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Investigating Relationships between Production Transfer Management and Transfer Success

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Purpose – This paper explores the operationalization of production network coordination - the production transfer - and the relationships between transfer risk sources, preventive actions, supply chain disruptions, corrective actions, and losses, to better understand how to mitigate the risk and achieve an effective transfer process.

Methodology – A longitudinal field-study of a production transfer from Norway to Spain that was studied in-depth for 25 months.

Findings – The paper presents the implications of three areas of importance for production transfer success: (i) how the transfer influences the plant roles, ii) the cross-locational management of the transfer project at the sender and receiver, and (iii) whether adapting the transferred production to the receiver's environment is an enabler or an inhibitor of transfer success.

Practical implications – The findings about how to mitigate the transfer risk and the frameworks of risk sources, supply chain disruptions, losses, and preventive and corrective actions, along with the examples from the in-depth study can aid the practitioners in managing production transfers and achieving the relocation goals.

Originality – This is one of the first studies of a production transfer, which is from the perspective of both transfer parties, and addresses both preventive and corrective actions and all the transfer phases. Moreover, this study addresses the operational aspects of production network coordination, which received limited attention in earlier research.

Keywords Production Transfer; Production Network Coordination; Manufacturing Relocation; Supply Chain Risk Management

Paper type Research paper

1. Introduction

Many of today's production companies are structured as production networks, with plants dispersed across the globe. To improve their overall performance, production networks need to improve the coordination of the flows of raw materials, goods, personnel, equipment, information and financial resources between the network nodes. The *production transfer* (PT) process is the operationalization of production network coordination strategies (Fredriksson and Wänström, 2014). This process may for instance, occur when companies transfer production from an old plant to a new one, or when they relocate product volumes and portfolios within their existing production networks (Loertscher and Riordan, 2019). The PT includes the transfer of knowledge, equipment, inventories, personnel, administrative systems and sub-suppliers between two plants - the *sender* and *receiver* (Fredriksson and Wänström, 2014).

Earlier studies within the coordination of global production networks have mainly focused on strategic decisions, such as 'make-or-buy', supplier selection, plant roles, and the level of network integration (Szász *et al.*, 2019, Scherrer-Rathje *et al.*, 2014, Ferdows, 1997), and not on the operational level and the actual implementation of network coordination strategies. However, to achieve the strategic goals of relocations within production networks, their operational implementation (through the production transfer process) needs to be successful (Fredriksson and Wänström, 2014, Kinkel and Maloca, 2009, Madsen, 2009). Otherwise, there is a risk that the implementation of the strategic decisions becomes so expensive and time consuming, that the production networks lose their flexibility and ability to adapt to changing conditions (Fredriksson and Wänström, 2014). The existing literature reports a number of failed PTs, that have, for instance, led to suboptimal product quality, lost market shares, significant cost overruns, reshoring or even factory closings (Kinkel and Maloca, 2009, Madsen, 2009). Moreover, it has been shown that achieving a stable production output during the start-up at the receiver tends to take much longer than what the transfer parties estimate – often several years (*ibid.*). Because of these challenges and the criticality of PT success, several PT scholars and practitioners have highlighted the importance of managing the risk during PTs. By studying the literature through the supply chain risk management lens, the authors found that a series of studies had already addressed central elements of supply chain disruption scenarios during a PT. These include risk sources (e.g. Fredriksson *et al.*, 2014, Cheng *et al.*, 2010), supply chain disruptions that the risk sources may trigger (e.g. Manuj and Mentzer, 2008, Chopra and Sodhi, 2004), and losses caused by severe supply chain disruptions (e.g. Chopra and Meindl, 2013). Furthermore, some scholars have also addressed risk mitigation actions (e.g. Fredriksson *et al.*, 2015). However, so far, none have systematically studied the relationship between these elements. The *purpose* of this paper is to increase the knowledge about risk management during the PT process, by exploring relationships between risk sources, preventive actions, supply chain disruptions, corrective actions and losses during PTs. Thus, the paper aims to contribute to the knowledge about production network coordination.

2. Methodology

The research design followed the action research strategy described by (Coughlan and Coughlan, 2002), and is based on a longitudinal field study of a transfer of electronics from

Norway to Spain, which was studied in-depth for 25 months (May 2016 - June 2018). The longitudinal field study was conducted as recommended by Ahlström and Karlsson (Ahlström, 2007, Karlsson, 2016, p.196).

PTs are particularly common among Nordic companies, as 48% of firms with over 50 employees relocate production (Heikkilä *et al.*, 2017). Of those, electronics firms relocate production most frequently. Thus, the selected electronics case can be regarded as a representative case (Miles and Huberman, 1994, Karlsson, 2016, p.172). Furthermore, the transfer to Spain provided a rare opportunity to study a noticeable organizational change over time, where the studied phenomena were likely to appear (Eisenhardt, 1989). A series of supply chain disruptions, with their causes and consequences were likely to appear, during the transfer of a family of electronics to a subsidiary located far away, and with modest production experience. Moreover, the long time span enabled the study of the PT impact on the plant role development in a production network.

As the sender (hereafter denoted *Sender.Co*) had experienced supply chain disruptions and losses such as excessive inventory levels, scrap levels, and start-up times during previous PTs, they decided to develop a thorough PT procedure. The lead and third authors developed a preliminary PT procedure based on the literature. Thereafter, the lead author implemented the procedure during the transfer of electronics and refined it with *Sender.Co* and *Receiver.ES* through action research (see Mogos *et al.*, 2018). This process provided the authors an excellent opportunity to closely study the relationship between i) risk sources, ii) preventive actions, iii) supply chain disruptions, iv) corrective actions and v) losses, before, during, and after the implementation of the PT procedure. Based on these five concepts, the authors developed an analytical framework (Figure 2, Section 3), which acts as a data collection and analysis ‘telescope’ pointed towards the transfer parties, to direct the researchers' attention towards specific aspects of the studied phenomena (Miles and Huberman, 1994). To this end, for each of the concepts, the authors identified a set of dimensions in the PT literature and in key (supply chain) risk management publications, which are presented in Section 3 and Appendix 1. The dimensions related to the *risk source* concept are based on a framework that two of the authors had developed (Mogos *et al.*, 2017). The dimensions related to the *supply chain disruptions* and *losses* are based on the frameworks provided by Manuj and Mentzer (2008) and Chopra and Sodhi (2004). The set of dimensions related to *losses* was supplemented with examples provided by the risk management literature (with Rausand, 2013). The *preventive actions* dimensions are based on the PT procedure that was

implemented at the transfer parties (Mogos et al., 2018), and the *corrective action* dimensions are based on Fredriksson et al. (2015) and Norrman and Jansson (2004).

Through the university where she worked, the lead author was involved in a research project with Sender.Co, which lasted from 2014 to 2018. In September 2016, she became part of the transfer project organization, having the role of Transfer Facilitator. Thus, she collaborated with all of Sender.Co and Receiver.ES's personnel involved in the PT. She prepared an action plan to facilitate the implementation of the PT procedure. This enabled her to meticulously record all the preventive and corrective actions that Sender.Co and Receiver.ES implemented.

A known challenge for action researchers is to both act, in order to contribute to practice, and reflect on the action as it happens and after, in order to contribute to the body of knowledge. To ensure research quality, action researchers must deliberately and frequently open their reasoning to public critique, and actively seek alternative explanations (Coughlan and Coughlan, 2002). To this end, the lead author frequently discussed results with academic reviewers and other researchers outside the project, at the university, at workshops with PT practitioners, and at various conferences.

An interview guide was developed based on the analytical framework. The lead author applied the guide to interview the Project Owner (Sender.Co), Project Manager (Receiver.ES), Quality Assurance (QA) & Risk Manager (Sender.Co) and Lean Manager (Sender.Co), as they were the most knowledgeable about how the PT was conducted. The data collected through the interviews is presented in Appendix 2. The interview guide included the following questions:

- Which of the risk sources are relevant for the sonars (acoustic sensors) transfer?
- (If the risk source is relevant) Did the transfer parties implement any preventive action, and if so, what was implemented?
- Did any supply chain disruption(s) occur after the implementation of the preventive actions, and if so, what occurred?
- Did the transfer parties implement any corrective action(s), and if so, what was implemented?
- Did the transfer parties incur any losses because of the supply chain disruptions, and if so, what were the losses?
- Should the sonars transfer have been conducted differently, and if so, how?

Apart from semi-structured interviews, the empirical data were collected at both transfer

parties' sites through methods, such as studies of documents from Sender.Co and Receiver.ES, informal conversations, and field notes during meetings and tours at Receiver.ES's site. The action research approach made it easier to determine the causal relationship between risk events (risk sources, disruptions, etc.) compared to retrospective studies. Moreover, the variety of collection methods for the same phenomenon enabled the triangulation of data, further increasing the internal validity. To ensure the reliability of collected data, the lead author recorded the date, place and individuals present, for all the observations and their interpretations. To increase the external validity, the authors compared the findings from the sonars transfer study with the informants' reports about other PTs. Sender.Co had conducted 19 other PTs - two of them to Receiver.ES. A publication of the lead author includes descriptions and analyses of five of these PTs - including all the PTs to Receiver.ES (Mogos, 2020). Furthermore, the findings were reviewed by managers and other personnel at both transfer parties, during workshops and interviews.

After collecting the empirical data, the lead author wrote the 'narrative' of the studied PT - as a first step in the data analysis process (Ahlström, 2007, Karlsson, 2016, p.232). Second, the narrative was divided into the main phases of a relocation process: transfer-object selection, receiver selection, PT preparation, PT execution and PT start-up. Third, the events were coded in a database, for retrieval and organization purposes (ibid.). Finally, the relationships between the risk sources, disruptions, losses, and preventive & corrective actions during the sonars transfer were derived from the narrative, through logical relationship building.

3. Analytical framework

The transfer of production from a sender to a receiver introduces new risk sources, related to the capability gap between the transfer parties and their relationship (Malm *et al.*, 2016, Terwiesch *et al.*, 2001). During the PT, the roles of the sender and receiver within the production network evolve and their relationship changes, which may introduce new risks, influencing their future collaboration (Szász *et al.*, 2019). All these risk sources may trigger supply chain disruptions and significant losses, if they are not managed by help of preventive and corrective actions (Fredriksson *et al.*, 2015). This section presents the framework used to analyse the PT (risk) management, after an introduction of the main risk management concepts in the paper.

Figure 1 illustrates the relationship between these concepts. The figure is adapted after the Bow-tie diagram, an established tool for risk assessment (e.g., Ferdous *et al.*, 2013, Rausand, 2013). Bow-tie diagrams provide a graphical visualization of risk scenarios, and of the role of preventive and corrective actions. In the context of PTs, the preventive and corrective actions act as barriers between the risk sources and the supply chain disruptions, and between the supply chain disruptions and the losses, respectively.

A *risk source* (e.g. the receiver's lack of experience with a certain production equipment (Tatikonda and Stock, 2003)) is a tangible or intangible element, which alone or in combination with other risk sources has the intrinsic potential to give rise to a disruption (ISO, 2009, Norrman and Jansson, 2004). According to the Supply Chain

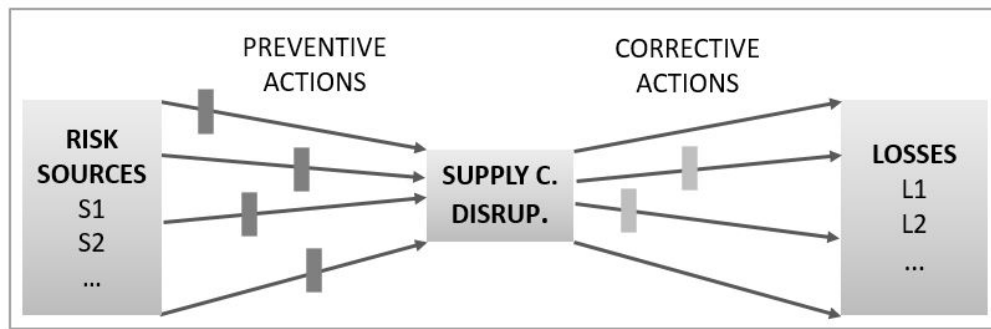


Figure 1: The relationship between central risk management concepts during production transfers (based on a Bow-tie diagram)

Council (McCormack *et al.*, 2008), a *supply chain disruption* is an abnormal situation - in comparison to everyday business - which leads to negative deviations from certain performance measures and may lead to losses for the affected companies (e.g. a machine breakdown leading to capacity deviations (Almgren, 1999)). A *loss* represents a significant negative consequence (McCormack *et al.*, 2008) (e.g. the inability to meet the demand on time (Chopra and Meindl, 2013)). Finally, a *preventive action* is an action taken to reduce the likelihood of supply chain disruptions (McCormack *et al.*, 2008), and, in contrast, a *corrective action* is an action taken to reduce the impact on performance of supply chain disruptions that could not be avoided (McCormack *et al.*, 2008).

The analytical framework follows the logic of Figure 1. The complete framework is presented in Appendix 1 and summarized in Figure 2. The five sets of dimensions in the framework are presented in the remainder of the section.

3.1. Potential risk-sources during PTs

As described in the methodology section, the set of risk source dimensions stems from a

framework that two of the authors have earlier developed (Mogos et al., 2017). Based on Argote et al., the risk sources are classified as follows (risk sources): i) *related to the transfer-object*, ii) *related to the sender*, iii) *related to the receiver* and iv) *related to the relation between the sender and the receiver* (Argote et al., 2003). Based on Tatikonda and Stock (2003) and Fredriksson et al. (2015), the *risk sources related to the transfer-object* can be either related to the *product design and production process* or to the *production planning and control*. For the former subcategory, one example is when the process of producing the transfer-object (e.g. a product) is modified. The larger the modifications applied to the transfer-object, the higher the risk of, for example, quality non-conformances when the receiver starts producing the transfer-object. For instance, if certain components were replaced by cheaper ones, the new ones would have to be thoroughly qualified, and the transfer-object should be tested to ensure that it functions as required.

Based on Malm et al. (2016), the *risk sources related to the sender* are mainly related to the sender's *disseminative capacity*. These risk sources include, for example, the sender's willingness and capability to adapt the transfer-object (e.g. production processes) to the receiver's environment, and the employees' motivation for the transfer and for knowledge sharing. For instance, the employees' lack of motivation to transfer essential knowledge to the receiver—because they fear losing their jobs—would contribute to a higher risk-level.

The *risk sources related to the receiver* are either related to the receiver's *absorptive capacity* or to their *physical location*. Naturally, in addition to the sender's disseminative capacity, the risk level and the success of a PT would depend on the receiver's 'absorptive capacity' (Malm et al., 2016), for instance, the receiver's level of experience with similar production activities. Furthermore, the risk level will not only be influenced by internal risk sources at the receiver but also by contextual risk sources related to their physical location (Grant and Gregory, 1997) for instance, the suitability of the infrastructure or of the import duties.

The *risk sources related to the sender-receiver relation* are either associated with their *earlier relation and physical proximity* or with the *power balance* between them. Examples for the first subcategory include the relational closeness between the sender and receiver, and the physical proximity between related processes after transfer execution. For instance, the risk is expected to be lower when the sender's and receiver's sites belong to the same company or if related processes such as product development

and production are performed at locations close to each other so that the personnel can easily meet and collaborate (Fredriksson et al., 2014, Terwiesch et al., 2001). The *power balance* refers to the sender's and receiver's negotiating powers. A receiver with little negotiating power might get too dependent on the sender (e.g. vulnerable to senders' demand changes or lost sales), whereas a receiver with dominant negotiating power might not collaborate appropriately (Gelderman and Van Weele, 2003, Kraljic, 1983) during the PT.

3.2.Potential preventive actions during PTs

The preventive actions stem from a framework that the authors had earlier developed (Mogos et al., 2018), based on comprehensive procedures from the existing PT literature (Fredriksson et al., 2015, Terwiesch et al., 2001, WHO, 2011). The preventive actions are to be implemented during the PT preparation phase. The preventive action-dimensions include: i) *organization and project management* (e.g. the transfer parties agree on transfer performance indicators and their continuous monitoring), ii) *quality management* (e.g. the sender evaluates the receiver's readiness with regards to facilities, equipment and support services), iii) *knowledge transfer* (e.g. the sender verifies the knowledge transfer at the receiver, for instance by checking the transfer documentation and testing the personnel), iv) *transfer of administrative systems* (e.g. the transfer parties update their ERP systems), and v) *supply chain transfer* (e.g. the transfer parties establish relationships to subsuppliers of raw materials).

3.3.Potential supply chain disruptions during PTs

The academic literature provides a number of potential supply chain disruptions during PTs, although various terms are used such as 'disturbances' (e.g. Almgren, 1999, Madsen, 2009), 'disruptions' (e.g. Minshall *et al.*, 1999), 'risks' (e.g. Malm, 2013)), 'unexpected events' (e.g. Fredriksson et al., 2015), 'unforeseen events' (e.g. Arica *et al.*, 2016) and 'risk drivers' (Chopra and Sodhi, 2004). It was found that Chopra and Sodhi's (2004) along with Manuj and Menzer's (2008) frameworks address most of the potential supply chain disruptions during PTs. Thus, the set of dimensions in Figure 2 are based on these two studies. These are: i) *supply disruptions* (e.g. material shortage), ii) *operational disruptions* (e.g. quality non-conformance), iii) *demand disruptions* (e.g. sudden demand change), iv) *Health Safety and Environment (HSE) disruptions* (e.g. product safety non-conformance), v) *natural disasters* (e.g. earthquake), vi) *labour strikes*, vii) *security*

disruptions (e.g. hacking of information system), viii) *macroeconomic disruptions* (e.g. fuel price escalation), and ix) *policy disruptions* (e.g. quota restrictions). Furthermore, in line with the Supply Chain Council, the identified disruptions are divided into supply

Risk sources	Preventive actions	Supply Chain disruptions	Corrective actions	Losses
Related to Transfer-object: Product and production process Planning and control Related to Sender: Disseminative capacity Related to Receiver: Absorptive capacity Physical location Related to Sender-Receiver Relation: Earlier relation and physical proximity Power balance	Organisation & Project Management actions Quality Management actions Knowledge Transfer actions Administrative Transfer actions Supply Chain Transfer actions	Internal to Supply Chain: Supply disruptions Operational disruptions Demand disruptions HSE disruptions External to Supply Chain: Natural disasters Labour strikes Security disruptions Macroeconomic disruptions Policy disruptions	To mitigate: Supply/operational/demand disruptions To mitigate: HSE/security/macroeconomic /policy disruptions, natural disasters, and labour strikes	Human and Health losses Material losses Environmental losses

Figure 2: The Analytical Framework Used to Collect and Analyse the Case Data

chain disruptions that are *internal* and *external* to the supply chain (McCormack et al., 2008).

3.2. Potential corrective actions during PTs

To the best of the authors' knowledge, Fredriksson et al. (2015) is the only publication explicitly presenting corrective actions during PTs and was a starting point for identifying dimensions of corrective actions. However, the corrective actions on which Fredriksson et al. (2015) focus are primarily relevant *for the mitigation of the impact of supply, operational, and demand disruptions* (e.g. safety stock and express transport). Therefore, based on Chopra and Shodi (2004), Manuj and Mentzer (2008), and Norrman and Jansson (2004), the list was supplemented with corrective actions *for HSE, security, macroeconomic and policy disruptions, and for the mitigation of natural disasters, and labour strikes* (e.g. established Business Continuity procedure and backup information system).

3.3. Potential losses during PTs

In line with Rausand (2013), the potential PT losses that this study identified in the literature are divided into three major dimensions: *human and health* (e.g. fatality and temporary harm), *material* (e.g. lost sale and stock-out), and *environmental* losses (e.g. damage to fauna or flora). Note that the losses listed in the framework from Appendix 1 are not exhaustive but only representative of each category. The examples are provided by Rausand (2013), Manuj and Mentzer (2008a), Manuj and Menzer (2008b) and Chopra and Sodhi (2004).

4. A case of PT from Norway to Spain

This section will present the PT case that was studied during the longitudinal field study. The case company is briefly described in Table I.

Sender.Co purchased Receiver.ES's company in 1996 and had experienced good collaboration ever since. During 2015, Sender.Co successfully transferred production to Receiver.ES – the assembly of a product module. In May 2016, Sender.Co decided to relocate the production of a product family of sonars to Receiver.ES. The product family consisted of nine different sonar variants. During the transfer the receiver evolved from a regional production plant, carrying out simple assembly activities, to a regional production plant with material development capabilities.

Table I: A description of the case company

Main case company	Norwegian technology company
Industry	Maritime supply
Area served	Global
No. of employees	Ca. 4000
Revenue	Ca. 1000 million EUR
Sender	Production site in Norway
Products	Electronics
Core competency	Innovative products
Product variety	Ca. 1000
Product volumes	Usually less than 1000 items
Receiver	The Spanish plant of a subsidiary
Transfer-object	Assembly of acoustic sensors, and production of their housings Production of sensors technology kept at the sender due to Intellectual Property
Transfer reason	Large customer network around the subsidiary Labor cost is three times lower than in Norway
Experience	Assembly of other product families and repair services on acoustic sensors

The timeline of the production relocation from Sender.Co to Receiver.ES is displayed in Figure 3.



Figure 3: The timeline of the transfer of sonar production from Norway to Spain

5. Key relationships between risk sources, supply chain disruptions, losses and risk-mitigating actions during the studied PT

This section presents the most noteworthy key relationships that were identified in the empirical findings in Appendix 2. They are summarized in Table II and described in the remainder of this section.

Table II: Key empirical findings and potential preventive actions

	Risk source	Preventive action	Supply chain disruption	Corrective action	Loss
1	Long geographical distance and organizational differences	Cross-locational project manager with clear role and responsibilities Regular status meetings	Without preventive actions: supply disruptions, such as significant schedule disruptions	Without preventive actions: repeated rescheduling of activities and overtime	Without preventive/corrective actions: material losses, such as stock-out
2	Receiver's low absorptive capacity: lack of machine capability Transfer product: engineering changes from the sender	Formal agreement Freeze the transfer scope, including the machine specifications for the transferred production	Without preventive actions: supply disruptions, such as significant schedule disruptions	Without preventive actions: repeated rescheduling of activities, and equipment modification because of changed production requirements	Without preventive/corrective actions: material losses because of significant start-up delay, such as excessive equipment capacity and inventory
3	Receiver's low absorptive capacity: greenfield site without clear layout specifications	Close collaboration on layout development Freeze layout design after joint agreement	Without preventive actions: supply disruptions due to lack of clear layout specification, such as significant schedule disruptions	Without preventive actions: repeated rescheduling of activities and overtime	Without preventive/corrective actions: material losses because of significant start-up delay
4	Receiver's low absorptive capacity: modest experience with transferred production	Extensive learning-by-doing training of the receiver's personnel at sender Reducing the production output at the sender only gradually	Operational disruptions, such as quality non-conformances Supply disruptions, such as schedule disruptions	Large safety stock at the sender Rescheduling of activities	Material losses, such as scrap
5	Transfer product: engineering changes from the sender Receiver's low absorptive capacity	Minimize the modification of the transferred product-specification	Without preventive actions: operational disruptions, such as quality non-conformances, and supply disruptions, such as significant start-up delay	Without preventive actions: equipment adjustment to the new viscosity of the product material, and large safety stock at the sender	Without preventive/corrective actions: material losses, such as scrap

	Risk source	Preventive action	Supply chain disruption	Corrective action	Loss
6	Receiver's location: new subsuppliers at the receiver	Keep existing subsuppliers until the production steady-state Sender involved in subsupplier qualification Establish multiple sources of supply	Without preventive actions: supply disruptions, such as material shortages, schedule disruptions, or supplier bankruptcy	Without preventive actions: multiple corrective actions needed, such as safety stock and express transport	Without preventive/ corrective actions: material losses, such as lost sales and market share
7	Production transfer process	Apply a thorough transfer procedure from the start of the transfer, by help of an action plan	Without preventive actions: multiple supply disruptions possible	Without preventive actions: multiple corrective actions needed, such as safety capacity and reservation breaking	Without preventive/ corrective actions: multiple losses possible

Relationship 1 (Table II): Sender.Co and Receiver.ES were aware of potential risk sources related to the relation between them, such as the considerable geographical distance. To mitigate this risk, the transfer parties named PT managers at both sites and implemented a series of other preventive actions to ensure a close collaboration. Although the transfer parties named a Project Owner at Sender.Co and a Project Manager at Receiver.ES., Sender.Co did not name a Cross-locational Transfer Coordinator, even though it was recommended in the PT procedure, fearing that this additional management layer could negatively impact the information flow. Instead, an Action Plan Administrator was named at Sender.Co. However, this was the first time that the administrator had this role, and his responsibilities were not clear to all the personnel. According to the administrator, *'Many are thinking that I'm the captain of this ship because I update the TAP [Transfer Action Plan], but I'm just sitting with the map!'* The administrator felt that he did not have sufficient authority to require all the action owners to close their actions, and he often experienced that action owners were *'waiting with their action because another action is delayed.'* Moreover, at the end of the PT, the sender's and receiver's informants reported that status meetings had not been frequent enough, and thereby the tasks had not been sufficiently well-coordinated. All this unavoidably led to schedule disruptions and the need for corrective actions such as the repeated rescheduling of activities, overtime, and a high risk of material losses for both transfer parties. At the end of the PT, both transfer parties acknowledged that a cross-locational project manager should have been named in the early phase of the PT, and his/her role and responsibilities should have been clarified to the transfer personnel during joint meetings. Furthermore, the Action Plan Administrator and QA & Risk Manager (Sender.Co) reflected that during

future PTs, the Action Plan Administrator should hold regular status meeting with the transfer team to review whether the actions are closed or not.

Relationship 2 (Table II): The transfer parties also faced risk sources related to the receiver's 'absorptive capacity', such as when new equipment needs to be integrated into the receiver's production system. After Receiver.ES had purchased expensive machines, Sender.Co changed their product specifications and asked Receiver.ES to develop a new molding material. When the machines were tested, Receiver.ES found out that the equipment had to be modified because of the higher viscosity of the new material. Moreover, because of the long material development process and the delay of production start-up, Receiver.ES did not get any return on their investment on the new equipment for almost one year (an estimated loss of 30 000 EUR/ month). Thus, the demand changes after equipment purchase led to excessive equipment capacity, excessive inventory, and possibly other material losses. According to the transfer parties, had they signed a formal agreement freezing the modification of the transfer scope after signing the agreement, they could have avoided later changes of demand and subsequent losses.

Relationship 3 (Table II): The risk sources related to the Receiver.ES's absorptive capacity also included the 'immaturity' of the receiver's production site. The layout of the new production plant that Receiver.ES rented had to be modified, and the plant posed similar challenges to the transfer parties as a greenfield site. Receiver.ES lacked well-documented layout specifications from the sender when the modification of the new production plant started, and later, during the construction process, the sender recommended several changes. This led to several months of delay, to overtime, and to the rescheduling of activities. The construction project lasted for over half a year more than what Receiver.ES initially planned, significantly delaying the Start-up. In hindsight, the sender's and receiver's informants agreed that they should have collaborated closely when the layout plan was prepared and that they should have frozen the layout design after they agreed on the final version.

Relationships 4 and 5 (Table II): The transfer parties also faced several risk sources related to the modification of the transfer object before the Execution phase. Sender.Co's informants reported that the material R&D in combination with Receiver.ES's modest experience with sonar production was a major risk source during the sonars transfer. Preventive actions that were implemented to mitigate this risk included providing a video of the production process to the receiver, and long periods of hands-on training at the sender's site (e.g. up to ten months for Receiver.ES's assembly and molding operators).

Receiver.ES's personnel even produced the sonars autonomously at the Norwegian site and prepared a large safety stock prior to the start-up at Receiver.ES. Moreover, Sender.Co reduced the outputs only gradually as the production stabilized at Receiver.ES.

Despite of these preventive actions, disruptions (mostly in the form of schedule disruptions and quality nonconformances) and material losses (mainly scrap) occurred. Corrective actions primarily included the rescheduling of activities and extensive safety stock at the sender. The start-up began 10 months later than initially planned and informants from both transfer parties reported that the material R&D was one of the main reasons for this. At the end of the sonars transfer, the sender and receiver's informants reflected that one of the main things they learned from the sonars transfer was that *'the more significant the changes applied to the transferred production are [referring to the material R&D], the higher the risk level and the longer the transfer process can be'*. Interestingly, although the Start-up started much later than initially planned, the sender and receiver's informants evaluated it as a short process without notable supply chain disruptions, and the thorough training in Norway was often singled out as a success factor.

Relationship 6 (Table II): To avoid introducing additional risk sources, such as the risk of suboptimal material quality and service level, and material losses such as lost sales and market share, the only subsuppliers that the transfer parties changed before the production reached steady state were the ones providing molding materials; however, this increased the inbound logistics costs. Additionally, to ensure a rigorous qualification of all the new subsuppliers, the transfer parties implemented a change control process at Receiver.ES, with a requirement that qualifications must always be conducted in close collaboration with Sender.Co. In addition, during the transfer-risk assessment carried out by Receiver.ES, the personnel identified the risk that subsuppliers could unexpectedly stop their supply because of product or raw material shortages or supplier bankruptcy. Thus, necessary preventive actions were implemented to establish relations to secondary subsuppliers for standard items, and long-term partnerships with subsuppliers of bottleneck items.

Relationship 7 (Table II): Although the production start-up was delayed by 10 months, the transfer parties evaluated it as a short process (2 months) without notable supply chain disruptions. Apart from a thorough training in Norway, the transfer parties emphasized that the process was facilitated by the implementation of the transfer procedure and action plan, based on the preventive action-dimensions in Appendix 1. Both the Action Plan Administrator and QA & Risk Manager reflected that the PT procedure ensured that

preventive actions were implemented and thereby reduced the number of disruptions. Those interviewed at Receiver.ES emphasized that due to the implementation of the transfer procedure, the sender's assistance was more appropriate and timelier than during previous PTs. However, had they implemented the transfer procedure right from the start of the transfer, they could have avoided several of the delays and other disruptions, such as the purchase of unsuitable equipment and the disruptions during the construction process at the new plant. Furthermore, the Action Plan Administrator and QA & Risk Manager added that the procedure could have been a cloud-based solution.

6. Discussion

The purpose of this paper was to increase the knowledge about risk management during the PT process, by exploring relationships between risk sources, preventive actions, supply chain disruptions, corrective actions and losses during PTs.

This section discusses the key-relationships from the previous section in light of earlier research on production network coordination, particularly within the topics of network plant roles, and PT (risk) management.

6.1 Development of capabilities and plant roles during PTs

Earlier research shows that a PT process can be considered as successful if the receiver achieves a full-scale and stable production output (*steady state*) according to schedule and at the targeted performance levels (Terwiesch et al., 2001, Almgren, 1999). Performance measures can be related to the yield and quality during Start-up (ibid.), the cost and time to reach the steady state (Ferdows, 2006, Grant and Gregory, 1997), and to the receiver's capability development (Fredriksson *et al.*, 2019, Malm et al., 2016). The PT in the longitudinal study was not aimed at developing the receiver's capability from the beginning. However, the empirical findings show that the sender's decision to change the molding material required implementing capability development actions in order to decrease the PT risk. First, due to the material change the receiver developed their *product engineering capabilities*. Second, by modifying the production equipment and the product test system, and by developing the layout together with experienced personnel from the sender, they enhanced their *process engineering capability*. Third, through the extensive learning-by-doing training at the sender's plant and their contribution to the upgrading of production procedures, the receiver enhanced their *production capability*.

Finally, the receiver developed their *procurement and supplier selection capabilities* – due to the need to procure the necessary material for the transferred production and the need to select suppliers of raw materials for the new molding material. Thus, based on the plant roles literature (Ferdows, 2006), through the capability development the receiver's network role changed from a Server plant - a regional production plant, carrying out simple assembly activities, to a Contributor plant – a regional plant with material engineering, process engineering, procurement and supplier selection capabilities.

Even though these changes led to a higher PT risk, recent studies within production network coordination show that the receiver's capability development is fundamental for the network coordination (Szász et al., 2019, Fredriksson et al., 2019). For instance, it can be easier to transfer production to this receiver in the future and even easier to transfer more complex products (e.g. implying material development). A more static role for the receiver would have implied that the gap between their absorptive capacity and the sender's disseminative capacity was not bridged, and the transfer capability of the network as a whole was not developed (Szász et al., 2019). Thus, an insight from this study is the need to incorporate the *absorptive and disseminative capabilities* into the plant role descriptions, alongside Ferdow's product engineering capabilities, production capabilities, etc.

However, the receiver's new role as a Contributor may introduce new risk sources. For instance, the receiver's increased negotiating power in the network might decrease their willingness to collaborate with the sender in the future (Gelderman and Van Weele, 2003). Moreover, their increased knowledge of the sender's IP-technology may increase the risk of IP loss (Manuj and Mentzer, 2008). Thus, the question of how the changed roles of the transfer parties, and their changed network relationship can influence the network coordination risk, can be an intriguing avenue of further research. In addition, future research can investigate how the different roles of the sender and receiver can influence the transfer risk, for instance when outsourcing from a Lead plant to a Contributor plant, or when reshoring from Server to Lead.

Grant and Gregory (1997) highlight the advantages of applying changes to the transferred production process to improve its 'transfer fitness', for instance by replacing complex systems with systems that are more user-friendly to the receiver. This study shows that the transfer parties should be aware that changes may introduce both new risk sources and opportunities. Thus, an intriguing avenue of future research is whether

adapting the transferred products or processes to the receiver's production environment is a facilitator or an inhibitor of efficient PTs.

Furthermore, Grant and Gregory (1997) argue that the receivers are the ones that are best fit to adapt the transferred production to match their own production environment. For instance, the receiver may know local subsuppliers that deliver cheaper and high-quality components or raw materials. Conversely, Fredriksson et al. show that often receivers do not have enough competency to take charge of issues such as the qualification of new subsuppliers during the PT (Fredriksson et al., 2019). The receiver in the PT study undertook all of sender's subsuppliers, except for the new molding material where the receiver selected local suppliers. Thus, this study adds to Fredriksson et al., indicating that despite higher inbound logistics costs and other short-term disadvantages, it might pay off to only change the subsuppliers after the production reaches steady-state in order to avoid introducing additional risk sources to an already risky transfer process (see Relationship 6, Table II). However, Aaboen and Fredriksson (2016) acknowledge that if receivers are not given enough mandate during the transfer process, they may not integrate the transferred production well enough into their own production environment. Thus, the question of how much and when the sender should empower the receiver to adapt the production to their own environment and select new subsuppliers, thereby enabling further capability development, also requires further research.

6.2 Development of production network relationship through cross-locational PT management

Apart from the plant role development, the PT affected the relationship between the transfer parties – seemingly in a favorable manner. The similarity of the sender and receiver's perception of their relation (Oosterhuis et al., 2011) increased as they gained a shared understanding of their role in the network. Their relationship closeness (Fredriksson et al., 2014, Terwiesch et al., 2001) also increased significantly due to the production collaboration. However, the case findings also indicate that a cross-locational PT manager would have significantly facilitated the PT process (see Relationship 1, Table II). The PT literature shows that dedicating personnel to the PT at the sender (e.g. Fredriksson et al., 2015) and having a project manager at the receiver's site (Terwiesch et al., 2001) has a positive impact on the transfer outcome. However, surprisingly, the PT

scholars have so far paid little attention to the role played by the cross-locational project management, connecting the sender's and receiver's organizations during transfers.

The case findings also show that even though the transfer parties belong to the same firm, the cross-location management still implies signing a comprehensive formal agreement that specifies the responsibilities of the transfer parties and the transfer scope (Danilovic and Winroth, 2005, Franceschini *et al.*, 2003, Zhu *et al.*, 2001). Moreover, the transfer parties should freeze the modification of the PT scope after reaching an agreement, to avoid disruptions, such as the sender's 'last-minute' demand changes, which can lead to considerable material losses (see Relationship 2, Table II). By freezing the PT scope the transfer parties will avoid ending up in an unnecessarily long preparation phase, that can lead to rushed or extremely delayed PT execution and start-up - also a common challenge with R&D projects.

Furthermore, the in-depth study indicates that the transfer parties should collaborate closely when the layout plan is prepared. Apparently small omissions (cable trays, the location of pillars, utility connections, etc.) can lead to significant schedule disruptions (Kowalski *et al.*, 2018). Thus, preparing and agreeing on a comprehensive, updated, and timely layout plan ahead of the layout work can significantly facilitate the PT (see Relationship 3, Table II).

Finally, in line with WHO (2011), Zhu *et al.* (2001), and Terwiesch *et al.* (2001), this study's findings shed light on the importance of a thorough transfer procedure that should be implemented right from the start of the PT through an action plan (see Relationship 7, Table II).

7. Conclusion

The operationalization of production network coordination strategies (i.e. the PT) leads to increased supply chain risk (e.g., Chopra and Meindl, 2013, Kinkel and Maloca, 2009). The purpose of this paper was to increase the knowledge about PT risk mitigation, by exploring relationships between risk sources, preventive actions, supply chain disruptions, corrective actions and losses during PTs.

Table II summarises the key relationships that were identified in the longitudinal field study. Based on these, three topics of importance for PT success and for further research were derived and discussed: i) how the transfer influences the plant roles in a production network and how the plant roles influence the transfer risk, ii) to what extent cross-

locational project management is a facilitator of efficient PTs and collaboration between network nodes, and iii) whether adapting the transferred products and processes to the receiver's production environment is a facilitator or an inhibitor of efficient PTs.

Furthermore, this is one of the first studies of a PT, which takes the dyadic perspective of both the sender and receiver, and addresses both preventive and corrective actions and all the transfer phases. The paper also presents one of the first literature reviews of the five central concepts in this paper.

The findings about how to mitigate the transfer risk and the frameworks of risk sources, preventive actions, supply chain disruptions, corrective actions and losses, along with the examples from the in-depth study can aid the practitioners in managing PTs and achieving the production relocation goals.

The main limitation of this study is the fact that it is based on a single PT case. However, in longitudinal field studies the generalization is not towards the measurement of phenomena or the samples. Longitudinal studies are more interested in the meaning of phenomena and tend to rely on one or few cases. Thus, the generalization rather depends on the quality of the process of identifying sequences and patterns in the events, and on how well the collected theoretical and empirical evidence supports the findings (Ahlström, 2007, Karlsson, 2016, p.196). The research process is arguably robust in this paper due to the literature-based analytical framework used to collect and analyse the findings, and due to the depth of the PT study.

Nevertheless, future research should continue to investigate how PT processes can be conducted, to mitigate the transfer risk and facilitate successful production relocations. Moreover, it can investigate how the different roles of the sender and receiver can influence the transfer risk, for instance when outsourcing from a Lead plant to a Contributor plant, or when reshoring from Server to Lead.

Moreover, the digital transformation trend plays a central role in the future of production relocations. Innovative communication and monitoring technologies facilitate the management of globally distributed activities within production networks. (De Backer and Flaig, 2017, ManuFuture-EU, 2019). The communication technologies also enable less timely and costly co-locational project management, which is highlighted as a PT facilitator in this study. Furthermore, the benefits of advanced process simulation technologies should be investigated (Leng *et al.*, 2019), as they provide opportunities for modelling, dynamically simulating and real-time monitoring the impact of the PT on the production environment at the transfer parties. Furthermore, the five risk frameworks can

be subjected to additional empirical validation (e.g. during PTs with different characteristics), or even to large surveys with PT practitioners from various companies—with the aim of developing a toolbox for systematic PT risk management. Finally, the topic of pandemic and epidemic risk management prior, during and after PTs is an extremely intriguing avenue for future research. Potential supply chain disruptions that can be addressed include material shortages and price escalations, transportation disruptions, labor force absenteeism, supplier and subsupplier bankruptcy, schedule disruptions, information system disruptions and cyber-attacks.

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Appendix 1. Potential Risk Sources, Preventive Actions, Supply Chain Disruptions, Corrective Actions, and Losses during PTs, based on the existing literature

Risk sources	Preventive actions	Supply chain disruptions
<p>A. Related to the transfer object</p> <p>a) Production process and product:</p> <p>R1. The similarity of the transfer-object produced by the receiver to the object originally produced by the sender (if the transfer-object is modified, the risk level may increase) (<i>Tatikonda and Stock, 2003</i>)</p> <p>R2. Degree of internal modularity and external modularity (e.g. the risk level may be higher when the transfer-object is part of a larger system) (<i>Beckman and Rosenfield, 2008, Tatikonda and Stock, 2003</i>)</p> <p>R3. The amount of elements, configurations, and functions that the transfer-object has (e.g. BOM complexity) (<i>Tatikonda and Stock, 2003, Beckman and Rosenfield, 2008</i>)</p> <p>R4. The size of the product tolerances (small tolerances may increase risk level) (<i>Fredriksson et al., 2014</i>)</p> <p>R5. The facility to codify (document) the tacit knowledge about the object (<i>Tatikonda and Stock, 2003</i>)</p> <p>R6. The transfer-object's maturity (e.g. with well-defined processes) (<i>Tatikonda and Stock, 2003, Grant and Gregory, 1997</i>)</p> <p>R7. The relevance of the documentation (e.g. updated and representative) (<i>Tatikonda and Stock, 2003, Grant and Gregory, 1997</i>)</p> <p>R8. The facility to protect the Intellectual Property (IP) (<i>Grant and Gregory, 1997</i>)</p> <p>R9. Facility to find alternatives when adapting the production process to receiver's environment (<i>Grant and Gregory, 1997</i>)</p> <p>b) Planning and control:</p> <p>R10. Availability of raw materials (<i>Kraljic, 1983</i>)</p> <p>R11. The extent to which the manufacture of products is complete prior to customer order (e.g. made-to-order may be more risky than made-to-stock) (<i>Fredriksson et al., 2014</i>)</p> <p>R12. The certainty of customer demand (e.g. assortment and volume) (<i>Fredriksson et al., 2014</i>)</p> <p>B. Related to the sender</p> <p>a) Disseminative capacity:</p> <p>R13. The degree of experience sender has with transferring production (<i>Fredriksson et al., 2014</i>)</p> <p>R14. Sender's capability and willingness to make adaptations (<i>Grant and Gregory, 1997</i>)</p>	<p>A. Organization and Project Management (<i>WHO, 2011</i>)</p> <p>P1. Establish a project team with project managers and representatives from all the disciplines affected by the transfer and from both the sender and receiver. Assign a general project coordinator. Clarify the role and responsibilities of each member. (<i>Madsen, 2009</i>)</p> <p>P2. Establish a Process Improvement team with representatives from all the relevant disciplines and from both the sender and receiver. (<i>Fredriksson et al., 2015, Madsen, 2009, Terwiesch et al., 2001, Rudberg and West, 2008</i>)</p> <p>P3. Establish a Supplier Development team with representatives from all the relevant disciplines and from both the sender and receiver. (<i>Modi and Mabert, 2007, Dyer et al., 2000</i>)</p> <p>P4. Establish a Risk Management team with representatives from all the relevant disciplines and from both the sender and receiver. (<i>WHO, 2011</i>)</p> <p>P5. Organise a project start-up meeting with the sender's and receiver's personnel involved in the transfer. Announce the object of the transfer, reasons for the transfer, the relationship between the sender and receiver, expected performance targets, etc. (<i>Dudley, 2006, McBeath and Ball, 2012</i>)</p> <p>P6. Evaluate regulatory requirements in the sender's and receiver's countries and in any countries to where the product is to be supplied (<i>WHO, 2011</i>)</p> <p>P7. The sender and receiver to agree on performance targets (e.g. KPIs) and their continuous monitoring (<i>Terwiesch et al., 2001, Almgren, 1999</i>)</p> <p>P8. Sign a formal agreement. Include in the agreement specifications about expected performance targets and how to monitor those, profit and risk sharing, the rights to access confidential information, product ownership, Request for Proposal, etc. (<i>Danilovic and Winroth, 2005, Franceschini et al., 2003</i>)</p> <p>P9. Prepare a project management plan (<i>Terwiesch et al., 2001</i>)</p> <p>P10. The sender and receiver to hold regular status meetings and send meeting notes to all the affected personnel (<i>Rehme et al., 2013, Zhu et al., 2001</i>)</p> <p>P11. Create a Transfer Protocol that includes all the transfer documentation and is easily accessible to all of the sender and receiver's</p>	<p>A. Internal to the supply chain</p> <p>a) Supply disruptions (<i>Manuj and Mentzer, 2008</i>):</p> <p>D1. Material shortage (<i>Manuj and Mentzer, 2008</i>)</p> <p>D2. Material quality non-conformance (<i>Manuj and Mentzer, 2008</i>)</p> <p>D3. Material price escalation (<i>Manuj and Mentzer, 2008, Chopra and Sodhi, 2004</i>)</p> <p>D4. Supplier bankruptcy (<i>Manuj and Mentzer, 2008, Chopra and Sodhi, 2004</i>)</p> <p>D5. Schedule disruption (<i>Manuj and Mentzer, 2008, Chopra and Sodhi, 2004</i>)</p> <p>D6. Technology access disruption (<i>Manuj and Mentzer, 2008</i>)</p> <p>D7. Transportation disruption (<i>Chopra and Sodhi, 2004</i>)</p> <p>b) Operational disruptions (<i>Manuj and Mentzer, 2008</i>):</p> <p>D8. Equipment disruptions (e.g. breakdown or stoppage) (<i>Manuj and Mentzer, 2008</i>)</p> <p>D9. Quality non-conformance (<i>Manuj and Mentzer, 2008, Chopra and Sodhi, 2004</i>)</p> <p>D10. Yield non-conformance (<i>Chopra and Sodhi, 2004</i>)</p> <p>D11. Labour force disruption (e.g. illness) (<i>Chopra and Sodhi, 2004</i>)</p> <p>D12. Forecast error (<i>Chopra and Sodhi, 2004</i>)</p> <p>D13. Technology change (<i>Manuj and Mentzer, 2008</i>)</p>

Risk sources	Preventive actions	Supply chain disruptions
<p>R15. Facility to pilot and test the adaptations at sender prior to transfer execution phase (<i>Grant and Gregory, 1997</i>)</p> <p>R16. The possibility to reserve resources at the sender for necessary tasks during the transfer execution and start-up at the receiver (<i>Fredriksson et al., 2014, Fredriksson et al., 2015</i>)</p> <p>R17. Employees' motivation for the transfer (e.g. high when no lay-offs) (<i>Fredriksson et al., 2014</i>)</p> <p>C. Related to the receiver</p> <p>a) Absorptive capacity:</p> <p>R18. The receiver's experience with similar production (<i>Tatikonda and Stock, 2003, Fredriksson et al., 2014</i>)</p> <p>R19. The extent to which the receiver's existing equipment can be used (<i>Fredriksson et al., 2014</i>)</p> <p>R20. The production site's maturity (e.g. greenfield is more risky than brownfield) (<i>Cheng et al., 2010</i>)</p> <p>R21. Employee's productivity, educational level, language homogeneity and turnover (<i>Grant and Gregory, 1997</i>)</p> <p>R22. Production and packaging rooms, the testing/production/packaging equipment, inventory control mechanisms, documentation, the absence of banned substances, waste management, and other HSE aspects (<i>WHO, 2011</i>)</p> <p>R23. Layout and material flow, efficiency of space usage, levels of inventory and work-in-progress, duration of changeover, installation and maintenance protocols, planning and control, value chain information sharing and other data systems (e.g. level of integration between systems), order management, quality management (e.g. TQM), visual management (e.g. <i>Alfnes and NTNU, 2006</i>)</p> <p>R24. Workers' technical capabilities (e.g. to adapt the production process to their own environment and the use of leading technology) and organizational practices (e.g., customer focus, housekeeping) (<i>Alfnes and NTNU, 2006, Grant and Gregory, 1997</i>)</p> <p>R25. Level of teamwork and worker empowerment and flexibility (<i>Alfnes and NTNU, 2006</i>)</p> <p>R26. Employees' motivation for the transfer (e.g. high when no lay-offs) (<i>Fredriksson et al., 2014</i>)</p> <p>R27. The relational closeness within the supply chain (e.g. the receiver has close subsuppliers that deliver high quality items) (<i>Alfnes and NTNU, 2006</i>)</p> <p>b) Physical location:</p> <p>R28. The quality, cost, flexibility, service level, reliability, and proximity of local and international subsuppliers (<i>Chopra and Meindl, 2013, Grant and Gregory, 1997</i>)</p> <p>R28. The quality, cost, flexibility, service level, reliability, and proximity of local and international subsuppliers (<i>Chopra and Meindl, 2013, Grant and Gregory, 1997</i>)</p>	<p>personnel involved in the transfer. The protocol should be continuously updated (<i>Terwiesch et al., 2001, Ferdows, 2006</i>)</p> <p>P12. The sender and receiver to prepare a Communication plan. To include a Crisis management procedure and to address the impact of confidentiality on the open communication of technical matters (<i>Danilovic and Winroth, 2005, Norrman and Jansson, 2004</i>)</p> <p>P13. Reduce the outputs at the sender only gradually, as the production stabilizes at receiver (if possible) (<i>Fredriksson, 2011, Terwiesch et al., 2001, Minshall et al., 1999</i>)</p> <p>P14. Plan the transfer during a low customer-demand period (if possible) (<i>Madsen, 2009</i>)</p> <p>B. Quality Management (<i>WHO, 2011</i>)</p> <p>P15. Evaluate the receiver's readiness with regards to facilities, equipment and support services (e.g. by a Gap Analysis) (<i>Malm et al., 2016, Modi and Mabert, 2007</i>)</p> <p>P16. Assess the transfer risk. Include customs clearance and material supply risks (<i>Minshall et al., 1999, Fredriksson et al., 2015</i>)</p> <p>P17. Identify and implement preventive-actions to mitigate the risk of supply shortages (e.g. safety stock and safety capacity). Identify corrective-actions to mitigate the risk of supply shortages (e.g. overtime and express transports) (<i>Fredriksson et al., 2015, Gero and Stefan, 2009</i>)</p> <p>P18. Improve the transferability of the transfer-object (upgrade or replace obsolete equipment, codify tacit knowledge, etc.) (<i>McBeath and Ball, 2012, Madsen, 2009, Minshall et al., 1999</i>)</p> <p>C. Knowledge Transfer (<i>Fredriksson and Wänström, 2014</i>)</p> <p>P19. The sender and receiver to jointly develop a training plan (<i>Madsen, 2009</i>)</p> <p>P20. Train the receiver's personnel. Send personnel from the receiver to the sender for training and to improve the transferability of the production-system (<i>McBeath and Ball, 2012, Terwiesch et al., 2001, Madsen, 2009, Galbraith and Galbraith, 1990, Minshall et al., 1999</i>)</p> <p>P21. Transfer photographs and a video-taped review of the production process to the receiver (<i>Galbraith and Galbraith, 1990, Minshall et al., 1999</i>)</p> <p>P22. Define and implement a Change Control process at the receiver (<i>Terwiesch et al., 2001</i>)</p> <p>P23. Conduct activities to enhance the receiver's performance level (e.g., VSM, RCA, FMEA, Lean, Six sigma and APQP) (<i>Modi and Mabert, 2007</i>)</p> <p>P24. Verify Knowledge Transfer at the receiver (e.g. check documentation and test personnel) (<i>McBeath and Ball, 2012</i>)</p>	<p>D14. Information system disruption (<i>Chopra and Sodhi, 2004</i>)</p> <p>c) Demand disruptions (<i>Manuj and Mentzer, 2008</i>):</p> <p>D15. Sudden demand change (e.g. volume and assortment) (<i>Manuj and Mentzer, 2008</i>)</p> <p>D16. Bullwhip effect (<i>Manuj and Mentzer, 2008, Chopra and Sodhi, 2004</i>)</p> <p>D17. Payment disruption (<i>Chopra and Sodhi, 2004</i>)</p> <p>d) HSE disruptions:</p> <p>D18. Product safety non-conformance (<i>Manuj and Mentzer, 2008</i>)</p> <p>D19. Chemical/physical/biological/radiological hazardous event (e.g. fire) (<i>Manuj and Mentzer, 2008</i>)</p> <p>B. External to the supply chain</p> <p>a) Natural disasters (<i>Chopra and Sodhi, 2004</i>):</p> <p>D20. Earthquake, pandemic, etc. (<i>Chopra and Sodhi, 2004</i>)</p> <p>b) Labour strikes (<i>Chopra and Sodhi, 2004</i>)</p> <p>c) Security disruptions (<i>Manuj and Mentzer, 2008</i>):</p> <p>D21. Hacking of information system (<i>Manuj and Mentzer, 2008</i>)</p> <p>D22. Computer virus (<i>Chopra and Sodhi, 2004</i>)</p> <p>D23. Infrastructure disruption (<i>Manuj and Mentzer, 2008</i>)</p> <p>D24. Freight breach (e.g. by vandalism or sabotage) (<i>Manuj and Mentzer, 2008</i>)</p> <p>D25. Armed conflict (<i>Chopra and Sodhi, 2004</i>)</p> <p>D26. Terrorism (<i>Manuj and Mentzer, 2008, Chopra and Sodhi, 2004</i>)</p> <p>e) Macroeconomic disruptions</p>

Risk sources	Preventive actions	Supply chain disruptions
<p>R29. The appropriateness of the quality, cost, and availability of local utilities (<i>Grant and Gregory, 1997</i>)</p> <p>R30. The appropriateness of the space and format of buildings (<i>Grant and Gregory, 1997</i>)</p> <p>R31. The appropriateness of tele-communications, road, rail, shipping and airfreight infrastructure (<i>Chopra and Meindl, 2013, Grant and Gregory, 1997</i>)</p> <p>R32. The appropriateness of import duties (<i>Chopra and Meindl, 2013, Grant and Gregory, 1997</i>)</p> <p>R33. The appropriateness of quotas, labor law, government emission regulations, planning permission regulations, approval and licence requirements, and other legal demands (<i>Grant and Gregory, 1997</i>)</p> <p>R34. The appropriateness of the cost of capital, land, inventory, and the foreign exchange requirement (<i>Grant and Gregory, 1997</i>)</p> <p>R35. The appropriateness of the local temperature range, humidity level, and air quality (<i>Grant and Gregory, 1997</i>)</p> <p>R36. The appropriateness of the receiver's location in terms of geo-risk (e.g. if area is prone to natural disasters) (<i>Kraljic, 1983</i>)</p> <p>R37. The level of governmental stability (<i>Kraljic, 1983</i>)</p> <p>R38. The closeness between job positions (e.g. manager-operator) (<i>Grant and Gregory, 1997</i>)</p> <p>R39. Individuals' willingness to assume responsibility and the appropriateness of receiver's approach to problem solving and quality perception (<i>Grant and Gregory, 1997</i>)</p> <p>D. Related to the sender-receiver relation</p> <p>a) Earlier relation and physical proximity:</p> <p>R40. The degree of experience the sender and receiver have with transferring production between them (<i>Tatikonda and Stock, 2003, Fredriksson et al., 2014</i>)</p> <p>R41. The relationship closeness between sender and receiver (<i>Fredriksson et al., 2014, Terwiesch et al., 2001</i>)</p> <p>R42. The similarity of the transfer parties' perception of their relation (<i>Oosterhuis et al., 2011</i>)</p> <p>R43. The physical proximity between related processes (e.g. the development and manufacturing units) after transfer-execution (<i>Fredriksson et al., 2014, Terwiesch et al., 2001</i>)</p> <p>R44. Sender's and receiver's negotiating power (<i>Kraljic, 1983</i>)</p>	<p>D. Transfer of Administrative Systems (<i>Fredriksson and Wänström, 2014</i>)</p> <p>P25. Prepare a list of items and documentation to be transferred. Specify transfer means, if purchases are required, costs and lead-times to the receiver (<i>Minshall et al., 1999</i>)</p> <p>P26. Review, update and create missing documentation. Translate documentation, if necessary (<i>McBeath and Ball, 2012, Fredriksson et al., 2015, Terwiesch et al., 2001, Minshall et al., 1999</i>)</p> <p>P27. The sender to provide the receiver information on all HSE issues associated with the transfer-object: material safety data sheets, inherent risks (e.g. exposure limits), exposure-mitigation actions, emergency planning (e.g. in case of fire), waste management, etc. (<i>WHO, 2011</i>)</p> <p>P28. The sender to transfer all the necessary information. The receiver to review the information from the sender, identify gaps (in facilities, systems, capabilities, testing methods, etc.), and notify the sender. Thereafter the receiver should develop documentation (e.g. operating procedures) based on this information. (<i>WHO, 2011</i>)</p> <p>P29. Make robust forecasts (of start-up time, new lead times, new quality levels, learning curve, etc.) (<i>Fredriksson et al., 2015, Minshall et al., 1999, Steenhuis and De Bruijn, 2002</i>)</p> <p>P30. Update the planning and control systems (e.g. ERP) (<i>Fredriksson et al., 2015, Minshall et al., 1999</i>)</p> <p>E. Supply Chain Transfer (<i>Aaboen and Fredriksson, 2016</i>)</p> <p>P31. Establish relationships to sub-suppliers of raw materials, components, parts, etc. (<i>Aaboen and Fredriksson, 2016</i>)</p>	<p>(<i>Manuj and Mentzer, 2008</i>):</p> <p>D27. Wage/interest/exchange rate escalation (<i>Manuj and Mentzer, 2008</i>)</p> <p>D28. Price escalation (e.g. fuel) (<i>Manuj and Mentzer, 2008, Chopra and Sodhi, 2004</i>)</p> <p>e) Policy disruptions (<i>Manuj and Mentzer, 2008</i>):</p> <p>D29. Quota restriction (<i>Manuj and Mentzer, 2008</i>)</p> <p>D30. Sanction (<i>Manuj and Mentzer, 2008</i>)</p> <p>D31. Tax/fee escalation (<i>Manuj and Mentzer, 2008</i>)</p>

Appendix 2. Examples of risk sources, supply chain disruptions, losses and preventive and corrective actions during the sonars transfer

Risk-sources in the case	Examples of preventive actions	Supply chain disruptions	Examples of corrective actions	Potential losses
In the area where Receiver.ES was located, there were good material technology experts, and Sender.Co wanted to increase the robustness of the transferred products. Thus, they commissioned Receiver.ES to develop a new moulding material (R1), and Receiver.ES employed a researcher with a PhD in Material Technology in this regard.	Sender.Co and Receiver.ES established a Process Improvement team with representatives from both parties (P2). Receiver.ES's R&D specialists went to Norway for training (P20). The moulding operators received between 6-10 months of learning-by-doing training. Sender.Co provided to the R&D specialists the necessary documentation to start the R&D, and the specialists developed the documentation related to the new material (e.g. operating procedures and procedures for problem-solving), with assistance from the rest of the Improvement team (P28). The Process Improvement team held frequent (often weekly) status meetings (P10). For all the changes applied to the transferred production, the transfer parties implemented Sender.Co's Change Control process at Receiver.ES's (P22) purchasing, warehouse, and production departments. Sender.Co reduced the outputs only gradually as the production stabilized at Receiver.ES (P13).	Schedule disruptions (start-up started 10 month later than initially planned) (D5); quality non-conformances (D9) such as air bubbles in the new molding material (until it stabilized). Moreover, when the material blending machines were tested, Sender.Co and Receiver.ES found out that the machines did not work because the viscosity of the new moulding material was higher than the old one.	Rescheduling (C8), large safety stock at receiver (C1). Moreover, part of the machines and all the moulds had to be adjusted to the new viscosity.	Scrap (L10) and other materials losses (L23) Ca. 30 000 EUR/month lost, shared equally between Sender.Co and Receiver.ES.
Receiver.ES had limited experience with sensor production (R18). However, they had successfully taken over production from Sender.Co before, the assembly of a subassembly.	A crisis procedure (when/how/whom to alert) was implemented (P12). Sender.Co reduced the outputs only gradually as the production stabilized at Receiver.ES (P13). Hands-on training was held at Sender.Co (the assembly and moulding operators for several months) (P20). The production process was videotaped (P21). Receiver.ES's operators produced autonomously at Sender.Co for several months prior to Start-up (P24). Regular and frequent status meetings were held (P10). Sender.Co evaluated Receiver.ES's facilities, equipment and support services during the visit in Nov. '16 and identified gaps compared to Sender.Co's environment (P15) (thus, several new preventive actions were added to the transfer plan). Sender.Co sent personnel during Execution and Start-up to provide assistance to Receiver.ES.	Schedule disruptions (D5)	Rescheduling (C8), large safety stock at receiver (C1)	Scrap (L10), other materials losses (L23) (ca. 30 000 EUR monthly shared equally between Sender.Co and Receiver.ES)
During the visit in Spain, the transfer parties decided to implement Sender.Co's ERP production module at Receiver.ES, with which Receiver.ES did not have experience. At that point, Receiver.ES was using a planning and control system developed in-house that, according to Sender.Co, could not	Receiver.ES's personnel travelled several times to Norway for ERP training (P20). Sender.Co verified the ERP implementation before the Execution phase (preventive action added by Sender.Co and Receiver.ES to the preliminary Transfer plan).	NA	NA	NA

Risk-sources in the case	Examples of preventive actions	Supply chain disruptions	Examples of corrective actions	Potential losses
cope with the increasing amount of product variants. (R18)				
Most of Receiver.ES's equipment could not be used for this production. It had to be either purchased or transferred from Sender.Co. (R19)	NA	Sudden demand change (D15) . The equipment was purchased ca. 1 year prior to Prototype & Pilot phases. Sender.Co required Receiver.ES to develop a new molding material after the equipment had been purchased, which delayed the process considerably.	Rescheduling (C8) . Moreover, part of the machines and all the moulds had to be adjusted to the new viscosity.	Excess capacity (L12) , excessive inventory (L11) , and possible other material losses (in total, ca. 30 000 EUR monthly shared equally between Sender.Co and Receiver.ES)
Because of increasing production activities, Receiver.ES had to buy new premises to move to before Start-up, and the layout inside the building had to be modified (R20) .	None significant. Receiver.ES did not have clear and complete specifications about the layout when they started to modify the interior of the new building. Sender.Co recommended several changes throughout the construction process.	Schedule disruption (D5) . The construction workers that were contracted for the 1st part of the building project submitted too costly an offer for the 2nd part, and the process of contracting new builders delayed the process approximately three months. Quality non-conformances (D9) ; schedule disruption (D5) . For instance, during their visit at Receiver.ES in Nov.'16, Sender.Co's personnel required some layout modifications that had not been specified before.	Rescheduling (C8) ; Overtime (C10) . The modifications were easy to make since the construction workers had only recently started with the work.	Material losses because of delays (ca. 30 000 EUR monthly shared equally between Sender.Co and Receiver.ES) Possible material losses because of the modifications
Apart from the subsuppliers of molding raw materials that were selected by Receiver.ES, Sender.Co and Receiver.ES decided to maintain the existing subsuppliers throughout the transfer. (R28)	Sender.Co and Receiver.ES defined and implemented a Change Control process at the receiver (P22) to ensure that the new subsuppliers are rigorously qualified together with Sender.Co. Moreover, Receiver.ES's personnel conducted a transfer risk assessment (P16) and identified a certain risk that subsuppliers could unexpectedly stop their supply. Thus, it was decided to establish a long-term partnership with critical vendors and have agreements with secondary subsuppliers for standard items.	NA	NA	NA
Sender.Co's and Receiver.ES's sites were located far from each other. Therefore, had a frequent	During the first validation workshops in Sept. '16, Sender.Co's personnel established a project with representatives from all the	Schedule disruptions (D5)	Rescheduling (C8) , Overtime (C10)	Possible material losses, such as stock-

Risk-sources in the case	Examples of preventive actions	Supply chain disruptions	Examples of corrective actions	Potential losses
<p>transfer of personnel between sites been needed, it would have been very costly for both parties. However, the distance between the development and manufacturing of the acoustic technology and the distance between the development and manufacturing of the moulding material were small since the processes were collocated at Sender.Co and Receiver.ES, respectively. Moreover, although the availability and transportation of acoustic technology might delay the assembly of the sensors, the transportation means were reliable, and Sender.Co and Receiver.ES were located in the same time zone. (R43)</p>	<p>disciplines affected by the transfer and with project managers at both Sender.Co and Receiver.ES (P1). In addition, cross-locational Process Improvement (P2) and Risk Management teams (P4) were created. The team members' roles and responsibilities, as well as main contact points for each member at the other transfer party were documented in an organization chart for the transfer (P12). This chart was stored in an electronic directory (a transfer protocol) that could be accessed by both transfer parties (P11). The Transfer Action Plan and all the future transfer documents would be stored in this directory. Other actions were organising a joint Kick-off (P5) and regular status meetings (P10), as well as providing Receiver.ES a videotape of the production process (P21). However, the workshop participants did not name a cross-locational PT manager, as was recommended in the Transfer Procedure (see P1), fearing that an additional management layer could have a negative impact on the information flow. An Action Plan Administrator was named instead.</p>	<p>The actions owners did not always updated the status of the actions when the Action plan administrator asked them to, and sometimes the administrator felt that he did not have sufficient authority to facilitate the closing of the actions as scheduled.</p>		<p>out, for both Sender and Receiver</p>