab was observed to have a non-hierarchical decision process, involving much consensus, and the learning often acts across hierarchies (Paper II). This can be explained by Saab's horizontal organization and by the low power distance in Swedish culture (Hofstede and Hofstede, 2005). In more hierarchical organizations in cultures with greater power distance (Hofstede and Hofstede, 2005), the communication initiative is more often one-way and top-down. Such communication differences are essential when communicating between different cultures. When Saab initiates communication at a non-accepted "wrong" level, the recipient may feel the Saab project managers 'losing face' by exposing their ignorance to project members from a lower hierarchical level.

7.1.4 CONCLUSION

The first research question identified the factors that can have a major effect on the technology transfer realization within related offset in within aircraft production. These are presented in the bullet list below.

- The activities to be transferred
    - Capability gaps
    - Knowledge transfer.
- Related offset business
    - The purpose of related offset business
    - Seller's fulfilment of offset obligations before contract termination
    - Related offset business include hierarchical levels
    - Related offset work package identification to meet the buyer's request
    - Assessment of the receiver in two steps.
- Contextual differences
    - Cultural and communication challenges.

7.2 How to manage future related offset technology transfer realizations

RQ1 identified factors that can have a major effect on the technology transfer realization within related offset in connection to aircraft production, see 7.1.4. These factors set the basis for RQ2. The focus in RQ2 is on how to manage the prerequisites that related offset business provide, and how to manage capability gaps between sender and receiver where there are cultural and communication challenges.

RQ2: How can future related offset technology transfer realizations connected to aircraft production be managed?

7.2.1 Structured related offset process

To manage future technology transfer within related offsets, it is important to have a process to guide the way through the necessary activities. A structured related offset process is needed in order to manage the related offset business prerequisites identified in 7.1.2. In Paper I, a structured related offset process was developed; an overview of that process is illustrated in Figure 7.4. The process includes eight phases, and the hierarchical structure of the related offset business is emphasised by dividing the phases into two hierarchical levels. The two levels are 'related offset negotiation' and 'related offset realization'. The first three phases of the process take place on the 'related offset negotiation' level. Phases 4 to 7 are performed within the 'related offset realization' level. Finally, phase 8, the contract termination, can occur at both levels, see Figure 7.4.

The strategic decisions taken in the negotiation phases 1 to 3, shown in Figure 7.4, have large effects on the realization phases, phases 4 to 7, where the operational decisions are taken by the sending and receiving companies. Thus, the decisions taken in the negotiation phases of the offset business need to be clearly communicated to personnel of the sending and the receiving company involved in the realization phases.

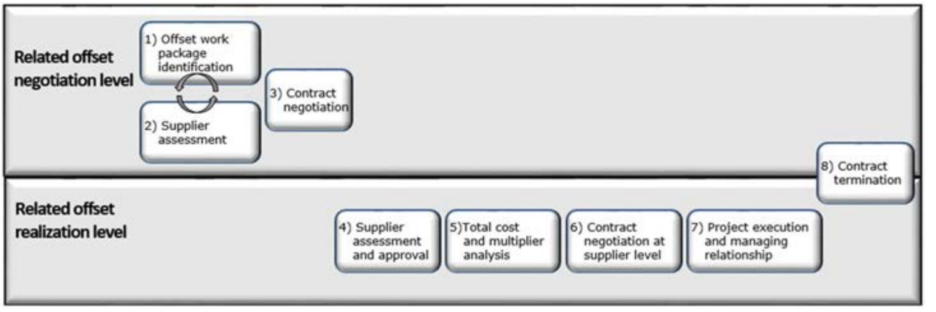

Figure 7.4: A hierarchical overview of the phases in the suggested structured related offset process.

The structured related offset process, presented in Figure 7.4 is described in more detail in Table 7.1, which include activities for each phase. The structured related offset process is a further development of an outsourcing process outlined by Fredriksson and Johansson (2009). Outsourcing and offset can be seen as business actions that share some common attributes: both imply shifting the location of activities from one part to another, and they include similar decisions, challenges, and solutions. Differences between outsourcing and related offset business are presented in 7.1.1. These differences were translated into activities, which are noted in italics in Table 7.1. For the original outsourcing process, see appended Paper I.

Multipliers are often applied within related offsets when defining the offset work packages. By applying multipliers, the buyers can control what they want the seller to propose (Kirchwehm 2014; Wessner and Wolff, 1997). Multiplier negotiation is added in phase 1, and multiplier analysis is added in Phase 5; for these phases compared to the original outsourcing process, see Table 7.1. The aim of the first phase of the studied related offset process was to define the work packages. Hence, phase 1 was renamed 'offset work package identification', see Table 7.1. The output of phase 1 should be included in the supplier/receiver assessment criteria used in phase 2 'supplier/receiver assessment'. In the structured related offset process, these two phases are iterated, see Table 7.1.

In Case B, which is included in Paper I, the receiver had already been selected in the negotiation phase of the offset contract at a governmental level. This in itself is not a novel discovery (Axelsson and Lundmark, 2009). However, this divides the supplier/receiver assessment into two phases in the structured related offset process, phases 2 and 4 in Table 7.1. In Table 7.1, the receiver of the technology transfer is referred to as 'supplier' as the receiver of the technology is the company that will act as a supplier in production of the aircraft. In phase 2, the supplier/receiver assessment is at a more general level, based on the buyer's requirements in the offset contract. A second assessment, phase 4, is performed on an organizational level (Paper I). Readiness for technology transfer within Saab on the organizational level (i.e., disseminative capacity) was identified as an important parameter (Paper VI). To allow readiness within the sending organization, there is a need to thoroughly assess the receiver to identify what needs to be adapted, and to what extent, through a gap analysis. The gap analysis aims to compare the receiver's capabilities to Saab's capabilities (Paper I). When assessing the receiving unit, an important part is to include the cultural and language differences (Paper VI).

Within the structured related offset process, the contract negotiation is divided into two phases, 3 and 6, shown in Table 7.1. Phase 3 includes defining legal/commercial terms and conditions as well as the offset multipliers. Phase 6 involves contract negotiation at a supplier/receiver level (discussed in Paper I). In a related offset, the assessed capability of the supplier/receiver (phase 4) affects the relationship with the supplier/receiver. According to the focus group described in Paper I, a large capability gap leads to a closer relationship with the supplier/receiver. Subsequently, the 'project execution' and 'managing relationship' will be conducted in parallel as phase 7. It is important within phase 7 to identify continuous improvement opportunities in order to close the assessed gaps from phase 4. Finally, in related offset, the seller must fulfil its part of the offset contract before the contract between seller and supplier/receiver can be terminated (in phase 8).

Table 7.1: A suggested structured related offset process, based on an outsourcing process. The differences are italicized.

Phase 1: *Offset work package identification*

- Strategic analysis
- Defining core activities
- Activity stratification based on evaluating the relationship between production activities and/or products involved
- Identifying possible types of relationship with supplier/receiver
- *Cost estimation and multiplier negotiation*

Phase 2: Supplier assessment

- Defining critical assessment and supplier/receiver selection criteria
- Pre-screening
- Supplier/receiver assessment *at a general level*

Iteration of phases 1 and 2

Phase 3: *Contract negotiation*

- Defining legal/commercial terms and conditions

Phase 4: *Supplier assessment and approval*

- Supplier/receiver assessment *and gap analysis*

Phase 5: *Total cost and multiplier analysis*

- Estimating the costs of conducting the activity internally
- Estimating the costs associated with potential suppliers/receivers
- *Multiplier analysis*

Phase 6: *Contract negotiation at supplier level*

- Reaching agreement on supply and logistics terms
- Determining mutual commitments

Phase 7: *Project execution and managing relationship*

- Establishing team, strategy, and schedule
- Establishing basis for supplier/receiver integration
- Adapting organization to supplier/receiver performance
- Establishing communication, information, and monitoring systems
- *Identifying continuous improvement opportunities in order to close assessed gap*
- Continuous performance assessment

Phase 8: Contract termination

- Assessing the alternatives of prolonging relationship, replacing supplier, or insourcing
- Establishing basis for reviewing core competence strategy
- *The seller has fulfilled its part of the offset contract before termination*

7.2.2 How to manage capability gaps

In this chapter, the factors identified in 7.1.1 and 7.1.3: capability gaps, knowledge transfer, and cultural and communication challenges, set the base when presenting the results of how to manage assessed capability gaps between sender and receiver. As stated in chapter 7.1.1, the ability to manage capability gaps between the sender and the receiver is an essential part of an effective technology transfer. This is in agreement with Lyles and Salk (1996), Salomon and Martin (2008), and Galbraith (1990). When there are large capability gaps within technology transfers, the success of the knowledge transfer between the sender and the receiver is important (Paper VI). In Case B, Saab underestimated the effort needed to both assess the capability gaps and to manage these assessed gaps.

In Paper VI based on all industrial cases, a model to identify and manage capability gaps in a structured way, was developed, see Figure 7.5. The left side of Figure 7.5 focuses on capability assessments at both the individual and the organizational level. The assessment should include both the receiver's and the sender's capabilities. In the centre of Figure 7.5, the capability gap is identified based on the capability assessment and a STTP (Skills and Technology Transfer Program). The right side of Figure 7.5 focuses on how to manage the assessed capability gaps. As Paper VI notes, capability gaps between sender and receiver exists on both an organizational and an individual level. Both the organization and the employees must have the competence and the capability to produce the product. Facilitating tools described to bridge capability gaps in the right side of Figure 7.5 include Saab's industrialization process, Personal Development Plans (PDP), and On-the-Job Training (OJT).

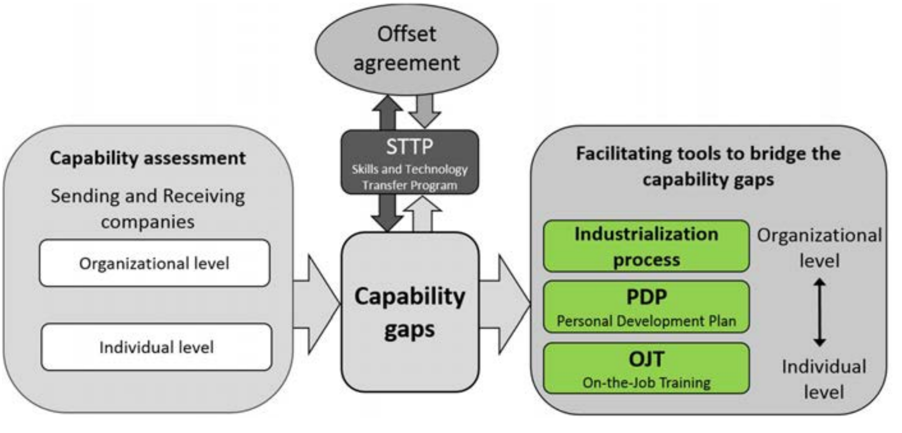

Figure 7.5: Model for bridging the capability gap between sending and receiving companies (developed in Paper VI).

STTP (Skills and Technology Transfer Program)

The Skills and Technology Transfer Program (STTP) can be described as a learning program at an organizational level, see the centre of Figure 7.5. The STTP is based on the offset agreement and the assessed capability gap. The STTP is a link between the PDP (Personal Development Plan) and the offset agreement. In Case B, Saab was the responsible part for developing the STTP. Then, the STTP was developed in cooperation with the buyer in order to meet the requests in the offset agreement.

Industrialisation process

At Saab, the industrialization process occurs in the interface between product development and manufacturing. The output of the industrialization process at Saab is intended to provide the production unit with the ability to deliver ordered products on time, at the requested quality, and at the agreed-upon cost. This process is more thoroughly described in Paper I and in Case A. In Case A, the industrialization process is applied within Saabs product realization process. In Paper VI, it is suggested that Saab's industrialization process should be repeated at the receiving company during the technology transfer realization. The focus should be on how to adapt the receiver's manufacturing system to reduce capability gaps between the sending and the receiving companies on an organizational level. The assessed capability gap sets the baseline for what the industrialization process should focus on. In Paper VI, it was identified that the industrialization process could be used to increase the sender's disseminative capacity, and the receiver's absorptive capacity at an organizational level. In Paper VI, the disseminative capacity of the sender refers to the ability to assess the capability gap between the sender and receiver, and to convert this assessment to adaptations of production system. The receiver's absorptive capacity constitutes of the ability to recognize, assimilate and use that knowledge (Paper VI).

PDP (Personal Development Plan)

The PDP (Personal Development Plan) include detailed plans and schedules at an individual level – in other words, an individual training plan. The PDPs' content is based on the STTP and the assessed capability gaps. Hence, it was possible to adapt the PDP to fit the individual needs of the receiver's employees. In Case B, the PDPs were developed when personnel from the receiver (Denel) in South Africa were sent to Saab in order to learn from Swedish employees. This involved employees from all levels in the organization, from blue-collar workers to engineers. This way of working was noted as successful in Paper VI. The learning programs (STTP and PDPs) was applied on both an organization and an individual level connected both to the offset agreement and to the assessed capability gaps. In Paper VI, it was noted as important to negotiate the content of the learning programs, already during the negotiation of the offset agreement. It is during the negotiation the different technologies divided into work packages are identified. If the learning programs is jointly developed, such as in Case B, it can increase the implementation success.

OJT (On-the-Job Training) and cultural differences

There are several tools to facilitate transfer of knowledge in an aircraft production environment, one of which is mentor-novice training. Mentor-novice training is a type of peer-to-peer training. At Saab, mentor-novice training is called On-the-Job Training (OJT). The detailed differences between peer-to-peer training, mentor-novice training, and OJT will not be discussed further. In Paper VI, OJT was identified as a tool to manage capability gaps at an individual level, see Figure 7.5. At Saab, OJT is a part of blue-collar workers' training. A more experienced blue-collar worker acts as a mentor for new employees with the goal to transfer the tacit knowledge related to production. Madsen (2009) has created a "Knowledge conversion and development through a transfer" model inspired by the "four modes of knowledge conversions" model of Nonaka & Takeuchi (1995). The Madsen model identifies how to convert knowledge, and as expected is the most challenging area to transfer tacit knowledge. The PDPs are more focused on explicit-to-explicit knowledge conversion, whereas the OJT is focused on tacit-to-tacit knowledge conversion (Madsen, 2006; Nonaka and Takeuchi, 1995). The results in Paper III show that one specific method is not enough to exchange or transfer tacit knowledge. It is important to work with different approaches and combine them, in order to have the best possible exchange of knowledge, involving both explicit and tacit knowledge.

An important part of OJT is the interaction between the mentor and the novice. At Saab, the focus is placed on exchange of knowledge; interaction between mentor and novice will probably generate more effective knowledge building between the employees at the sending and the receiving companies. In Paper III, the difference in exchange and transfer of knowledge is emphasized, as shown in Figure 7.6. To capture and exchange tacit knowledge, there is a need to communicate. Both the sender and the receiver must be able to communicate, and the receiver of information may respond. A two-way communication illustrated in the left side of Figure 7.6 enables knowledge exchange. If knowledge is transferred with only one-way communication (the right side of Figure 7.6), it is harder to capture tacit knowledge.

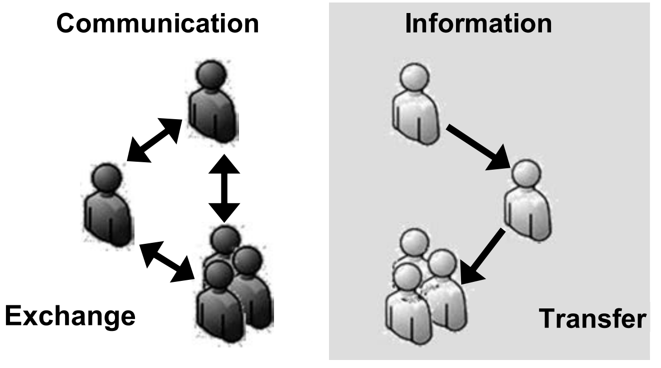

Figure 7.6: The difference between communication (exchange) and information (transfer) of knowledge, from Paper III.

In agreement with Madsen (2009), this research indicates the need to consider how to use mentor-novice training. Paper VI notes that, by connecting the OJT to a "Personal Development Plan" (PDP), more structure was provided. PDPs and OJT are suggested to increase the sender's disseminative capacity and the receiver's absorptive capacity at an individual level (as discussed in Paper VI).

A risk with OJT observed at Saab is that bad habits are transferred to the new context. Below is a citation from a production engineer at final assembly in Gripen production.

> *"A large challenge today is that people are habit-driven. When they find a way of working, it will follow them through life. To change habits is a challenge. Often, a behaviour is taught, not the cause and effect. In the beginning, they learn by trial and error, and found alternative ways to perform the assembly. This can evolve to non-value adding activities that can exist for long time. It is hard to change something that is developed through experience and not documented in the production documentation. "*
>
> Production engineer, Gripen fighter final assembly

Such habits can be both good and bad; some knowledge is priceless and hard to reproduce. However, some knowledge can involve extra operations or unnecessary work.

In a transfer context, it is important to physically perform the OJT at the sending company, since the OJT becomes a part of a social network (Paper III). Working with social networks in a transfer context can help bridge the cultural differences (Paper VI). By deliberately placing individuals from the sending and the receiving companies in a work context that involve cultural differences, the awareness will increase. Moreover, this can be a means to alleviate differences, in accordance with Najafbagy (2008). Paper II investigates cultural and communication differences; compilation of empirical data indicated that many cultural differences that emerged could be divided into three main categories:

- Organisational structure, hierarchy, and delegation of responsibility;
- Consensus behaviour and avoidance of conflicts;
- Individual motivation factors.

These results matched the theory well, according to both Lewis (2006) and Hofstede and Hofstede (2005). For industries in small countries, with a strongly defined culture, such as Sweden, the employees have to be able to adapt to operate in other cultures. It is important to carefully select and train the employees that will work in close cooperation with people from other cultures. For example, managers, who are highly respected in their home country, may have difficulty achieving success in other cultures. Successful managers in countries with low power distance (Hofstede and Hofstede, 2005), such as Sweden, are masters of delegation and communication. If these managers lead operations in countries with high power distance, which often appreciate distinct leaders with authority, the Swedish managers will most likely fail.

Many cultural challenges could have been more easily understood and handled if both teams had undergone more cultural training (Paper II). Many projects at Saab involve cultural training in the form of practical information conveyed: by internet, lectures, seminars and so forth. Some projects have workshops, the main objective of the workshops was to open the consciousness for future cultural challenges. The teams appreciated this type of training; the atmosphere got more personal and comfortable. The results are hard to measure, but some cultural differences were resolved and already discussed during the workshops. It is essential for Saab to organize suitable types of cultural training and to adjust the training to match the culture within the sender and recipient countries. Cross-cultural training can lead to higher efficiency within organizations and shorter adjustment time for individuals placed at the receiving company.

PRODUCTION DOCUMENTATION IN 3D

At Saab, the discrepancies between design drawings and production documentation created a large challenge in transfer of production (see Study 1 in Appendix I). In Paper IV, Model Based Definition (MBD) has been identified as a tool to work with the discrepancies. MBD is a way of managing engineering and business processes using computer based 3D models as sources of information for design, production, distribution, technical documentation, services and the overall product life cycle (Alemanni et al., 2011; Nestor and Unroth, 2013).

With MBD, the 3D model can be combined with Product and Manufacturing Information (PMI) (Lokay, 2016). At Saab, the 3D models applied in MBD communicates the Product and Manufacturing Information (PMI), including data such as geometric dimensions and tolerances and 3D annotation. When MBD is applied throughout production, the sender and the receiver see the same information in the 3D model (Quintana et al, 2010). At Saab, MBD manage and structure the Product and Manufacturing Information (PMI). At Saab the PMI in 3D, is referred to as 'production documentation in 3D', and that wording is henceforth applied here. In Case A, it was observed at Saab, that production documentation in 3D enables better possibilities to improve the 2D work instructions, especially through better visualisation.

The implementation of MBD at Saab is described in Paper V. Before MBD was introduced, the production documentation was produced outside the design documentation, thus "invisible" to the design engineers. Reports were then filed in binders and regulations, while requirements and analysis documentation were saved on paper. The drawing kit compiled for the Gripen fighter consisted of ~10,000 paper drawings and ~50,000 production documents (Paper III). When MBD was implemented at Saab, teams were set to work with improvements of the production documentation before the conversion to 3D (Paper III). The role models for the visualisation of the production documentation in 3D were IKEA and LEGO. IKEA and LEGO, both apply non-text based instructions.

In Paper III, production documentation in 3D was identified as a tool at Saab, to transfer both tacit and explicit knowledge between individuals. In Paper V, it was noted that it was easier for the blue-collar workers to view the production documentation in 3D, the model provide a realistic view of the designs. With 3D production documentation, the blue-collar workers are able to see the article or product virtually before it is physically manufactured; no prototypes are needed (Paper III and Paper IV).

Production documentation in 3D provides greater possibilities for training in simulated situations, and increases the possibilities of differentiating off-line learning from on-line learning (Paper III and Paper IV). On-line (double-crew) learning takes place while the production is in operation, whereas off-line learning takes place separately from the operation of manufacturing equipment (Madsen, 2009). This saves cost since the operational time in the production will increase. Off-line training can increase the quality of the product. It is possible to train virtually, and reduce beginners' mistakes. The off-line training can be performed whether a new product is launched or an existing product is updated in a new version (Paper IV).

3D production documentation are not included in Figure 7.5, this facilitating tool were identified in Paper IV, and Figure 7.5 was developed in Paper VI. In Figure 7.7, 3D production documentation is added as a facilitating tool to bridge capability gap on an individual level.

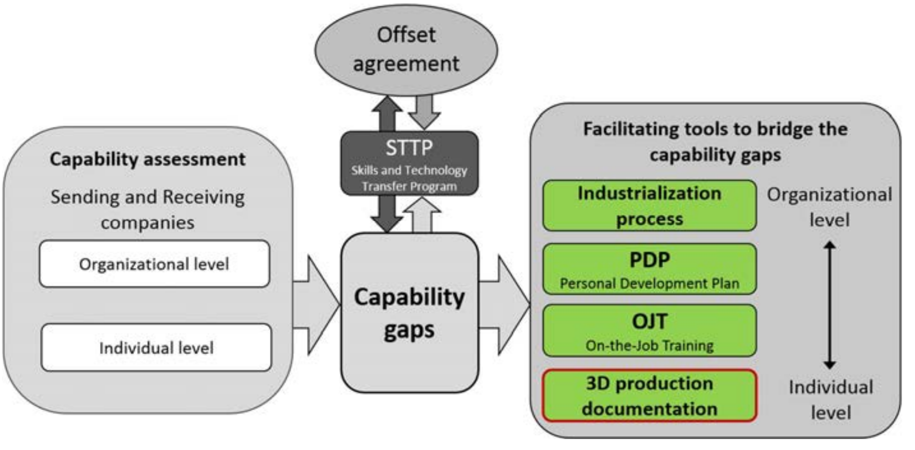

Figure 7.7: 3D production documentation is added as a facilitating tool to bridge capability gap.

7.2.3 CONCLUSION

To answer the second research question, tools for facilitating future related offset technology transfer connected to aircraft production were developed.

In 7.2.1 a structured related offset process including activities, starting from negotiation to realization and contract termination was presented, see Table 7.1. The structured related offset process covers two different hierarchical levels: 'related offset negotiation level', and 'related offset realization level', as seen in Figure 7.4.

In 7.2.2, a model for bridging capability gaps between the sending and the receiving companies was presented, see Figure 7.7. Furthermore, tools facilitating the management of capability gaps between the sending and the receiving company were presented. These tools were:

- Skills and Technology Transfer Program (STTP)
- Industrialization process
- Personal Development Plan (PDP)
- On-the-Job Training (OJT)
- Production documentation in 3D.

8 DISCUSSION

In this chapter, the research contributions are discussed, including how the research objective was fulfilled through answering the research questions. Finally, directions for future research are discussed.

8.1 DISCUSSION OF THE RESEARCH CONTRIBUTIONS

The research objective for this thesis is: *'To extend the current understanding of technology transfer realization connected to related offset within the defence aircraft industry'*. The research objective has been fulfilled through addressing two research questions. The first question aimed to identify factors that can have a major effect on technology transfer realization in the research context. The second research question has a more normative approach, seeking facilitation tools to manage future related offset technology transfer realization connected to aircraft production.

RQ1: What factors can have a major effect on the realization of technology transfer within related offset connected to aircraft production?

As an answer to the first research question, the following factors were identified as having a major effect on the technology transfer realization within related offset connected to aircraft production:

- The activities to be transferred
  - Capability gaps
  - Knowledge transfer.
- Related offset business
  - The purpose of related offset business
  - Seller's fulfilment of offset obligations before contract termination
  - Related offset business include hierarchical levels
  - Related offset work package identification to meet the buyer's request
  - Assessment of the receiver in two steps.
- Contextual differences
  - Cultural and communication challenges.

Capability gaps within related offset are often large (Paper VI). Within this thesis 'capability gaps', is a factor of major importance. This is in line with earlier research that states that an essential part of an effective technology transfer is to bridge the capability gaps between the sender and the receiver (e.g., Lyles and Salk, 1996; Salomon and Martin, 2008; Galbraith, 1990). A successful knowledge transfer between the sender and the receiver is important in order to reduce capability gaps within related offsets (Paper VI). Knowledge transfers in other contexts have been extensively researched by amongst other: Argote et al. (2003), Easterby-Smith et al. (2008), Ferdows (2006), Madsen (2009), Minbaeva (2007), van Wijk et al. (2008), Tang et al. (2010), Szulanski (1996). Within the thesis, 'knowledge transfer' is identified as a factor that have a major effect on the realization of technology transfer. This research show that knowledge transfer is important to focus on within the realization of technology transfers, also within related offset.

The identification and the exploration of the factor "The purpose of related offset business", is a research contribution. This factor highlights the effects from related offset on the realization of the technology transfer. Earlier research by Eriksson (2007), Hoyt (2011), Mitra (2009), and Kirchwehm (2014) investigated the offset phenomenon at a general level; these studies covered the purpose, and results of offsets on a national level. However, their focus was not on the realization of the transfer. In the research, one effect of the 'The purpose of related offset business', was identified as an important factor, namely 'Seller's fulfilment of offset obligations before contract termination'. Due to the specific nature of the related offset business, this factor has not been consider in earlier research within other areas.

In 7.1.2, "Related offset business include hierarchical levels", was identified as a factor. The studied related offset business in Case B, have included three hierarchical levels during the offset agreement negotiation and during the realization of the offset agreement. The hierarchical levels are visualised in Figure 7.3. The hierarchical levels are: National level, Company level 'commercial', and Company level 'operations'. For example, Axelson and Lundmark (2009) and Jang et al. (2007) has noted that offsets are long-term industrial commitments. Kirchwehm (2014) added that, as an effect of these long-term commitments, the seller would often establish partnerships within the buying country on a national level and cooperate closely with domestic suppliers on a company level. This thesis contributes to knowledge by showing the effects of these hierarchical levels on the realization of the technology transfer. The identified factors 'Related offset work package identification to meet the buyer's request' and 'Assessment of the receiver in two steps' are in this thesis highlighted as important effects of the identified hierarchical levels in related offset business. Due to the specific nature of the related offset business, these factors have not been consider in earlier research within other areas.

Paper VI note that other researchers such as Hofstede and Hofstede (2005), Lewis (2006), have highlighted cultural challenges and Najafbagy (2008). However, it was noted in Paper VI that the identified factor 'cultural and communication challenges' in technology transfer realizations are enhanced by the difficulties to influence receiver selection in related offset businesses.

It was not possible in this thesis to identify all factors that can have an effect on the technology transfer. The focus in this research was on factors that in the performed studies were identified to have a major effect on the realization of a technology transfer. Depending on the research context, the effect of different factors can vary. This can partly be explained by the uniqueness of offset agreements. They differ from time to time depending on requests from the buyer. And, the public policies of individual countries can have an effect as well. The differences in requests can be exemplified by two separate related offset businesses connected to Saab. In studied Case B, the requests in the related offset agreement between Saab and South Africa included a request for employment opportunities for historically disadvantaged inhabitants in selected geographical areas. In the related offset agreement between Saab and Brazil, the main aim was to train Brazil's advanced aircraft industry so that it would eventually be able to maintain its own fleet of Gripen aircraft and develop its own technology. Based on content of these requests, the factors having a major effect on the technology transfer realization varies depending on the specific offset.

RQ2: How can future related offset technology transfer realizations connected to aircraft production be managed?

To fulfil the research objective and to answer the second research question, this thesis tried to grasp the technology transfer within a related offset business from beginning to end. Related offset business was studied from the point of initiation and negotiation to technology transfer realization and contract termination. This research contributes with its focus on related offset and by extending the understanding of related offsets through the studied in-depth industrial cases. Grandetti et al. (2009) noted that few authors have studied related offsets in depth. A major reason for this lack of studies is that offsets are surrounded with much secrecy. As a consequence, there is little access to data. Furthermore, much of the earlier research did not differentiate offset from countertrade, or offset from related offset (Stephen, 2014; Nassimbeni et al., 2014).

In 2014, Nassimbeni et al. emphasized that industrial implications and industry specific research still are lacking within related offset research. To fill part of the gap noted by Nassimbeni (2014), and to help the industry manage the prerequisites that related offset business provide, a structured related offset process is presented in 7.2.1. This structured process contributes to the management of future related offset technology transfer connected to aircraft production. The structured related offset process includes activities, starting from negotiation to realization and contract termination and thereby provides a thorough guideline of how companies should act in order to improve the efficiency of technology transfer in related offset. This research has also identified that a related offset business includes activities at different hierarchical levels. In the developed structured related offset process, the included phases are divided into two hierarchical levels: a 'related offset negotiation' level and a 'related offset realization' level, as shown in Figure 7.4. To manage future related offset technology transfer realizations, the hierarchical structure of a related offset business must be taken into consideration.

Within related offset, the assessment in the realization phase should focus on the capability gap between the sender and the receiver. And the assessment criteria should be based upon the activities to transfer. Among others, Grant and Gregory (1997) and Minshall (1999) have suggested that a process approach should be used in order to deal with capability gaps in technology transfers. However, the processes that these authors have suggested have a focus on the adaption of production processes to fit with the receiver's capability, and identification of suitable processes for transfer after a receiver is selected based on performance. The assessment tools by, for example Grant and Gregory (1997), often will not be applicable within related offsets. Within related offsets, the production processes should not always be adapted to fit with the receiver's capability. As the receiver is often selected based on the requests in the offset agreement and the goal is to increase its capability. Because of this inability to use earlier developed processes to deal with capability gaps within related offsets, the developed structured related offset process presented in this thesis is needed. In conclusion, the research contribution finds that a related offset process needs to focus on how to assess and overcome capability gaps between the sender and the receiver.

In 7.2.2, facilitation tools to manage capability gaps between the sending and the receiving company are presented. Figure 8.1 shows how the various suggested tools to facilitate management of capability gaps are applied at the different hierarchical levels: National, Company and Individual level. The Skills and Technology Transfer Program (STTP) is a learning program at the company level, linked to the national level through the offset agreement. The industrialization process was suggested as a mean to increase the receiver's absorptive capacity and the sender's disseminative capacity at a company level. A Personal Development Plan (PDP) is a learning program at an individual level, linked to the STTP. On-the-Job Training (OJT) is peer-to-peer training between individuals; it is structured through the PDP.

Finally, 3D production documentation was identified as a facilitating tool for knowledge transfer for the blue-collar workers on the shop floor (Paper III).

Jointly well-planned learning programs (STTP and PDP) can lead to a more structured On-the-job Training (OJT). A structured OJT can be seen as a mean to assure that the requested knowledge (from the negotiated agreement) is framed and exchanged. Jointly developed learning programs, such as in Case B and described in Paper I, can increase the implementation success of the learning programs, as noted by Knudsen and Madsen (2014). In addition, by applying such learning programs and steering the location of the OJT, cultural differences can be bridged (Paper VI). This research contributes by showing the benefits of a structured OJT (On-the-Job Training).

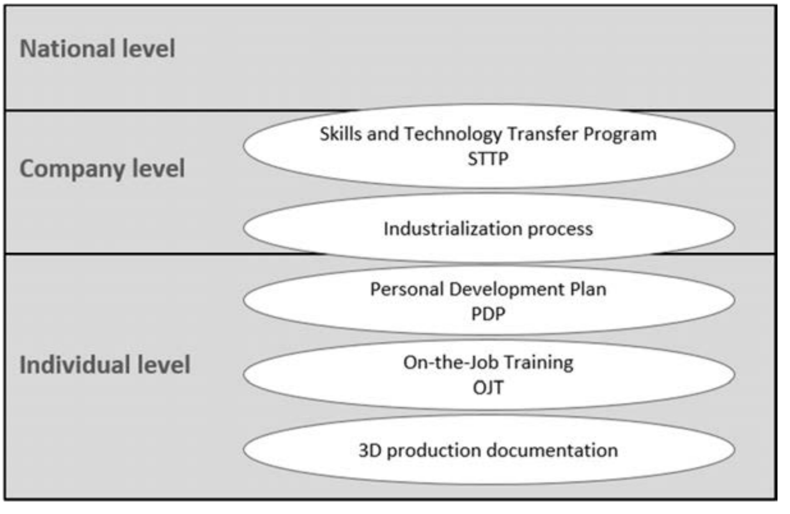

Figure 8.1: Suggested tools to facilitate management of capability gaps between a sending and a receiving company, presented at a national level, company level and individual level.

The hierarchical structure of the suggested facilitation tools to manage capability gaps are shown in Figure 8.1. This structure, in combination with the activities in the structured related offset process (7.2.1), contributes to a structured realization of the technology transfer. An important purpose in structuring the technology transfer realization is to facilitate the creation and maintaining of a link between the negotiated related offset agreement and the level of employees working with the realization of the agreement.

8.2 FUTURE RESEARCH

This thesis is primarily based on in-depth case studies from one company in the aircraft industry. The aircraft industry is a specific context; however, offset business is not exclusive to the aircraft industry. Offset business is relatively common wherever there are large contracts involving technically advanced products or systems, the buyer is under governmental control, and where there are few potential buyers and sellers. For example, offset business is a part, in some form, of practically every large international agreement in defence-related industries (Ahlström, 2000). Therefore, to generate results that are more generalizable it is necessary to conduct studies of technology transfer realization in other contexts. It is also necessary to validate the developed structured related offset process and the identified facilitating tools to reduce capability gaps within related offset business. This can be done through applications in the industry, for example by applying new case studies.

Within related offset, the assessment of the receiver should focus on the capability gap between the sender and the receiver. The assessment criteria must be based upon the capability needed to produce or develop the work packages that are to be transferred. The main focus in this research has been on how to manage the already assessed capability gaps. Therefore, to increase the probability for success in technology transfer realization, research efforts should be directed to how to perform the actual assessment of the capability gaps.

The production processes within Saab vary greatly in types of knowledge required; knowledge can be explicit as well as tacit. The amount of tacitness, especially related to 'know-how' is associated with experienced personnel in combination with complex manual operations such as final assembly. The amount of tacit knowledge can sometimes be reduced by transferring tacit knowledge in to explicit knowledge by different means. However, the amount of tacit knowledge in final assembly is challenging to reduce, since a lot of such work consist of many complex and advanced manual operations. These operations are associated with a lot of craftsmanship and tacit knowledge. Research is needed to investigate to what degree means such as Model Based Definiiton (MBD) can be tools to reduce the need for craft in production, which could then reduce the amount of tacit knowledge needed.

It is important to reduce costs, related both to time and to quality, by improving learning curves for the blue-collar workers. Within technology transfers, efficient learning, training, guidance and quality assurance in assembly are needed. Augmented Reality (AR) and Virtual Reality (VR) can provide prerequisites for gaming and simulations. At Saab, AR and VR are viewed as future tools to transfer know-how on the shop floor. Research is required to study if tools, such as AR and VR, could improve the learning and to lessen the number of non-value-adding tasks.

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10 APPENDIX I

A complete description of the risk analysis, the mapping and the literature study are included in Appendix I. Appendix I is a part of the earlier published Licentiate thesis by the author (Malm, 2013).

Appendix I

1 IDENTIFYING IMPORTANT FACTORS IN TRANSFER OF AIRCRAFT PRODUCTION

The empirical result presents the setting for the case study and an investigation including three parts: mapping of Aeronautics production processes, a risk analysis, and a literature study. The risk analysis was performed at Aeronautics to investigate where the largest risks are within transfer of production. The production processes at Aeronautics were mapped to locate challenging factors and a literature study was performed to see where the challenges lie within the theory.

1.1 PRODUCTION PROCESSES MAPPED AT AERONAUTICS

Aeronautics production processes are mapped with vocabulary according to Groover (2008). The result from the mapping of production processes will provide with important factors in the transfer of aircraft production. Aeronautics has two main manufacturing processes; assembly and parts manufacture. Assembly consists of sub-assembly (tube and welding, and harness and panel), structure assembly and final assembly. Parts manufacture consists of bonded parts (composite), sheet metal parts, and machined parts. Support processes are comprised of surface treatment, including painting. All these processes are illustrated in the flow chart in Figure 1.

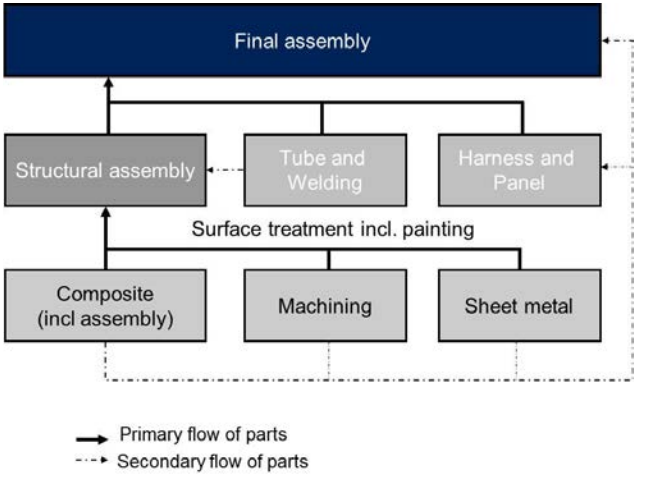

Figure 1: A flow chart of the production processes at Aeronautics

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Simplified, all manufacturing processes at Aeronautics follow the same main process as illustrated in Figure 2. The first step, “plan and order”, monitors incoming material and part deliveries in the resource planning system, and orders the start of the manufacturing process. The second step, “manufacture”, is the one that will be mapped; it is where the actual manufacturing takes place. The purpose of the third step, “receive and handle material”, is to receive, administrate and distribute purchased and manufactured goods.

Figure 2: General manufacturing process at Aeronautics

The manufacturing processes are further on mapped according to Groover’s (2008) vocabulary.

1.1.1 PARTS MANUFACTURE

Parts manufacture at Aeronautics consists of bonded parts, sheet metal parts, and machined parts.

BONDED PARTS

Approximately 20% of the total structural weight in Gripen aircraft is composite. The manufacturing consists of monolithic parts and honeycomb sandwich parts. The pre-impregnated materials used are carbon fabric, carbon tape and aramid fabric, while the honeycombs are aluminum and plastic (Nomex, Syncore) cored.

Machinery used includes material cutting machines, autoclaves, NC machining, ultra-sonic and X-ray equipment, laser projection lay-up tools and an Automatic Tape Layer Machine (ATLM), as seen in Figure 3. The ATLM is fully automated, and it is complemented with human surveillance. Many of the other machines are semi-automated. However, even though some automation is mentioned, the main part of the work is performed manually. Composite manufacturing is a complex process that requires extensive qualifications when production is transferred to new locations.

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Figure 3: ATLM at Aeronautics

SHEET METAL PARTS

Within the manufacturing of sheet metal parts there are several sub-processes which contain different processing operations, for example milling, chopping and sawing. The parts are later shaped by edging, pressing, stretch forming, joggling and straightening. The sub-processes also include property enhancing such as heat treatment and surface processing such as cleaning and surface treatment.

Here, two processes (stretch forming and straightening) are chosen to be described in further detail; they are thoroughly discussed in Paper III, with a focus on tacit knowledge. When stretch forming, the material is exposed to elongation. The sheet metal is pre-shaped before the stretch forming operation. The pre-shaped sheet metal is then clamped from beneath with a tool as shown in Figure 4. The tool is pressed upwards and pushes the sheet metal into the same shape as the tool. This process consists of machine force and manual precision and decision.

Figure 4: Sheet metal stretch forming process

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Parts that arrive at "straightening" undergo control of shape. When deviations occur the operator has to reshape the part to fit the tool. The straightening process consists of craftsmanship: the operator has a tool, a drawing and a large set of hammers. The level of automation is very low. The straightening process today is very difficult to conduct with the help of machines, as operators have to feel and see how the material is affected. The production documentation mainly consists of a drawing and the wording "control of shape". This type of documentation is remarkably short for such a complex process, due to the difficulty of describing skills.

MACHINED PARTS

Machined parts involve spars, stringers, skins, nuts, bushings and bolts. The manufacturing process includes integrated structural parts: stiffeners, brackets and connecting points are integrated into one machined part. The choice of production method within the manufacturing process is based on part requirements such as part thickness, size and complexity and available equipment. Almost half of all parts will require High Speed Machining (HSM) with >500m/min cutting speed in 5 and 7-axis NC machines. Remaining parts can be produced in 3, 4 and 5-axis conventional machining and multi-turning. HSM machining and conventional machining can be defined as a shaping process with material removal within a processing operation.

The level of automation within "machined parts" is convincingly higher than in other segments at Aeronautics. Some machines are fully automated, supervised by a worker. However, most of the machines are semi-automated.

SURFACE TREATMENT

This process describes cleaning, surface treatment, chemical milling, parts painting including primer and finishing coating, painting of assemblies and painting of a complete aircraft. Within the surface treatment process, the degree of automation is very low. It is a challenging process; the final result cannot be verified without destructive testing.

1.1.2 ASSEMBLY

SUB-ASSEMBLY

Sub-assembly is mainly a worker-machine system. The working operations often include manual work with the aid of some powered tools or other machines. Sub-assembly consists of several sub-processes: tube bending, welding, harness, panel and mechanical and electrical sub-units to final assembly.

High precision tube bending is a shaping process; the tubes consist of material such as titanium, aluminum, light-metal alloys and stainless steel. Semi-automated 4 and 6-axis NC tube bending machines are used, and several fixtures are employed for control of shape. The level of automation is low and the machines and tools are used as aids. A bended tube and a welding operation are shown in Figure 5.

Figure 5: Left: A tube that has gone through bending, a shaping process
Right: An operator in a welding operation

The welding operations are both a joining process and an assembly operation and are performed with titanium, light-metal alloys and stainless steel. Most of the equipment consists of manual welding tools and welding jigs.

Manufacturing of integrated electrical system harnesses is illustrated in Figure 6. Almost all harnesses are laser-marked and cut automatically. All placements are preformed manually, as an assembly operation with mechanical fastening. Sub-assembly also includes assembly of mechanical and electrical sub-units, such as pylons, as well as pedal gear for final assembly.

Figure 6: Manufacturing of integrated system harnesses (electrical)

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STRUCTURE ASSEMBLY

The main structural parts such as wings, fuselages and tail cones are assembled and later delivered to final assembly. The major structural build units for the Gripen are presented in Figure 7.

Figure 7: Major structural build units for the Gripen aircraft, a general sketch

Structure assembly is an assembly operation mainly involving mechanical fastening, both permanent fastening and threaded fastening. For example, the fuselage is assembled with approximately 50,000 fasteners and all joints are surface-sealed, referred to at Aeronautics as “soft joints”. Production methodology with soft joints for structural assembly allows keeping the weight low while maintaining high structural strength. No structural assembly during systems installation prevents FOD (Foreign Object Debris) and improves quality. Set joint technology is shown in Figure 8.

Figure 8: Fasteners with soft joint technology

Drilling, countersinking of holes, 5-axis NC machining and application of aluminum on wing skins for lightning strike protection is performed semi-automatically. All drilling can, when needed be performed manually with drill jigs. The most frequently used tools are different jigs: stationary assembly jigs, rotating assembly jigs, bench assembly jigs, and mounting and drilling jigs. The overall level of automation within "structure assembly" is very low.

FINAL ASSEMBLY

Final assembly is divided into three different areas: Station 1, Station 2 and the Functional test, as illustrated in Figure 9. Station 1 mainly consists of complex systems installation (electrical and mechanical); an example of installation is 90% of all harnesses and tubes, hydraulic equipment and fin and landing gears. The complexity is enhanced by the approximately 16,000 parts installed at Station 1.

Station 2 primarily consists of equipment installation and test; examples of installation are canards, airbrakes, front screen, canopy, radome, landing gear and doors. At the Functional test station the function test is conducted along with other activities like corrosion treatment and inspections. Final assembly is further discussed in Paper III, with a focus on transfer of tacit knowledge in a production environment.

Figure 9: The three different areas within final assembly

The main work tasks are manual assembly operations of cabling, electrical and mechanical components for structural assembled parts and conducting tests, inspection and troubleshooting of units and systems. The assembly operations consist primarily of mechanical fastening, such as position locking and mounting of fasteners. Joining processes such as sealing (adhesive bonding) are also performed. The assembly operations are performed in parallel with processing operations, such as machining of holes (shaping process). The level of automation is low, and the work is mainly manual.

The work assignments are very complex and the working sequences are long. The production is rate-based, but the rates are very low if compared to for example the automobile industry.

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The production documentation is extensive, and the operators are very dependent on drawings and on their own knowledge about the products. In Figure 10, a typical assembly situation for operators performing final assembly in the aircraft industry is shown. There are several operators, working at the same station at the same time, who must work in parallel without disturbing each other. The assembly is complex and the working positions can be very uncomfortable. The assembly operations are often in places hard to reach, and special assembly tools and mirrors are often needed.

Figure 10: A typical installation situation at final assembly

1.2 Risk analysis performed at Aeronautics

A risk analysis, called "risks with transfer of advanced production in offset business", was performed at Aeronautics during the second half of 2010. The result from the risk analysis will provide with important factors in the transfer of aircraft production. The risk analysis was performed according to an internal Aeronautics specification, which is thoroughly described in this section. The risk analysis meetings were divided into three occasions. In the first, the risks were plotted; in the second, the risks were assessed; and in the third, the solutions were discussed. The risk analysis was conducted in the form of a focus group, with members from the steering group and the reference group.

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The risk analysis was performed using a qualitative method (mini-risk), commonly used at Aeronautics used to handle risks in projects. The risk analysis includes the probability that a risk will occur in combination with the consequence of if the risk actually does occur. Those involved with the risk analysis all had experience working with transfer of aircraft production. The result from the risk analysis set the foundation for the risks to be investigated. Risk and uncertainty characterizes a situation where the result of an event or activity could deviate from the expected result. In the beginning of a project, many risks may be found, given the start-up phase of a project. Further ahead in a project life cycle, more resources and work have been introduced that may reduce the number of risks.

A risk analysis was performed to identify and evaluate risks, see results in Table 1. The probability of the risks and their consequences has been assessed by the focus group. The mini-risk method is relatively simple to use. In this case, the researcher called a meeting, with members from the steering and the reference groups. A risk analysis is usually performed with the help of a moderator, who supplies method support and acts as a meeting leader. It is recommended that the moderator is not directly involved in the subject of analysis to ensure their neutrality. Within this study, the researcher was the moderator, not according to recommendation. However, the researcher was well aware of the problem with bias and actively tried to avoid involvement. During the risk analysis meeting, risks were documented and the meetings were audio-recorded.

The work procedure started with establishing the theme, "risks with transfer of advanced production in offset business". All participants at the meeting wrote down risks on post-it notes, and all written risks were required to start with "The risk is that…" This standard text is used to simplify the process for all meeting attendees, and to facilitate understanding of the risks even after a period of time. The moderator placed the post-it notes in an area visible to all meeting members. At a given time, the brainstorming is stopped. Together, the group reads through the post-it notes to make sure everyone understands each risk. The discussion within the group is of great importance, and helps to evaluate the risks and the affecting consequences. All notes containing the same risks are grouped together. Then, the probability for the risks to occur was estimated. The estimation concerned economics, time and technical functionality. After probability estimations, actions were set to reduce or eliminate the risks. Both seriousness and priority of the risks were set, both short-term and long-term.

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Table 1: Risks connected to transfer of production from Aeronautics

Risk no.	Assessed risk value	Risks at Aeronautics when transferring production	Source of the risk
1	16	A risk that the experience within transfer of production at Aeronautics is too low and insufficient.	• Standardized transfer process
2	16	A risk that the demand on the critical resources will be too high when transferring production.	• Outside research area
3	16	A risk for increased cost and delays if specifications and requirements are not explicit enough for global use.	• Tacit knowledge • Configuration management
4	16	A risk that receivers of production have not been adequately assessed by Aeronautics.	• Standardized transfer process
5	12	A risk that Aeronautics has miscalculated the costs to transfer production in different work packages.	• Outside research area
6	12	A risk that essential cultural differences will appear once the cooperation is tighter.	• Cultural issues
7	12	A risk for increased cost and delays due to insufficient configuration management between the sender and the receiver of the production.	• Configuration management
8	9	A risk that the boundary for responsibility between Aeronautics and the receiver is unclear.	• Standardized transfer process • Communication
9	8	A risk that the production documentation is useless by others due to a large amount of tacit knowledge (“know-how”)	• Tacit knowledge
10	8	A risk that the design documentation will differ from the production documentation (at Aeronautics).	• Configuration management
11	6	A risk that improvement suggestions for production/design documentation from the shop floor will take too long to be addressed, due to the bureaucracy. This can lead to non-value adding operations.	• Configuration management
12	6	A risk that communication challenges will arise due to different mother tongue.	• Cultural issues

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The purpose of risk management is to present prerequisites to make decisions about actions in order to prevent identified risks. At risk handling, it is important to have focused on the severe short-term risks, and thereafter severe long-term risks. It is also important to ensure that actions are performed continuously.

Common problems that can arise during offset production transfer from Aeronautics to a receiver were identified through the risk analysis. The risks were graded to find those which were most critical. When exploring the result, a convincing share involved issues concerning the interface between design and production, cultural aspects and tacit knowledge.

Risks 2 and 5 are connected to other Aeronautic processes not related to transfer of production, and are therefore not part of the research within this dissertation.

The risks can be grouped as important factors as shown in Table 2, and further on the grouped risks will be named important factors. Risks 1, 4 and 8 are related to the fact that Aeronautics does not have a standardized transfer process; experience exists, but it is not complied and documented. This research project will identify and investigate important factors for this process.

Table 2: Important factors related to transfer of production from Aeronautics

Risk no.	Important factors in transfer of aircraft production
1, 4, 8	Standardized transfer process
3, 9	Tacit knowledge
3, 7, 10, 11	Configuration management
6, 8, 12	Cultural issues and communication

Risks 3 and 9 are related to knowledge in a production environment. The "know-how" and non-explicit knowledge are directly connected to tacit knowledge. Aeronautics is a company with low staff turnover; many operators have been at the company for 25 years or more and possess much knowledge. The production documentation has followed the operators, and extensive knowledge is connected to the operators.

Risks 3, 7, 10 and 11 are related to configuration management. Configuration management is very important within aircraft production, as all parts and material from production have to be traceable. This must function unconditionally and there is always a risk that something can go wrong when transferring production. Configuration management is a wide concept and will be further investigated in future research; the research herein has focused on the connection between design and production, which are dependent on each other and have to work in parallel. For example: when there is a design change, the production documentation often has to be updated and vice versa. There is always a risk with these types of connections that something can go wrong and the update can be delayed. One tool to work with the interface is Model Based Definition (MBD).

Risks 6, 8 and 12 are related to cultural and communication issues. At Aeronautics several transfer projects have gone through delays due to misunderstandings that can be related to cultural and communication issues.

1.3 Important factors in theory "Transfer of production"

Within this section, the literature from the theoretical framework for the licentiate thesis is summarized and categorized. The categorization is performed to facilitate a comparison between the mapping of production and the risk analysis. The categorization provides with important factors in the transfer of aircraft production.

One of the largest risks with product transfer is that full-scale production is not reached as planned (Madsen, 2009), which can lead to a lack of needed materials and extra costs (Fredriksson, 2011). Why is full-scale production not reached as planned then? Some theoretical challenges can be summarized as follows (for references see the theoretical framework in Licentiate thesis):

- The transfer of knowledge and technology
- Geographically spread supply chains
  - long transports
  - more advanced logistics
  - complex supply chains
  - increased lead times
  - decreased delivery accuracy
- Political differences
- Financial differences, such as different currencies and payment systems
- Different cultural settings
- Practical differences, such as different time zones

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1.4 IDENTIFIED FACTORS

The identified factors are based on the result from the risk analysis, the mapping of production processes and the literature study. This summary is presented in Table 3. Column one in the table presents factors with the transfer of aircraft production within an offset business, while the other three columns show the results from the risk analysis, the mapping of production processes and the literature study.

Table 3: Identified important factors related to the risk analysis, the mapping of production processes and the literature study

Important factors in transfer of aircraft production	Risk analysis	Mapping of processes	Literature study
Standardized transfer process	X		X
Transfer of knowledge	X	X	X
Transfer of technology		X	X
Configuration management	X	X	
Cultural challenges	X		X
Communication	X		
Low level of automation		X	
Aging machinery		X	
Complex processes		X	X
Geographically spread supply chains.			X
Political differences			X
Financial differences			X
Practical differences			X

In the next chapter, the categorization of the important factors will be described.

2 CATEGORIZATION OF IMPORTANT FACTORS

An investigation was performed consisting of three parts: a risk analysis, the mapping of Aeronautics production processes and a literature study. The investigation contributed with important factors within transfer of aircraft production in an offset business. In this Chapter, these factors will be categorised, as addressed in RQ 2.

2.1 ANALYSIS OF THE IDENTIFIED FACTORS

The identified factors are presented in Table 4. Column one in the table presents factors related to transfer of aircraft production within an offset business, the factors are connected with letters to more easily separate them in the discussion. The other three columns show the result from the separate parts of the investigation.

Table 4: Important factors related to the risk analysis, mapping of processes and literature study

Important factors in transfer of aircraft production	Risk analysis	Mapping of processes	Literature study
A. Standardized transfer process	X		X
B. Transfer of knowledge	X	X	X
C. Transfer of technology		X	X
D. Configuration management	X	X	
E. Cultural challenges	X		X
F. Communication	X		
G. Low level of automation		X	
H. Aging machinery		X	
I. Complex processes		X	X
J. Geographically spread supply chains.			X
K. Political differences			X
L. Financial differences			X
M. Practical differences			X

“A. Standardized transfer process” is an important factor. Today, a standardized transfer process is missing at Aeronautics. The conducted research will give criterions to design a transfer process at Aeronautics. This factor is indirectly involved in the research.

Appendix I

“B. Transfer of knowledge” and “C. transfer of technology” are central concepts in transfer of production. Transfer of knowledge is represented from all three parts in the investigation.

“D. Configuration management” is an important factor in the risk analysis and when the processes were mapped. It was not emphasized in theory, but this can be explained by the product transfers that were discussed. The importance of configuration management increases dramatically with increasing product complexity, such as in the aircraft industry.

“E. Cultural challenges” and “F. Communication” are closely related; good communication skills are definitely needed to decrease the risk for collision of cultures. Since they are soft values, they were not mapped in the production processes.

“G. Low level of automation” and “H. Aging machinery” are factors that not are prioritized. The connection between “low automation” and “hard to transfer” is not strengthened by any other source. The ageing machinery is a problem, but if Gripen production is transferred today, in all probability the ageing machinery will be replaced. The existing machines will stay at Aeronautics, as they are too old to buy in duplicate and still have profit in production.

“I. Complex process” is closely related to “C. Transfer of technology” and “B. Transfer of knowledge” since aircraft production is a complex process.

“J. Geographically spread supply chains” is a problem in the aircraft industry even before a transfer; the aircraft industry often has very long lead times, advanced logistics and long transports. This is a problem of lower concern, however, since it already exists.

“K. Political differences” and “L. Financial differences” are known problems and often occur in earlier stages than the transfer. This is often a major concern before and during the offset negotiations.

“M. Practical differences” is not often a severe problem; the practical differences cannot be forgotten but they are often explicit and easy to have in a checklist. For example; different working hours can most often be solved by a bit of flexibility from both the sender and the receiver.

Appendix I

2.2 CATEGORIZATION OF IDENTIFIED FACTORS

Based on the investigation and the description in Section 2.1, categories chosen to be further analyzed are shown in Table 5.

Table 5: Categorization of important factors in the transfer of aircraft production

Categorization of important factors	
Category 1:	Cultural challenges and communication
Category 2:	Configuration management
Category 3:	Transfer of knowledge and technology

Categories 1, 2 and 3 were all in the risk analysis, and both the mapping of production processes and the literature study supported the result from the risk analysis. The result from the risk analysis was of highest priority, followed by the mapping and finally the literature. This prioritization is based on the relation to the research area. The risk analysis involves people, who daily work with transfer of aircraft production. Mapping of production processes, maps the processes of today at Aeronautics, not the transferred processes. The literature is related to the research area divided in different areas, not all together.

11 APPENDED PAPERS

Appended Papers

The articles associated with this thesis have been removed for copyright reasons. For more details about these see:

http://urn.kb.se/resolve?urn=urn:nbn:se:liu:diva-132405

Notes