# Creating Supply Chain Resilience Through Scenario Planning

How a Digital Twin Can Be Used To Enhance Supply Chain Resilience Through Scenario Planning

Joachim Lindquist, Arla Supply Chain
Henning de Haas, Aarhus University

Title Page

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Henning de Haas

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## About the authors

Joachim Lindquist, MSc in Technology Based Business Development, is a specialist in Industry 4.0 / Supply chain 4.0, Supply Chain Maturity, Design and the use of digital twins for scenario planning. His practical supply chain experience covers a number of different roles and responsibilities in Arla Foods. https://www.linkedin.com/in/joachimlindquist/

Henning de Haas, Ph.D. is an Associate Professor at Aarhus University, Department of Business Development and Technology, and owner Haas Learning&Leadership consulting. Teaching areas cover Supply Chain- and Operations Management, Sustainable Supply Chain Management and Learning and Leadership. The practical supply chain experience covers a number of different leadership-, specialist- and consultant roles in companies like Bang&Olufsen A/S, LEGO System A/S, AGCO Corp, KK WindSolutions A/S, Vestas Windsystems A/S. Focus on a passion for people, learning, leadership and technology in supply chain. https://www.linkedin.com/in/henning-dehaas/

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## Executive Summary

This book focusses on the concept of supply chain disruptions and how supply chain resilience can contribute to both preparing for and reacting to the event causing disruption. Scenario planning will be explained and it will be looked into how scenario planning can be a contributing factor to ensure supply chain resilience through the creation of a digital twin of the supply chain system to enable scenario testing on the system. The case examples are retrieved from the supply chain of Arla Foods' butter, spread and margarine products (BSM-products).

To work within the areas of supply chain disruption, supply chain resilience and scenario planning it is important to understand what they actually are. The understanding of the topics will create a basis for working with the theories and link them together to increase the preparedness and reaction time to the events causing disruptions for companies. Building the digital twin of Arla's BSM supply chain, a software named Supply Chain Guru has been used. The software is a supply chain design tool which can be used for different kinds of supply chain network optimisation. To build the digital twin within Supply Chain Guru, knowledge and data of the current supply chain system is required. An AS-IS description of the physical supply chain is presented. The digital supply chain system will be used as basis to run different scenarios, through Supply Chain Guru, and thereby see the suggested solutions from Supply Chain Guru and investigate how these are contributing to creating supply chain resilience.

Scenario planning is defined in the theoretical framework as is also the process for how to develop scenarios. In this e-book four scenarios are developed to be able to do scenario planning in the BSM supply chain of Arla. The four scenarios are: Covid-19 lockdown, Brexit without deal, Conflagration at a dairy and Political regulations on transport. The scenarios all contain a problem that needs to be solved. This problem is considered as the main disruption for the supply chain. Running the scenario in Supply Chain Guru, constraints are added to the AS-IS model. The constraints are identified as implications of the event in the scenarios. By adding the constraints and running the model, Supply Chain Guru identifies suggestions to solve the problems which were described. The solutions within the scenarios are held up against the theory of supply chain resilience, to describe how the scenario planning can be used to enhance supply chain resilience

Finally, discussions and reflections on the above analysis and statements are provided. The discussions are regarding how scenario planning can be related to supply chain resilience as well as how scenario planning can be used to increase supply chain resilience. The discussion section also looks into what it requires, concerning digitalisation and data, to work with scenario planning through a digital twin. Furthermore, the consequences and paradoxes of working with supply chain resilience are reflected on and discussed.

# 1 Introduction

This book is written based on a Master's Thesis report in which it has been researched how scenario planning through the use of a digital twin of a supply chain, can be a contributing factor to supply chain resilience and thereby exploring possibilities on how to act ahead of possible supply chain disruptions and thus prepare for the unknown future.

## 1.1 Background description

Supply chains are the veins of companies. These veins can have costly consequences for companies, leading to companies striving for cost efficient supply chains, where all non-value-adding parts are discarded, and there is a continuously goal to be efficient. However, supply chains can be vulnerable when unforeseen events happen. The best example of such an event is the Covid-19 pandemic the world society is facing as this is written, spring 2021. The pandemic has, until now, meant that more countries have shut down their society for months leading to supply chains standing still. Having a stagnated supply chain leads to financial pressure and it affects the bottom line of companies as well as whole societies. When having vulnerable supply chains, it makes sense to start opening up topics on how to strengthen the supply chain and prepare it for the unknown future and the events that might happen which in worst case could stun the supply chain. This could be natural disasters, economic crises, global pandemics or even political decisions and regulations. To be able to predict and foresee which actions can be taken in the future to accommodate these events, companies need to emphasise even more on how to prepare their supply chain for the unknown uncertainties in the future.

Arla Foods amba is owned by farmers across Europe and has its headquarter located in Viby, Denmark (Arla, 2020). Arla produces food in the dairy industry for markets across all the world. The raw material is quite easily accessible for Arla as the owners, farmers, are providing the raw materials for the supply chain of Arla by yielding milk from the main resources, cows. Arla offers a wide variety of brands where some of the most famous are Castello, Cheasy, Buko, Kærgården and Lurpak. The many brands mean that there is a great variation in products produced and offered to the markets as the portfolio consists of yoghurt, cheese, butter, milk, chocolate milk, skyr etc. Most recently Arla has also entered the market of plant-based products.

Having many different brands and product categories complicates the supply chain of Arla and it can be complex to focus on all products within the supply chain at the same time. Therefore, Arla has divided their products into three main categories; MYPC (Milk, Yoghurt, Powder, Cooking), BSM (Butter, Spreadable, Margarine) and cheese. This means that the supply chain is differentiated according to the category split. Arla is, as other companies, facing an uncertain future with different threats of supply chain disruptions and needs to consider how to accommodate these possible unforeseen issues. Since Arla is a world known cooperative with a revenue, in 2019, of 10.5 B.EUR (Arla Foods, 2019) it reflects that Arla is a company of a size where technologies and digital solutions can and should play a vital role when optimising and preparing the supply chain for possible upcoming uncertainties in the future.

In order to accommodate possible future supply chain disruption, the obvious next move for Arla is to look into how digitalisation and technologies can play a part in developing supply chain resilience. Scenario planning on different levels of the supply chain design can be a powerful tool when investigating supply chain resilience and when creating understanding of which actions to take when the unforeseen occurs. Considering the aspects of resiliency and cost-effective, streamlined supply chains, an interesting paradox occurs. This paradox can be used in an effective way to gain advantages, and at the same time reduce the vulnerability of supply chains.

## 1.2 Purpose of the book

The purpose of this book is to research how scenario planning can contribute to supply chain resilience. By use of the technology "digital twin", the supply chain was digitalised, to be able to run different developed scenarios. A software solution called Supply Chain Guru, created by the company Llamasoft and provided by Optilon, was used to facilitate the digital twin and run the scenarios. By running the scenarios, insight, inputs and possible solutions on how to react on supply chain disruptions was created, assessed and compared to theory. The insights of scenario planning through a digital twin were the foundation for analysing how scenario planning can be used in regards to develop supply chain resilience. Based on the above a research question was stated:

*"How can supply chain resilience be enhanced through scenario planning?"*

In order to support the research question, four sub-questions were created, and answered throughout the research;

- What are scenarios and scenario planning?
- How is a digital twin developed?
- How does Arla's supply chain react to disruptions?
- What are the implications of supply chain resilience?

## 1.3 Structure of the research

This book is structured into four sections. The four sections are a guide through the research. The research is structured according to, 1) The theoretical framework, description of the AS-IS supply chain of the case, but anonymised. 2) The analysis through creation of a digital twin and development of scenarios containing disruptions. 3) The analysis is based on knowledge gained from the theoretical framework as well as the current situation stated. 4) The results and finding from the analysis are discussed and reflected on. The discussion part holds up the analysis results against the theoretical framework and focus on the problem formulation. The four sections are visualised in figure 1.

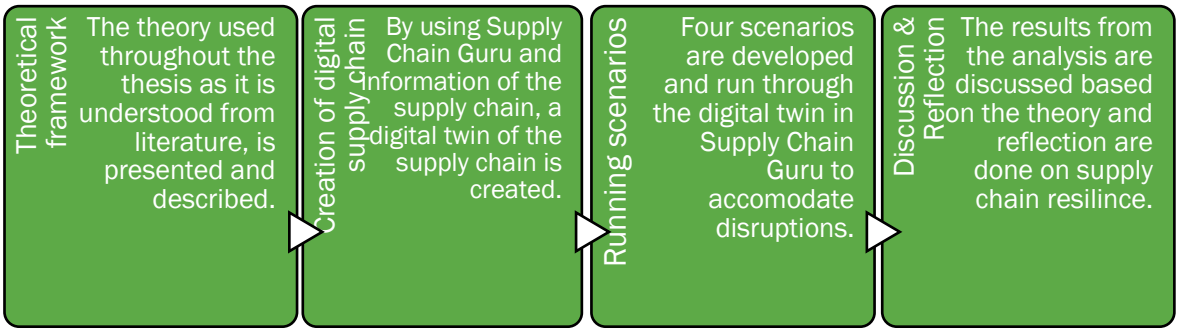


*Figure 1, Book structure overview, own production*

# 2 Research Method

The research has been conducted based on different data. Both quantitative and qualitative. The quantitative data has been manipulated in order to blur the actual data from Arla. The qualitative data comes from different kind of fieldwork that is summarised in the following table (figure 2).

| Participation ID | Fieldwork technique | Source | Purpose | Output |
|---|---|---|---|---|
| A | Webinar | Professor CBS / Optilon | Inspiration on supply chain disruption and resilience | Presentation of Supply Chain Disruptions and example on how Ericsson approached a disruption |
| B | Interview | Supply Planner, Arla Foods | Obtaining data and knowledge on current supply chain set-up for the Danish market | A description of the supply chain set-up for the Danish market, as well as a description of how the supply planner operates the supply chain of BSM |
| C | Training sessions | Senior Business Consultant, Optilon | Training in Llamasoft's Supply Chain Guru | Competencies on how to build systems in Supply Chain Guru and how to use it as a tool for supporting scenario planning |
| D | Webinar | Optilon | Inspiration on supply chain trends and knowledge on supply chain design | Additional knowledge on supply chain design and how to approach it, and the newest trends within SCM |
| E | Interview | Senior Strategy and Design Consultant in Supply Chain, Arla Foods | Gaining knowledge on current work with digitalisation in Arla as well as understand how disruptions and resilience have affected work with supply chain formerly | Introduction to strategies and design supply chain-wise in Arla foods. Presentation of the implications of latest disruption, Covid-19. Also, presentation of work with supply chain resilience |
| F | Youtube | IKEA - Supply Chain Conference 2017 | Understand how IKEA has used Supply Chain Guru for their supply chain network optimisation | A thorough description of the use of Supply Chan Guru at IKEA both for optimisation and organisational-wise. Also, examples on how to use Supply Chain Guru |
| G | Questionnaire | Global Production Planner specialist, Arla Foods | Getting insight in the production within the BSM supply chain | Descriptions of production at Holstebro dairy as well as numeric data such as capacities and demands |
| H | Interview | Senior Specialist Supply Chain Innovation, LEGO | Understand how LEGO has used Supply Chain Guru and worked with resilience | A description of how LEGO uses supply chain design tools and to which extent. Also, descriptions of how LEGO reacted on Covid-19 and how they work with supply chain resilience |
| I | Interview | Business Consultant, Optilon | Get further understanding of Supply Chain Guru features, such as $CO_2$ and how it has been applied at IKEA | A presentation of how IKEA has been working with transportation $CO_2$-wise. Also, a thoroughly description of how the work with SCG at IKEA has been conducted |

*Figure 2, Overview of fieldwork, own production*

## 2.1 Disclaimers

Since the supply chain of Arla is very complex due to the big number of different products running through it, it is more suitable to differentiate the supply chain and only focus on certain products. It has been chosen to focus on the Butter product category in the research, meaning products outside this product category has not be taken into consideration. Also, due to many links and notes in the supply chain, every aspect and processes of the supply chain cannot be taken into

consideration. Therefore, the research was based on the network of the supply chain rather than looking into the different actors and processes of these, such as production or purchasing. As Arla is operating on many different markets around the world, it was decided to delimitate these markets to the German market, the Danish market and the British market, in order to reduce complexity.

In the research the software Supply Chain Guru was used. To use the software to its full extent is very complex and it takes a lot of time to learn and use it. Therefore, the use of the software was done in a simpler manner to be able to get a useful output of the application. Using Supply Chain Guru at a simpler level means that there is a risk of the analysis not being as extensive as if Supply Chain Guru was used to its full extent. On the other hand, using Supply Chain Guru on a simple level supports very well answering the problem formulation and can to a high extent fulfil the purpose of creating a digital twin for scenario planning.

As already mentioned, all data related to Arla Foods has been anonymised in order to blur the actual data. The data has been multiplied with a factor meaning, the data is showing the actual situation. However, this has not impacted the analysis and output of it, since the results are the same, with the factor in mind.

# 3 Theoretical Framework

To state the relevant theory for the research a theoretical framework has been developed. The framework describes the theories that was worked with in the research to create an understanding of what it implies. Also, the theoretical framework describes what is considered as the reality of understanding of the concerned theories for the research. Furthermore, examples from the real world are provided to add a practical understanding of the theory as well. To visualise the theoretical framework an onion model has been created. The model describes the core of the theory and how extra layers add on to the knowledge base. The onion symbolises that the centre is the theoretical area from which the following layers of theory spring, like when an onion grows.

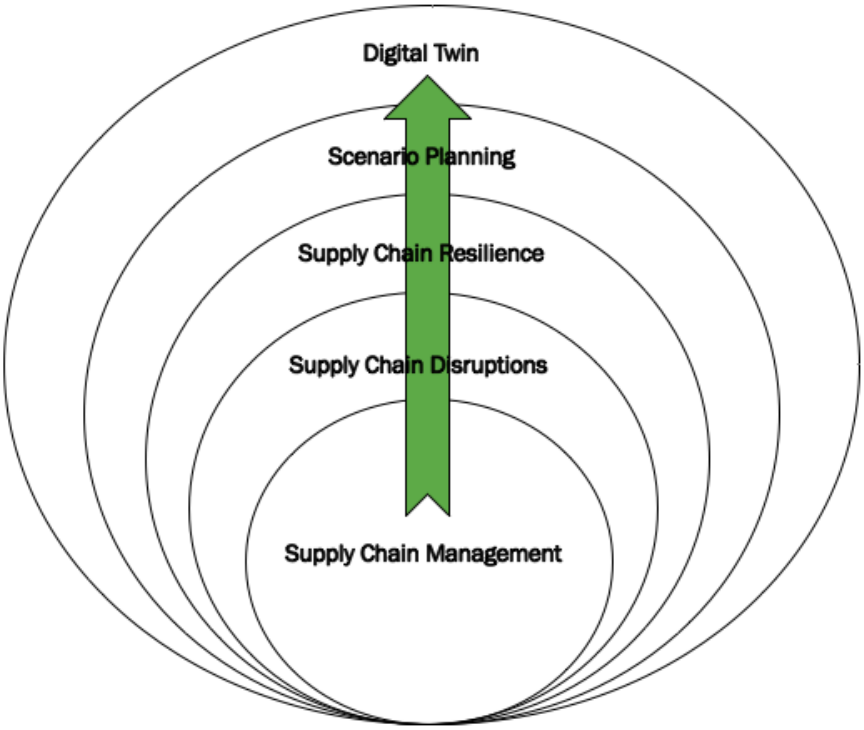


*Figure 3, Onion model, own production*

The theoretical framework, which creates a basic understanding, has its core in Supply Chain Management. The layers added on the Supply Chain Management are Supply Chain Disruptions, Supply Chain Resilience, Scenario Planning and Digital Twin. Furthermore, to top up, the theoretical framework will present and describe what paradox theory is, to be able to discuss the paradoxes of supply chain resilience.

## 3.1 Supply Chain Management

Supply chain management (SCM from here) is in the centre of the theoretical framework for this book. Douglas M. Lambert is used as the basis for setting the frame of SCM for this research and creates the common standpoint of what SCM is. According to Lambert (1998, p.1) SCM is "*the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers, and other stakeholders.*". Considering this statement, SCM can be boxed in as the network of businesses that adds value to a product or service. Lambert later states that SCM is misunderstood by practitioners, consultant and academics, as being either logistics, purchasing or operations management. His comprehension of SCM is that it is not a chain of businesses, but rather a network of businesses and relationships,

meaning that the management of relationships and network is the main task in SCM (Lambert, 2008). To back that up Lambert (2008) states that *"At the end of the day, supply chain management is about relationship management. A supply chain is managed, link-by-link, relationship-by-relationship, and the organizations that manage these relationships best will win."*

Knowing that SCM is about the relationships in the supply chain network between businesses, it gives a broader understanding to dive into and look at the internal perspective of SCM. Between supply chain professionals it is a common thing that SCM is not only for the operation, purchasing or logistic departments, but is regarding every business function. Thomas Blackstock, who was vice-president of supply chain operations at Coca-Cola 1988-2006, said in a speech in (2005) that *"supply chain management is everybody's job"*. This statement is backed up by John Gattorna (2006)

> *"We have to embrace a far more liberal view of the supply chain. In effect, the supply chain is any combination of processes, functions, activities, relationships, and pathways along which products, services, information and financial transactions move in and between enterprises. It also involves any and all movement of these from original producer to ultimate end-user or consumer, and everyone in the enterprise is involved in making this happen."*

Based on the two above quotes, SCM cannot only be considered as a task for logistics, purchasing and operations, as Lambert also states. It needs to involve every aspect of the business, from sales, customer service, logistics, purchasing to marketing. Every aspect of the company that adds value to the product or service, and that maintains the relationship must be considered as part of the supply chain and thus responsible for managing the supply chain. Understanding this means that SCM is not only about looking at different aspects of the supply chain, but having a more holistic view on the synergies both inter- and intraorganizational.

Christopher (2005) has the same view on SCM as Lambert. He considers SCM as a question of maintaining and working with network and relationships. He visualises the network of the supply chain as illustrated below.

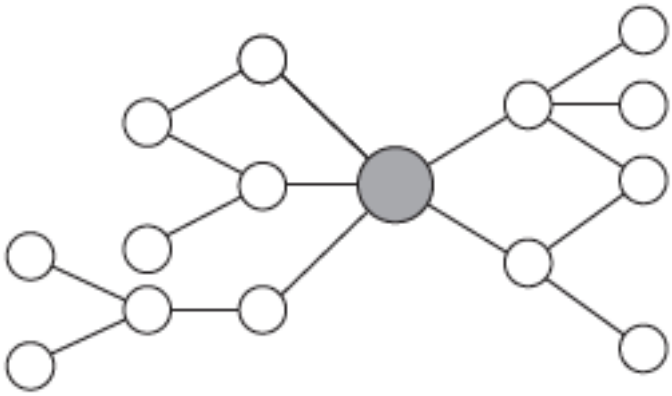

*Figure 4, The supply chain network, Christopher (2005), p.5*

A map like the one above invites to investigating in the physical aspect of SCM. The grey dot in the middle of the network is the focal company of the supply chain network, from whose point of view the supply chain is seen. The network consists of suppliers and customers, called tiers. The levels after the nearest tiers are called sub tiers. The dots are also called notes, which will be the standard for this book when looking at similar maps. According to Christopher (2005), SCM consists of physical aspects bonding the supply chain network together. The aspect which is one of the main fac-

tors in SCM, is time. Time is considered as, maybe, the most valuable resource. In a SCM perspective, time can be calculated and considered in lead time. Lead time can be considered as "time to market". Investigating further into this, Christopher (2005) says that lead time is the time from when the product/service is in its design phase till it hits the market. Lead time can also be considered as the time from placing an order at the supplier to receiving the goods. Holding time up against the above map, it is important to be aware of the time spent from the two sub tiers nearest to the edges of the network chain. Other factors that play a role in the SCM are obviously costs. The cost of getting the product/service to the market contributes to the valuation of the product and being cost efficient potentially leads to profits for companies. Time and costs are considered as competitive factors as well. When trying to be a competitive supply chain, time and cost are in many cases the decisive competitive parameters.

Demand and supply are other aspects that need to be managed when working with SCM. The demand should be fulfilled, and the supply should be accurate. In other words, the demand and supply need to be balanced, while still monitoring and optimising time and cost. These factors and parameters will through the book be understood as the decisive factors when assessing supply chains and managing supply chains (Christopher, 2005). Linking this to the former descriptions of SCM, it makes good sense that maintaining the network and relationship in supply chains is about monitoring time and costs of the network.

In conclusion, SCM is in the research understood as the management of network and relationships within the supply chain. The supply chain consists of many different links, both internal and external, and every business process considered contributory in changing raw materials into products or services for the end-user is considered a part of the supply chain and thus of SCM. Different aspects are important when working with SCM, as time and cost are factors that need awareness when balancing demand and supply. When managing the supply chain, unknown events might occur. The following section focuses on describing and understanding the theory of supply chain disruptions.

## 3.2 Supply Chain Disruptions

As already introduced, supply chain disruptions (SCD from here) can happen at all times, stun whole supply chains and be very damaging to companies. This section will look into what SCD is and investigate former SCDs in order to create a common understanding and to be able to work further with the theory of SCD through this book. SCD can, in short, be defined as events that affect and jeopardise the flow and business activities of a supply chain. Bugert (2018) describes SCD as a combination of unforeseen events and the resulting consequences of these and categorises SCD as either natural or man-made triggers. Besides natural disasters or man-made catastrophic events, SCD can also be driven by labour dispute and supplier bankruptcy. In other words, many different events can disrupt the supply chain and it might therefore be difficult to cope with (Chopra, 2004).

According to the Supply Chain Resilience Report from 2017, which surveyed a sample of 400 companies from 65 different countries, 65% of the participants in the survey had in 2017 experienced at least one SCD (Alcantara, 2017). Considering these numbers, they indicate that SCD have hit many companies and the events that cause SCD affect many. To clarify what SCD is and which events have caused SCD, a timeline has been created. The timeline beneath visualises randomly chosen events that have been disruptions for different supply chains and have been leading to great damage and need for reactive change. Showing these example gives an understanding that events causing SCD have many faces and can be hard to predict, as they come from both malicious attacks, natural disasters, political issues and latest a global pandemic.

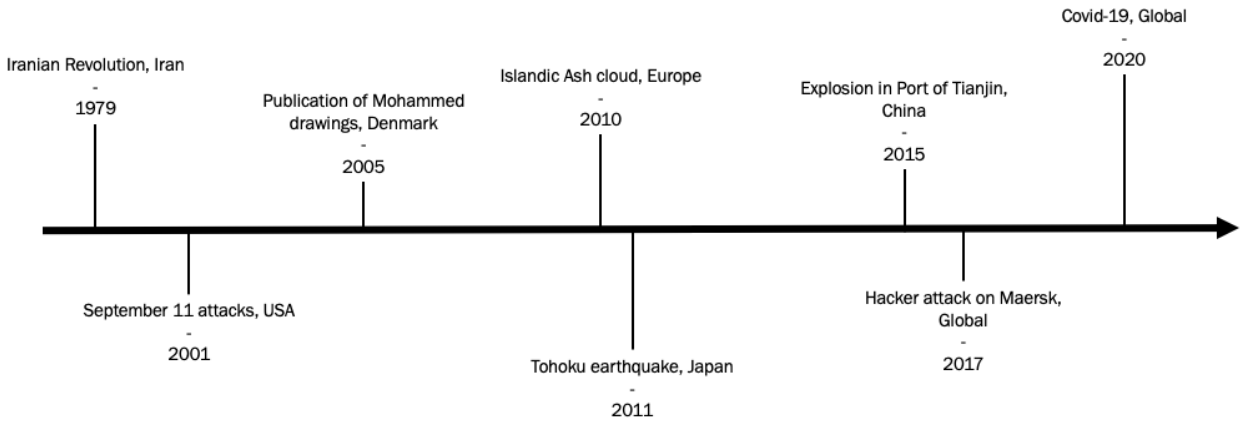


*Figure 5, Random sample of events leading to SCD, own production*

Nassim Taleb (2010) has developed the theory about black swans and white swans. The theory is in itself quite simple. A white swan has been seen many times and is the most frequent colour of swans, while black swans are much rarer and not seen often, however still existing. The theory is that it is more difficult to foresee and predict black swans than white swans. Taleb (2010) gives different examples of black swans in his book; September 11 attacks, burst out of World War 1, and the dissolution of the Soviet Union, just to name a few. On the other hand, however, in an interview with Bloomberg (https://www.bloomberg.com/news/videos/2020-03-30/nassim-taleb-says-white-swan-coronavirus-pandemic-was-preventable-video) Nassim Taleb challenges the view on Covid-19 as an event, which was possible to foresee, as he states that the pandemic was preventable. Additional to Tabel, Wucker (2020) states that the pandemic was not a black swan, but rather a white swan; *"In this vein, we have seen both financial crashes and pandemics many times before and know they will continue to occur. If you cannot picture another one coming, you are wilfully blind"* (Wucker, 2020). Despite Wucker and Taleb stating else, it is difficult to conclude that the Covid-19 pandemic was not a black swan leading to a SCD, since the predictability of it has been difficult for many, everything considered.

Despite many companies being hit by SCD, there is a common agreement between researchers that SCD is considered an unpredictable event that happens rarely, in other words in most cases a black swan, that can lead to a potentially great damage to supply chains. However, considering the theory of the white swan, Taleb states that white swans can cause disruptions as well. SCD is considered a supply chain risk. According to Knemeyer (2009) and other authors on the topic, a supply chain risk can be defined as:

$$Supply\ Chain\ Risk = Probability\ (of\ an\ event) \times Business\ Impact\ (or\ serverity)\ of\ the\ event$$

According to Knemeyer, SCD is categorised by having a very low probability and a catastrophic business impact. In Figure 6 it is visualised how SCD is defined in the supply chain risk matrix. To compare SCD with other possible supply chain risks or operational risks, such as variability in demand, damage or delayed transportation, these would be in the upper half of the matrix. The matrix gives a great understanding of how to relate SCD to other known issues and disruptions for companies and supply chains. Considering the timeline above, it suits well the definition of SCD in the matrix, as these events are quite rare but have been catastrophic to companies. However, the events have happened in relatively few years, but still cannot be considered as likely, since we do not see events with such an impact strike the same areas that often.

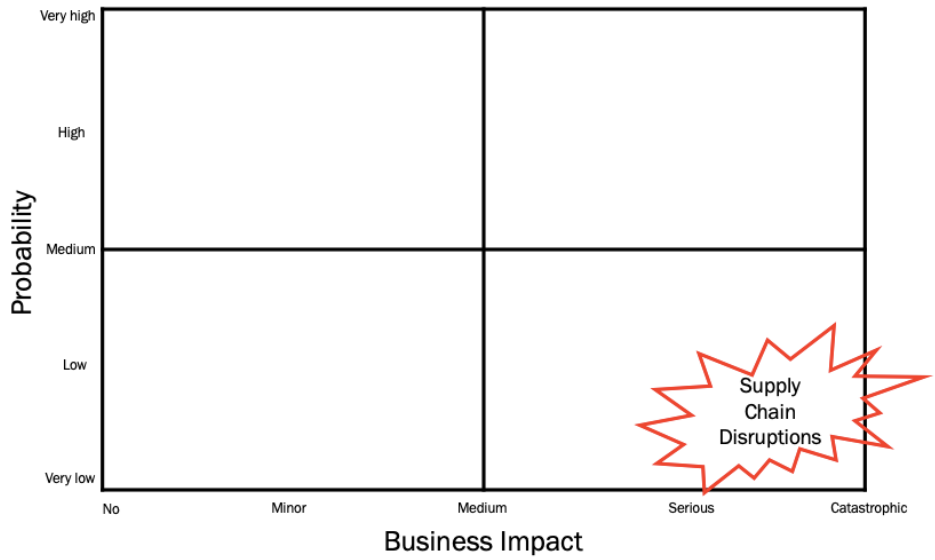


*Figure 6, SCD risk and impact, Knemeyer (2009), p.142*

Talking about SCD and supply chain risk, vulnerability of the supply chain needs to be taking into consideration. The reason behind SCD having a potentially catastrophic impact on supply chains is that supply chains over time have become more vulnerable to disruptions. Vulnerability of the supply chain has in a study by Cranfield University for the UK government been defined as; "*an exposure to serious disturbance, arising from risks within the supply chain as well as risks external to the supply chain*" (Christopher, 2005). As cost efficiency and globalisation have taken over the focus when designing supply chains, vulnerability has increased. Commonly, supply chain and business practices are designed based on the bias that the world is stable. SCM practices such as decentralisation, globalisation, outsourcing and Just-In-Time (JIT) are commonly used in SCM in order to bring down costs.

Considering the timeline, the events happen all over the world in different places. By exploiting the globalisation, decentralising and outsourcing, the number of exposure points of a supply chain is increased. Besides the increase in points of exposure, it also increases the distance and lead time of the supply chain, meaning that reaction time is much slower. On top of that, by applying JIT practices, the flexibility of the supply chain is decreased (Stecke, 2009). When driving a cost-efficient supply chain, the business impact of a potential SCD will be greater. The question of whether to expose the supply chain to the risk is difficult to answer. However, as seen in the timeline, by globalising the supply chain and having a supply chain with increasing vulnerability, the probability of being hit by SCD is greater due to the fact that supply chains spread out all over the world might be more exposed to these risks.

McKinsey has investigated and analysed how structures of supply chain networks can have implications on vulnerability of supply chains. The different parameters McKinsey mentions in their analysis are; concentration, substitutability, interconnectivity, depth, visibility and dependence. To translate these parameters, McKinsey says that increasing dependency on single suppliers invites to vulnerability, as also having no substitutes of suppliers will lead to supplier disruptions causing bottlenecks for the supply chain. Interconnectivity between suppliers will increase the vulnerability as well, as a disruption of one supplier may affect the others, and thereby the disruption is spread out. Also, when considering the depth of supplier network, vulnerability can occur when having a too deep network, where companies cannot see sub tier suppliers. Depth can correlate with the

factor, visibility, as the deep network can decrease the visibility of suppliers. Not having full transparency of the supply chain will increase vulnerability. Lastly, dependency is regarding how dependent sub tier suppliers are on their customers. If suppliers are very dependent on companies around them, they are more vulnerable to financial shocks hitting these companies (Lund, 2020).

An example of a SCD of current interest is the ongoing global Covid-19 pandemic. Since the virus closed down the Hubei Province in China, supply chains, having parts of the chain located in Hubei, needed to react to the disruption of the supply chain. Later in 2020 the virus came to Europe and the rest of the world and supply chains all over the world were affected of plants not running due to whole society closedowns. Furthermore, a general uncertainty spread in society leading to drops in economies. According to Danmarks Statistik, the BNP of Denmark saw a historic decrease due to the pandemic and the employment fell as well, leading to a drop in the buying behaviour, hitting supply chains (Danmarks Statistik, 2020). Companies were not prepared for a disruption with this impact and according to Choi (2020), 70% of 300 respondents to a survey in end January and start February, following the breakout in China, said that they were only still doing data collection and assessment, manually trying to identify suppliers located in the lock-down areas in Hubei. It is clear that most companies were not abreast in preparing for a SCD like the global pandemic, and it now has great consequences for companies, since their supply chains were not prepared for such a disruption. The lack of resilience of the supply chain has been clear in this example. The following section will emphasise on what supply chain resilience is, as well as investigate different approaches to create resilience.

## 3.3 Supply Chain Resilience

When preparing for disruptions in supply chains, creating resilience is a great way to do so. Supply Chain Resilience (SCRES from here) comprehends the ability to meet and respond to unforeseen events and the ability to recover from these quickly in the best way and possibly using the disruption as a stepping stone for moving the companies into a more desirable state. Furthermore, SCRES can be a factor in creating sustainable competitive advantage as continuously developing new capabilities on adapting creates more resilience and put companies one step ahead of competitors (Hohenstein, 2015). Ponomarov (2009) agrees with the former statement, as SCRES is defined as the *"capability of responding to disruptions through adequate preparation well in advance and maintaining continuity of operations".* Translating the definitions into own words, SCRES is understood as the robustness and elasticity of supply chains; having a solid robustness and a high degree of elasticity meaning that the supply chain has resilience. To visualise how SCRES is understood for this research, Ponomarov's figure is used as basis for the definition of SCRES.

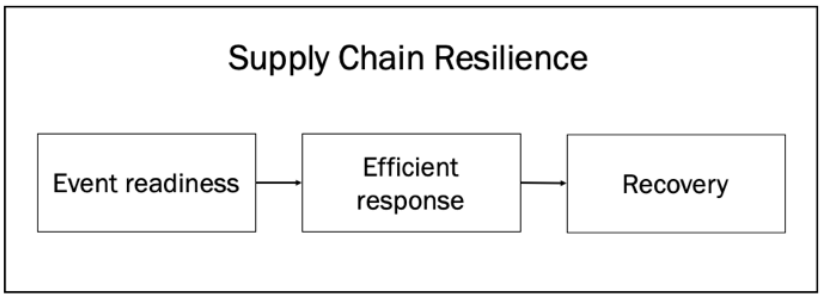


*Figure 7, Supply Chain Resilience, Ponomarov (2009), p.135*

To improve the resilience of supply chains and ensure that the supply chain is prepared for unforeseen disruptions, different tools and processes can be used. These resilient processes are usually flexible, agile and able to change fast, in order to respond to the event happening. Investigating

some of the different strategies for mitigating SCD and improving the SCRES are for instance to maintain multiple facilities with flexible resources, carry excess inventory, flexible transportation solutions, standardising processes etc. (Stecke, 2009). Knemeyer (2009) describes how a process for proactively planning for unexpected events in the supply chains can be; 1) identify key locations and threats, 2) estimate probabilities and potential loss for each key location, 3) evaluate alternative countermeasures for each key location, 4) select countermeasures for each key location. Digging deeper into this process and opening up the four processes, they are very focused on identifying where the supply chain is most vulnerable. Remembering the example of SCD from the Hubei Province in China, where companies tried to identify links of their supply chain located in the affected area, this focus on identifying key locations makes very good sense. Also, Cranfield University has published a guide for how to work with SCRES, where they emphasise the visibility of supply chains and discuss how to improve transparency of the supply chain. They describe mapping tools as a help for identifying pinch points and critical paths within in the supply chain (Cranfield University, 2003). Thus, it is clear that visibility, transparency and identification of locations in the supply chain is important when enhancing SCRES.

A further look in Cranfield University's practical guide for creating resilience gives more evidence on how resilience can be created. Cranfield University describes that risks and uncertainties should be a factor influencing the supply chain design and structure, as well as SCRES should imply agility and flexibility in the supply chain. Taking a step from the strategic to the tactical level of SCRES, Cranfield suggests that activities should be carried out to prepare for disruptions. Some of these processes are identifying vulnerability of products, suppliers, locations etc, like already described, as well as plan business continuity and creating processes to ensure the learnings from previous disruption experiences. Since objectives when designing supply chains have formerly been to make them cost-efficient, Cranfield University has suggested that when not having a resilient supply chain, it makes sense to consider to re-engineer the supply chain. On top of this, they have provided steps for how to (re-)engineer the resilient supply chain. First, companies need to understand their supply chain. As already stated, this involves understanding the notes and networks within the supply chain and understand where suppliers, as well as suppliers' suppliers, are located in order to know where the supply chain is vulnerable. Second, the supplier base strategy needs to be investigated. It is known that singe sourcing is most beneficial from a cost perspective, but "putting all eggs in one basket" may end up being damaging as the single supplier might face disruptions such as bankruptcy, for instance. Third and last, are design principles for supply chain resilience. The principles that have emerged are not quite compliant with the most cost-efficient supply chain, but may, however, be beneficial when engineering the resilient supply chain. A principle is, for instance, to "hold options open". This is for instance multi sourcing of raw material, to reduce vulnerability. Also, the disposition of excess inventory or capacity is mentioned as a principle (Cranfield University, 2003).

Swink (2020) has in his white paper for Association for Supply Chain Management (ASCM) described how past experiences have led to knowledge to be able to gain an advantage for future disruptions. According to Swink (2020) "*developing a more resilient supply chain puts money in the bank and makes the world a better place*". Swink is of the firm belief that SCRES is close to being the most important area for businesses to focus on, as this is where the competitive advantage is ensured. In the white paper, the commonly known tool from LEAN, 5S has been taken and transformed into a SCRES tool, based on past experience. The 5S should be used to build SCRES and is explained in Figure 8 beneath. The 5S is, for this book, understood as a tool/framework which seeks to initiate SCRES. It is important to state that the 5S is not a step-guide like the

one known from LEAN, but more of five different initiatives which increase the SCRES. Thus, the S's are rather independent from each other.

| S | Description |
|---|---|
| Scanning | Investments in technologies and capabilities for scanning are needed to be able to get a broader understanding of activities deeper in the supply chain as well as understanding the environment of the different links in the chain, political, weather etc. |
| Smart | Investments in predictive analytics are needed. These include for instance artificial intelligence which should lead to create a culture of learning organisation. The supply chain would then be able to learn from past disruptions to apply the knowledge and data from these disruptions to prepare for or react on new possible disruptions. |
| Scalable | The ability to be able to scale up and down to match the supply and demand as well as creating a variable cost-structure with on-demand capacity. Buying technologies and capacity makes companies less scalable. Leasing solutions are to be preferred. |
| Shiftable | Being able to shift from one product to another (example; Carlsberg shifting from beer to hand sanitizer). Also, invest in more generalised multipurpose resources such as employees and equipment. Lastly, develop more options – do not single source. This S is considered quite expensive, but should be looked at as a kind of insurance. |
| Sustainable | Aiming for economically sustainability, by avoiding lower risk options. Consider sourcing from local suppliers, stable economies and more mature sources, who are more scalable and shiftable. It is a known fact that sustainability may come at a price, but it is also considered as being worth it on the long term. |

*Figure 8, 5S for SCRES, Swink (2020), p. 8*

McKinsey has also published a report on how to work with SCRES. McKinsey's report will be used to build on top of the knowledge already gained about SCRES and will be compared to the former descriptions of SCRES. McKinsey comes up with three categories which all consist of different approaches to ensure resilience; Strengthen supply chain risk management and transparency, minimise exposure to shocks, and improve financial and operational capacity to respond and recover. Looking further into the three, they consist of different approaches. For the strengthen of risk management and transparency, approaches such as improving end-to-end transparency, mapping of the whole supply chain and collaboration and monitoring through digital tools, should be used. Minimising the exposure to shocks implies approaches as diversifying the supplier network and geographical footprint, build alternatives in logistic systems, bring key production in-house and harden physical plants and infrastructure. For improving the financial and operational capacity to respond and recover the approaches are to increase safety stock, flex production across suppliers, plant and channels, and building supplier financial health (Lund, 2020). These initiatives are relatively similar to the ones that Cranfield University described, and which were defined by Knemeyer. This means that there is a quite clear understanding of what SCRES is and consists of. SCRES is summarised in Figure 9 and visualises a summary of what is understood by SCRES in form of the House of Resilience.

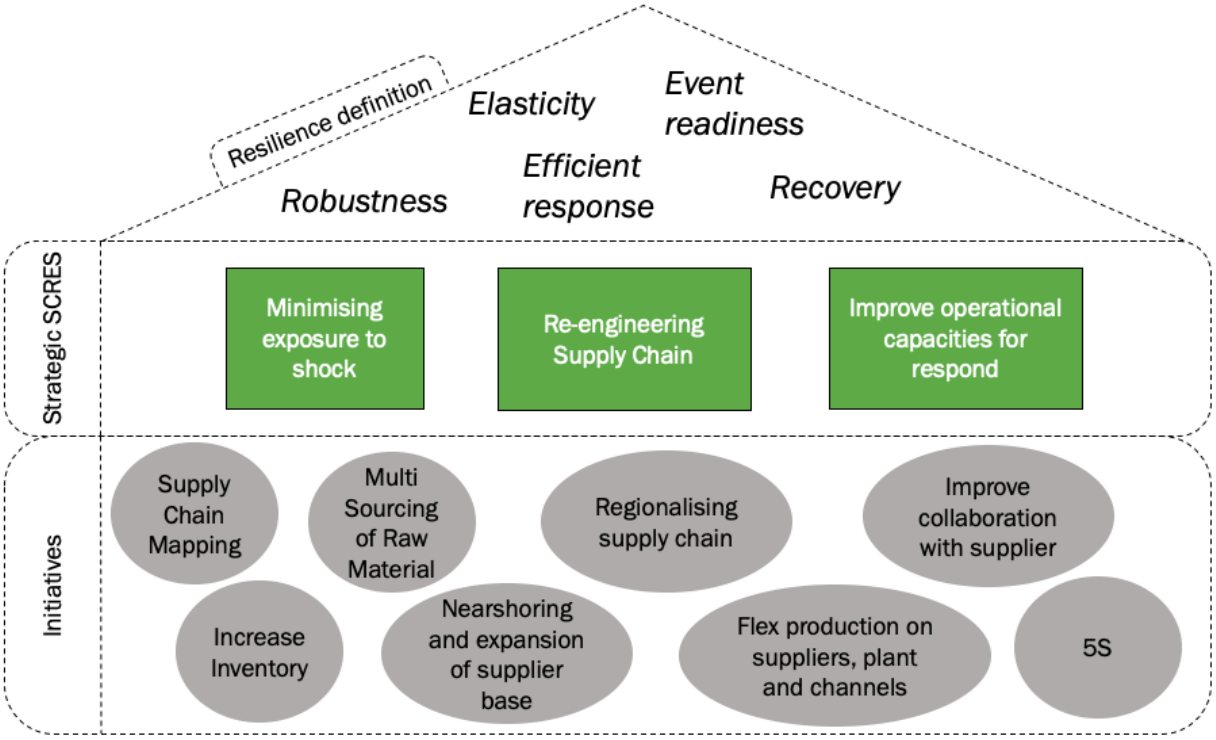


*Figure 9, House of Resilience, own production*

A way to design SCRES into the supply chain is by using scenario planning. Using scenario planning will make it possible to look into the future and see the effect of working with the different strategic SCRES or working with the initiatives. Also, scenario planning can help to prepare for the unknown events that cause the need of SCRES.

## 3.4 Scenario Planning

Considering scenario planning as an enabler for SCRES, it makes sense to research on what scenario planning actually is. First of all, it is important to understand what a scenario is. According to Cambridge Dictionary (2020) a scenario is *"a description of possible actions or events in the future"*. Cambridge Dictionary also defines Scenario Planning (Cambridge Dictionary, 2020);

> *"The study of possible future events in society, an industry, the economy, etc., and how they might affect an organisation, and the action of planning to prepare for them"*

With the above definitions in mind, scenario planning is, in this book, understood as a tool for planning and preparing for possible unknown events in the future. Linking this to already acquired knowledge on SCD and SCRES, scenario planning seems like a great tool to improve the SCRES and thus be more resilient whenever a disruption might hit. However, in order to get a better understanding of scenario planning and how it can be applied to create resilience, further knowledge is needed. Also, examples of use of scenario planning will contribute to the knowledge base of scenario planning.

Scenario planning can be done on different levels in companies. Both strategic and tactical scenario planning can be used, based on which level of the company that is applying the scenario planning. Strategic scenario planning is done at a high level in the business. This could for instance be scenario planning of environments in order to understand how to shape the business to meet

possible changes in environment or disruptions. Strategic scenario planning can support companies to navigate in uncertain situations or investigate how to prepare for the future on a strategic level. An example of strategic scenario planning as applied by Shell Oil, will be provided later in this section. Stepping down in organisations, tactical scenario planning is a possibility as well. Tactical scenario planning is regarding business administration at lower levels. This could for instance be transport policies, inventory levels, production strategies etc. A tool that can be used for tactical scenario planning is SAP Integrated Business Planning (IBP) (https://www.sap.com/products/integrated-business-planning.html) By using the tool, tactical scenario planning can be done in warehouses for instance and give insight in the impact of different scenarios to the inventory level, and how to react based on the scenarios.

According to theory there are different reasons for using scenario planning in industry. Some of the reasons are; uncertainty is high, too many costly surprises have occurred in the past, the industry is about to experience a significant change, a common language and framework is desired, etc (Schoemaker, 1991). Investigating further when to use scenario planning, Peterson (2003) has also provided a research on when it is adequate to use the tool of scenario planning. He states that when there is high uncertainty and the system affected might be uncontrollable, scenario planning should be used. Investigating further into scenario planning, a model for how to use the tool can be presented as five building blocks;

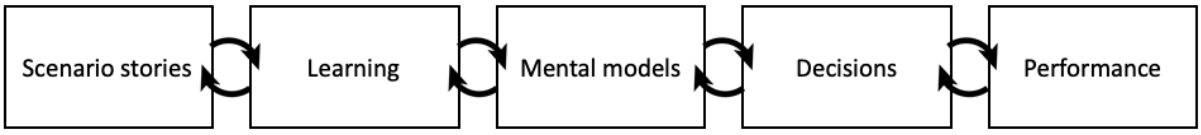


*Figure 10, Building blocks of scenario planning, Chermack (2003), p. 61*

The first of the five building blocks, scenario stories, is about describing “stories” of events that might happen. These scenarios should advantageously include; internally consistent, link of historical and present events with possible events in the future, plausibility, reflect events that have already happened but consequences are yet to unfold, identify indicators that the story is happening. The second building block is learning. When working with scenario planning it is important to learn on the go. Learning new things about the organisation and environment may open up for opportunities or threats to work with as well as challenging the current perception. The building block, mental models, is about challenging the reality and the assumptions one has of the reality. This could be to challenge the general perception and understanding of an organisation and environment. Decisions is about selecting actions or making up one’s mind. When making decisions it is important to have adequate information to do so, scenario planning contributes to providing the information required to making decisions. The last building block is performance. Performance regards the output of the scenario planning, as it stands for the improvements made and is affected by the four previous building blocks. The arrows in the figure visualises that the building blocks are interconnected and associated with each other (Chermack, 2003). For instance, learnings are based on the scenarios, but at the same time, scenarios should be adjusted according to the learnings.

To be able to use the tool of scenario planning it makes sense to gain knowledge on the processes of scenario planning. Furthermore, creating consensus on what the processes of scenario planning is gives an understanding of how it can be applied. Different step-guides have been created formerly on the processes. These step-guides will be the basis for how the process of scenario planning is understood for this book. First of all, focal issues need to be identified. By focal issues is

meant the area that needs to be investigated by the scenarios. Issues consist of scope and decision variables, also it is a review of the past to understand the uncertainties. Second step is to identify the stakeholders or actors involved in the focal issues. The stakeholders that should be identified are both the ones that can be affected and the ones that can affect the focal issues. Third step is to assess every aspect of the focal issues and their actors. This is about linkage and relationship between the actors, and defining a system through for instance mapping. Next step is to identify key uncertainties, also called alternatives. The key uncertainties are alternatives to the focal issues that may significantly affect the focal issues. A description of how they matter and how they are interrelated to the focal issues should be made. Having set the stage, the next step is to build scenarios. The scenarios that are built are based on the previous steps. This means that focal issues, actors, assessment and key uncertainties are all input to the scenario. The scenario is most likely a narrative, which takes its point of departure in what has happened in previous events and then evolve into hypothetical future events. Having developed the scenarios, next step is to test the scenarios. Testing the scenarios is to make changes in the systems created. For scenario testing, models can be used to change the system, based on the scenario, and provide an outcome. The outcome of the testing is then evaluated and compared to the current organisation and environment. The testing outcome is considered as basis for planning of the uncertain future (Peterson, 2003; Schoemaker, 1991). Beneath, a model has been created to visualise and summarise the process of scenario planning.

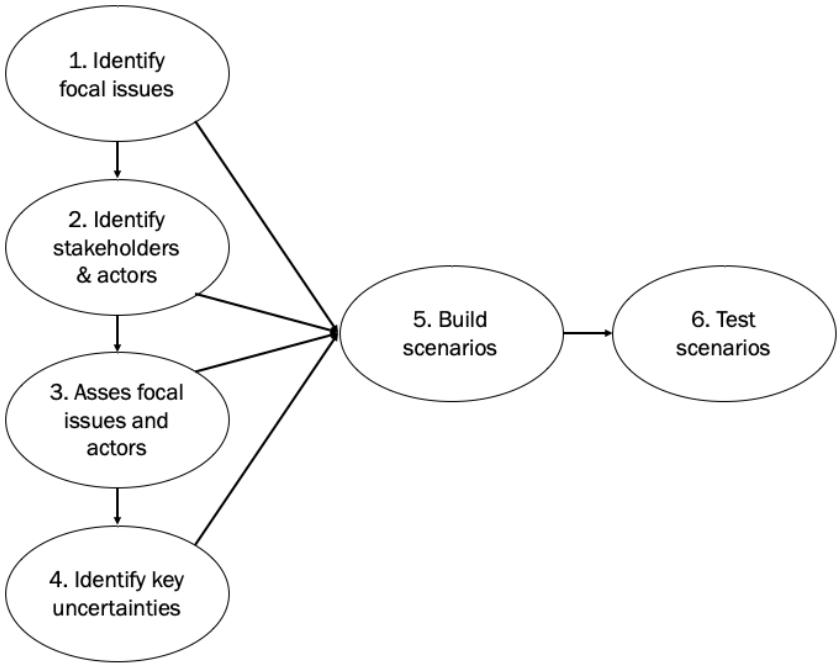


*Figure 11, Scenario Planning process, own production*

To further understand scenario planning, looking into history and how it has been applied before, can help to acquire knowledge on this. A good example of scenario planning is how Shell Oil has applied it. Back in the early 1970s, Shell Oil started with scenario planning in order to evaluate their long-term decisions. Their use of scenario planning in the 1970s regarding the oil crisis has become some kind of textbook example of how scenario planning can affect company strategies. Shell Oil operated in a market, where oil prices were low and were expected to remain low. However, Shell Oil considered an increase in prices to be possible and therefore they started to build scenarios that could entail higher oil prices. One of the scenarios they built was a coalition between

the oil producing countries causing limited supply and higher prices. Radical scenario, but plausible. Shell Oil then prepared for this disruption by adjusting the business to prepare for higher prices by increasing efficiency of refining and shipping operations. The changes and the ability to change rapidly gave an advantage for Shell Oil compared to their competitors by adapting much faster to expensive oil prices (Peterson, 2003).

When doing scenario planning it is possible to develop a twin of the systems in which the scenarios are tested, meaning that the testing of scenarios can be done without intervening with the physical system.

## 3.5 The Digital Twin

To do scenario planning it is helpful to build a system to test in. A system to test in could for instance be a digital twin of a supply chain. In order to understand what a digital twin is, this section will investigate the concept of the digital twin and clarify what it is and how it is understood for the research, as well as setting the frame for how to use a digital twin. To get the full understanding of the digital twin, it makes sense to look at the fourth industrial revolution, in other words, industry 4.0. Industry 4.0 is, in short, based on integrated cyber-physical systems, meaning that digitisation is in focus and psychical production, warehouses, systems, etc., are linked together in an open network. The purpose of industry 4.0 is to build autonomous value chains where data is flowing from one end to another and the information flow will run seamlessly (Colota, 2016). Industry 4.0 is based on technologies, such as internet of things, cloud computing, advanced robots, augmented reality, etc. As mentioned above the approach of creating a digital twin is part of industry 4.0.

Considering what a digital twin actual is, it can be defined as an evolving digital profile of a historical and a current set-up of a process, product or system. The digital twin is based on a lot of cumulative real-time data from the real world. The data and measurements create the twin to the physical set-up in a digital world. The digital twin helps to gain insight and understanding of the performance of the system, and thus possible improvements areas for the physical twin (Parrott, 2017). One can say that a digital twin is a real-time reflection between two spaces; the virtual space and the physical space. The virtual space is a real-time reflection of the physical space and the virtual space can undergo continuous improvement, which will reflect how it will affect the physical space (Tao, 2017). To get the last point of view on what a digital twin is, the following quote describes it well; *"the vision of the digital twin itself refers to a comprehensive physical and functional description of a component, product or system, which includes more or less all information which could be useful in all – the current and subsequent – lifecycle phases"* (Schleich, 2017).

The two spaces can be applied in different types of digital twins. Basically, everything can have a digital twin, both tangible and intangible. In literature, the more popular digital twins are production lines and the system of these. The production systems' digital twins are used as examples in different articles used for this section, such as Parrott (2007), Schleich (2017), Uhlemann (2017) and Tao (2017). However, beside creating a digital twin on a production system, twins can be created on other systems as well. Digital twins can be created based on whole supply chain systems. Drawing up the supply chain in software and putting in the factors and details within the system will create a twin of the system. Twins on products and services are built too. By building digital twins on products, it is possible to understand the product life cycle and foresee how the performance of the product will develop over time. Also, layouts of facilities can be built in a digital twin by the help of sensors. Doing so can support the development on facility layout without actually changing anything in the physical facility (Uhlemann, 2017)

A way to use the digital twin is for simulations. The advantage of having a digital twin is that simulations can be run and the output of the simulation can be used to gain a better understanding of the physical space. Uhlemann (2017) describes how simulation contributes to optimising on either systems or products. The simulation is done by transferring the AS-IS state into a future state, based on the inputs the simulation model is giving. Using a digital twin for simulation is a helpful tool to get an understanding of how a logistic system, for instance, develops over time. Of course, to be able to rely on the simulation the data input must be as accurate as possible. Having a digital twin, the data for the simulation is accurate and will reflect the physical twin well. Relying one's understanding and assuming based on a simulation also means that verification and validation of the simulation is necessary.

The understanding of digital twin is that it is used to do optimisation and to understand adjustments and behaviour of products or systems. The first example of a digital twin is seen in NASA's Apollo programme where at least two identical space vehicles were produced in order to mirroring the conditions of the vehicles during missions. Looking further into the industrial aspect of the digital twin, different companies employ digital twins with different purposes. General Electric focuses on forecasting performance of their products through their lifetime, Siemens uses it to ensure improved efficiency and quality within their manufacturing, and Tesla produces a digital twin for every car produced in order to synchronise data between the car and the factory to keep a status on the car (Schleich, 2017).

In order to bring the digital twin into a supply chain perspective, the digital twin in a supply chain can be considered as a system, which is drawn in a virtual space. In other words, the physical system of a supply chain, spanning from the suppliers to the customers. Depending on the level of detail, the digital twin can show the digital space down to certain processes, but can also just describe the network and dynamics of the supply chain. By having a digital twin of a supply chain system, a holistic view is ensured and changes within the supply chain and the implications of these can be monitored closely.

Understanding the different layers of the theoretical onion, the following part of the theoretical framework is to investigate what paradox theory is. To understand paradox theory will be part of the discussion section of this book as well as it will provide insight in which paradox occurs from the analysis.

## 3.6 Paradox Theory

When doing scenarios and trying to establish resilience in the supply chain, conflicting alternatives and initiatives can come up. Remembering SCRES could be increased by improving operational expenses, it clearly shows that this would be a conflict to the classic cost-efficient supply chain. Looking into what a paradox is, Cambridge Dictionary (2020) defines it as *"a situation or statement that seems impossible or is difficult to understand because it contains two opposite facts or characteristics".* This definition describes paradoxes as an extreme of two opposing factors. De Wit (2017) describes paradoxes as being a situation when two seemingly contradictory or mutually exclusive factors appear to be correct at the same time. Furthermore, he says, that a paradox has no solution, since there seems to be no way to integrate the two opposite factors into a consistent understanding of the problem. This means that the one working with paradoxes has to juggle with the problem without coming to a definitive solution (De Wit, 2017). One of the most famous paradoxes through time is the Socrates paradox "I know that I know nothing". This paradox describes well how a paradox can be difficult to understand and work within. The two definitions give a good understanding of what a paradox is. In order to dig deeper and gain knowledge on how to approach

paradoxes and apply paradox theory, further literature investigates into how to paradoxes are approached in businesses.

Smith (2016) states that paradox theory locates competing demands as inherent within organisations. Describing paradox theory as competing demands goes well in hand with the above-mentioned definitions, since competing demand typically can be between two opposite factors. Smith (2016) says that the paradox theory tells that competing demands are emerging through relational dynamics or individual sensemaking. In other words, more different environments and changes within external and internal environments foster the growing of competing demands in organisations. Paradoxes normally creates tensions between two facts. These tensions in organisations are normally contradictory, but also interdependent according to paradox theory. This means that the competing demands are usually persisting over time and it is not possible to resolve them totally, however the opportunity should be used to create sustainability and creativity, when dealing with the paradoxes. Working within paradox theory it requires ongoing responses to the problem, and the process is emphasised in the work, meaning that paradox theory invites to dynamic interactions within organisations.

When handling paradoxes as a tool for intervention of a problem that needs to be solved it is not having the right effect. Cunha (2019) says that researchers and practitioners operate with paradoxes, as if they were problems that need a solution, despite scholars saying paradoxes persist over time and are impervious to solutions. By treating the paradoxes as problems, contradictions can be harmful and give organisations negative outcomes. Trying to solve paradoxes as a problem means that the paradoxes are removed from their "natural state", and the benefits of working with paradox theory will be lost. It can be considered as abstract to work with paradox theory, as it is difficult, in a research designed like this, not to try to solve the assumed entailed paradoxes. Pålsson (2020) adds to the discussion by describing that usually paradoxes are referred to as "either/or", but suggests that paradoxes should be considered as a "both/and" way to manage contradictions. To build on top, acquiring more knowledge through historical examples can support to avoid treating the paradox as a problem that needs to be solved. The case of how Toyota has worked within paradox theory explains well how to navigate in paradoxes and contributes to the knowledge base of what paradox theory is.

In his book, *Extreme Toyota*, Takeuchi (2008) describes how Toyota bases their business on paradoxes. The book is based on six years of research in Toyota and dives into depth of the strategies of Toyota. Knowing this is business administration on a higher level than for this book, the example of Toyota still contributes very much to understanding how paradox theory can be employed. To exemplify paradox theory different paradoxes from Toyota's philosophy can be used:

- Toyota is bureaucratic and hierarchical, but supports free thinking
- Toyota aims for stability, but calls for paranoia
- Toyota is moving slowly and surely forward, is however taking big leaps
- Toyota is operationally efficient, but full of redundancy

The above four examples show how Toyota has incorporated paradox theory in their philosophy and instead of trying to solve paradoxes as a problem they use them to form the business. The research on Toyota provides another example of how paradox theory can be used on a lower business level. When developing the Lexus, Toyota faced paradoxes in the product development phase, due to Toyota setting "impossible goals". The paradoxes were for instance; high speed/stability and driving comfort, fast and smooth driving/unique fuel efficiency, noise abatement/light weight, elegant design/great aerodynamic performance etc (Takeuchi, 2008). By addressing and being aware of these paradoxes Toyota was able to develop, at that time, an innovation of a car in the American luxury car market. These ways to address paradox theory by Toyota contribute to gaining an understanding of how paradox theory can be approached in the industry.

## 3.7 Summary of Theoretical Framework

The knowledge and understanding of the theory are the foundational knowledge used for the analysis. To sum up, the onion in Figure 3 describes how the theoretical framework has been built. First of all, supply chain management is regarding how to manage the systems, networks and relationships within supply chains. The factors that are important to have in mind when working with SCM are time and cost. These factors need to be taken into consideration when balancing supply and demand in the supply chain. The next layer of the onion is supply chain disruption. SCD is, in short, a product of an unforeseen event. SCD is assessed through supply chain risks, which are defined based on probability of and impact of an event happening. According to theory, the more vulnerable a supply chain is, the more exposed it is to disruptions.

In order to comply with SCD, supply chain resilience is the next layer of the onion which is explored. SCRES is about how to accommodate disruptions, and can be divided into three factors; event readiness, efficient response, and recovery. By working with different resilience strategies and initiatives the development of these factors is supported. The strategies and initiatives determined are summarised in Figure 9. The following layer of the onion is scenario planning. According to theory, scenario planning is to study a future event and how it might affect an organisation, and thus plan based on these possible events. Different building blocks of scenario planning have been investigated; scenario stories, learning, mental models, decisions, and performance. Besides these, a six-step guide has been determined as well. These steps should be followed when developing scenarios and testing them. One way to approach and test scenarios is by using the concept of digital twins. Digital twins are virtual spaces based on a physical space and are considered as a digital real-time reflection on either systems, processes, or products. With the digital twin it is possible to further understand development of a physical product or system. Also, the digital twin can be used for testing to get a broader understanding of how the physical space will react when applying different initiatives.

Lastly, outside the onion, paradox theory was researched. Paradox theory is about working with paradoxes as not being a problem that needs to be solved but rather get the best possible output out of the paradox. In a business content, paradox theory can be compared to competing demands, which are two opposite factors that should be balanced. In the following chapters, the theoretical framework will be the ground pillar when analysing and discussing the case of Arla.

# 4 Creation of Digital Supply Chain

In the previous chapter, the theoretical framework of the book was set. This chapter will concentrate on the case, Arla Foods, and will use the theoretical knowledge and link it to the case of Arla's butter supply chain. In this chapter, a digital supply chain of the butter category of Arla is developed; in other words, a digital twin is created on the supply chain system. Knowing, from theory how a supply chain is constructed and what a digital twin is, it is possible, with the data provided by and obtained at Arla to develop a copy of the supply chain system. The chapter is divided into three sections; describing the physical space; Arla's current supply chain set-up and the actors, Presenting and describing the software in which the digital twin will be created, and describing the development of the digital twin, in other words, creating the virtual space. By merging the current physical supply chain system and the software Supply Chain Guru, a digital supply chain can emerge.

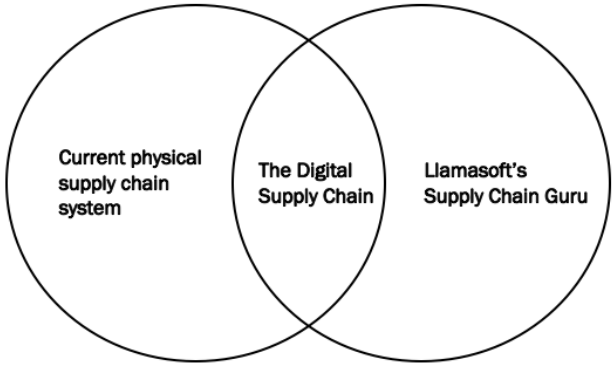


*Figure 12, Creation of Digital Supply Chain, own production*

## 4.1 Description of Current Supply Chain Set-up at Arla Foods

The following section is investigating and describing how Arla's current supply chain set-up of the butter category is. The knowledge of the supply chain is based on different interviews conducted and data gathered at Arla.

### 4.1.1 From Vessel to Shelf

Starting from the beginning of the supply chain and working downstream, the dairies of the butter products Lurpak and Kærgården are located in Denmark and Germany. Milk and cream from farmers around the countries are transported to the dairies where they are used to produce butter. According to a global production planner at Arla, the Danish dairy is the biggest butter dairy in the world, producing butter to every market in Arla's portfolio, highlighting Denmark, Germany and United Kingdom.

#### The Danish Market

An interview of a supply planner of butter to the Danish market has led to a broad understanding of the set-up of the supply chain. The supply chain is facilitated from the offices in Viby. The products are produced on the dairies and send to warehouses, From the warehouses the products are distributed further to customers located in the areas surrounding the warehouses. The production of butter is planned from the HQ in Viby. The production of butter for the danish market is solely based on forecast.

### The British Market

On the UK market, the supply of the butter products is facilitated and planned by the Supply Planning department as well. The department is located in Leeds where administration of Arla UK is located. Also, like the Danish market, the planning of production for the British market is centralised in the offices in Viby. Despite having a similar set-up regarding the planning for the UK market, the production for the UK market is both based on forecast and orders from the Supply Planning department. Two days after the products are produced and as soon as the quality checks approve, the products are shipped with trucks to the two warehouses in UK. Here they are kept on inventory ready to be distributed to the customers in the areas of the warehouses.

### The German Market

Planning-wise, the German market has the same set-up as the Danish and British markets. The planning is done in the local market, while the products produced in Denmark are planned by a department in Viby. The local planning departments are located in the Düsseldorf offices of Arla. Besides the Danish dairy, the dairy in Germany also supplies the German market with Kærgården. The production planning of Germany is done in Viby as well. When the German market orders products from Denmark they are produced based on the orders, not on forecast. Basing the production planning on orders also means that the lead time is a bit longer. Like the products shipped to the UK market, the products are shipped, as soon as they are produced and thus the Danish production site is not holding any inventory for the German market. The shipments from the German and Danish dairies are sent to two warehouses in Germany. The customers on the German gets products from the two warehouses.

### BSM Supply Chain Sum-Up

To sum up the above descriptions of the different markets, Figure 13, visualises the physical supply chain of butter to the Danish, British and German markets.


*Figure 13, Supply Chain Overview, own production*

# 5 Llamasoft's Supply Chain Guru

To create a digital twin of the physical supply chain there are different types of software created for the purpose. The American company Llamasoft has created the software called Supply Chain Guru (SCG from here) which is used to draw supply chains and based on this using linear programming of the software to identify optimisations of the supply chains. SCG is based on data and is a modelling, optimisation and simulation software which enables the answering of complex questions in the supply chain. By applying data from different sources, SCG enables the user to analyse alternative strategies for the supply chain, meaning that the software makes it possible to compare different scenarios in order to speed up the decision making and create a faster response time to changes in the environment. Also, SCG identifies tipping points in the supply chain to be able to select the most suitable strategies. The SCG is also a tool used to visualise supply chains and make it easy to understand the different notes and links of the supply chain. SCG can visualise current operations in different ways, through for instance maps, views, graphs and dashboard. In other words, SCG creates a digital twin of the physical supply chain (https://llamasoft.com/supply-chain-guru/). SCG offers five different solving methods which can lead to improvement of the supply chain

- Network optimisation
- Greenfield analysis
- Transport optimisation (Fleet management)
- Safety stock & Service optimisation
- Simulation

The five solving methods all contribute to optimisation or analysis in different areas of the supply chain. The solving methods are the first thing that is chosen when an area of improvement is identified. Before working with the SCG, it is important to clarify how to use the software and which data to feed into it. In general, the software works within the area of supply chain design, meaning that it looks more into the system of supply chains than processes, such as production for instance. Supply chain design is regarding going from an AS-IS supply chain to investigate and analyse how the TO-BE supply chain should look like (Participant D). In other words, supply chain design, one could say, is considering the re-engineering of the supply chain and the implications of this re-engineering.

## 5.1 The Design Ingredients

When working with supply chain design it is important to consider the design ingredients for a re-engineering of a supply chain. At the webinar of Optilon regarding supply chain design and network, design ingredients for working with supply chain design were introduced. These design ingredients are similar to the ones used when developing a digital twin of a supply chain system in SCG. Beneath, the design ingredients have been condensed into a table, to visualise what needs to be in place to develop a digital twin.

| 1. Data of Existing and Potential Supply Chain | 2. Tools & Technology for… | 3. Skills & Competencies |
|---|---|---|
| • Demand and service requirements<br>• Business rules and policies<br>• Capacities and capabilities<br>• Cost models | • … creating models and prescriptive analyses<br>• … doing data transformation<br>• … delivering experience/engagement layers | • Analytics and Modelling<br>• Project Management<br>• Storytelling and user experience<br>• IT Architecture |

*Figure 14, Supply Chain Design Ingredients, Optilon webinar, 7th of October 2020*

Comparing Figure 14 to SCG, it is rather obvious that the important inputs to an AS-IS model are the data of the existing and the potential supply chains. Step 2 are ingredients which SCG provides, in form of a tool and technologies. Step 3 is consisting of the skills and competencies which are required by, in this case, the researcher. Knowing how the current physical set-up in Arla's BSM supply chain is, as well as having Llamasoft's SCG available, it is possible to develop a digital twin of the supply chain. The following section describes how the digital twin has been developed through SCG as well as states which data is used to draw up the digital supply chain.

## 5.2 Data as Enabler for and a Result of Llamasoft's Supply Chain Guru

When working with SCG, there are some prerequisites for which data to use. Also, the output of SCG is based on data. In the above section, data for the SCG has already been touched briefly, in Figure 14. This section will dig deeper into what data SCG needs to perform simulations and provide the insight it is able to. Obviously, data on demand and supply is necessary as it is clear from section 3.1 that SCM is regarding balancing supply and demand. This data is the main driver for the model and is considered as the two most important inputs. Other inputs of data that can be used for the SCG are for instance costs of all the different processes of the supply chain, capacities of production, shipment methods, capacities of these, capacities of inventories etc. The scope of data that can be used in the software spans wide and makes SCG quite flexible in order to use it

for different insights and analyses. An example of how input data can shed light on a case is to use data of carbon footprint. Feeding the software with the carbon footprint data will enable SCG to calculate the footprint in the supply chain and use it as a factor in the whole supply chain picture when optimising or running scenario planning.

To be able to get the best insight possible, data needs to be available. As mentioned, the model can be used and run if supply-data, demand-data, and notes of the supply chain are in place. However, this will not give the best insight, but limit the model and its potential. Adding more data, such as factors to the supply chain, would definitely give the best possible outputs. This could for instance be to cost optimise the transportation network or cost optimise the supply chain in general. Obviously to do so, the model needs data of costs.

The outputs when using SCG are, as already mentioned, data, insights or possible optimisations. These can be interpreted as SCG is a software, which is fed with data and arranging this data to end up delivering new data and understanding. Holding this matter of fact up against this research and the problem statement, SCG should to a high extent be able to support scenario planning by using a digital twin. To exemplify further, using the SCG for testing different scenarios can give a great insight and understanding of how to react if events, like described in the scenarios, should happen. Thus, the response time, ability to recover, and preparedness will most likely be on a strong ground, since the digital twin has already provided inputs before the event happens. Also, by getting the insights and data, Arla can to a higher extent base their decisions and future supply chain initiatives on analyses and facts. The different possible data and insights SCG can provide must be considered as valuable for companies whenever preparing for SCD and emphasising on SCRES, as it makes the discussions on the two topics more facts related.

# 6 Cases of the use of Supply Chain Design Tools

To exemplify how supply chain design tools can be used, two examples from the industry shows it very well. An example of how SCG has been used, is IKEA. IKEA uses Llamasoft as their close partner in regards to supply chain network. Here SCG plays a major role. IKEA's work with supply chain network and design has over time developed and gained more focus within the organisation. This has led to IKEA creating a new organisation working with supply chain network and design, using the SCG. This new organisation has grown from two to 18 employees within a year and is an important illustration of the number of resources IKEA is spending on supply chain network. In general, IKEA uses the SCG for generating solutions and inputs for big changes in the network. The best example of this is how SCG was the main driver when designing and implementing a distribution center in Malaysia. Also, the SCG has been used in IKEA for projects on inventory optimisation and supplier footprint. The way IKEA has structured their work with SCG goes through three steps:

Preparations → Distribution Network Design → Supply Chain Network Design

IKEA used the preparation step to decide governance, describe processes and make a proposal on an organisation. The next step, IKEA started to build competencies and in general prepare the staff. This was done by creating one common network plan and ONE logistic network planning. The last step was when IKEA started to do network optimisations in regards to lower cost, and also risk management in the network by simulations. To ensure the best possible prerequisites for IKEA when working with SCG, Llamsasoft and Optilon made an assessment together with IKEA. In this assessment different factors were benchmarked in order to understand whether IKEA was ready to use SCG. The factors were; maturity, technology, process, people, and strategy. Looking at the example of IKEA, it seems like using SCG to its full potential is a rather big project which needs a lot of resources and awareness.

An interview with a business consultant from Optilon, who is currently working with SCG for IKEA, gave further information on how SCG can be used. During the interview it was told that a lot of time is spent to dig data out for projects like this. An example is the project about the $CO_2$ overview, which is made on the transportation in IKEA. A quote from a consultant which back that up is; "*IKEA has worked with SCG for 8 years, but I'm still searching for and creating data for the model on 3rd month now".* The interview showed that the work with data is taking a lot of time and this is the hard part of building a model in SCG, as well as it was identified that working with $CO_2$ emissions and basing the model to reduce these is a possibility when working with SCG.

Another example of use of supply chain design tools is LEGO. LEGO did, for a period, use SCG for their supply chain design initiatives, but is currently investigating the market for other supply chain design tools. However, the use of these tools and the potential with the tools are similar to SCG. LEGO has used supply chain design tools for different purposes. SCG was used for strategic network analyses to give insights. These were, for instance, whether a distribution center was placed in the right location and considerations of how a new market entry would implicate the supply chain network, and how a re-design of the design should look in regards to this. In other words, the different solving methods used by LEGO are network optimisation, transportation optimisation and greenfield analysis. Furthermore, LEGO has used SCG for doing a small amount of "what-if" analyses, which are quite similar to the purpose of this research. "What-if" analyses are used for the supply chain network design and are assessing different initiatives and scenarios.

Comparing to IKEA, LEGO is not using as many resources. They have neither developed an organisation for supply chain design. Instead, they are working with supply chain design in their logistic and supply chain departments. LEGO is working with supply chain design tools on both a strategic and a tactical level. This means that when making strategic decisions on the supply chain network, inputs for the decision process come from the supply chain design tools. An example is that the Chief Operations Officer (COO) has used the data, insights and input from SCG to make strategic decisions within the supply chain network. According to Participant H, the supply chain design tools are currently not used on an operational level and are still only used to a small extent on tactical level. This also means that the what-if analyses mentioned above are not as used as the potential would suffice. Currently, LEGO has not worked with supply chain resilience, thus it is difficult to infer how scenario planning can be used to enhance supply chain resilience at LEGO. However, having the knowledge on how SCG can be used strategically gives a great understanding of the possibilities of SCG.

# 7 The Digital Supply Chain

Having defined the current supply chain set-up of the butter supply chain for Germany, Denmark and United Kingdom, as well as having acquired a broad understanding of the supply chain design tool Supply Chain Guru, it is possible to use these two learnings to develop a digital twin of the butter supply chain. In order to build a digital twin of the supply chain, an AS-IS model of the supply chain was developed and drawn. The AS-IS model was used as the basis for testing different scenarios of possible supply chain disruptions. This will be done later on in chapter 8 where constraints to the AS-IS model are added.

## 7.1 Elements and Tables of the Digital Supply Chain

Due to the complex supply chain, with day-to-day demand from every customer, located all around every market, the digital supply chain of butter is simplified. Different adjustments have been done to simplify the model. For instance, the data which is used for the customer demand, only one

week of demand has been used. The week used for representation of the demand has been randomly chosen and is week 36, 2020. Having more than one week of demand will mean that the complexity increases heavily. According to Participant C, most sufficient for a model like this would be to have a time scope of one week to reduce the complexity of the model. Also, with the time limitations and since the data availability and structure of this compared to the requirements from the software are not aligned, at least not for building a 1:1 digitalisation of the physical supply chain system, the digital twin has been simplified. Various other adjustments, besides the reduced time scope, have been done in order to make it possible to create a model. These simplifying adjustments will be described in more detail when describing the development of the model. Not only Participant C was focusing on simplifying the model, also Participant F from IKEA was focussing on simplifying, as he mentioned *"First simplify, then optimise"*. These two inputs to building a model give a clear view that simplicity is necessary to start with.

When building a digital supply chain in SCG, there are some prerequisites to do so. When building a model, two inputs for the SCG are important; physical elements and behavioural tables. The physical elements of the digital supply chain are what it consists of. Examples of physical elements are plants, warehouses, customers and transportation modes. The behavioural tables are describing why and how the supply chain is driven. The behavioural tables are different policies, or in other words, methods on how the different elements of the supply chain behave. The behavioural tables that are needed are; customer orders, customer sourcing policies, production policies, inventory policies, and transport policies. These policies describe how processes are done in the supply chain. The transport policies, for instance, describe which transport methods are used, while the production policies describe how products are produced. The two inputs are the basis for the AS-IS model and are described to a greater extent in comparison to the case of Arla's butter supply chain beneath.

### Physical Elements

In this case of the Arla butter supply chain, the physical elements that should be entered in the digital supply chain are the warehouses, dairies, and transportation modes. Due to the relative complex supply chain and time limitations of this research, having all the customers included in the model will increase the complexity and time needed to be spent on collecting data. Therefore, the customers will be represented from locations located in bigger cities representing the area of demand for the related warehouse to this area. This means that for instance the warehouse in DK_WH_4 is facing demand from Copenhagen, and DE_WH 1, which is covering demand from eastern and northern Germany, is facing demand from a customer located in Hamburg. Described in detail, the physical elements of this chain consist of the dairies in Denmark and Germany. The transportation mode used in the supply chain and thus also in the model is trucks. The physical elements are entered in the model in SCG and are, to some extent, considered as the ground pillars for the supply chain twin.

Besides the physical elements, the products involved in the supply chain are important to describe as well, as they obviously play a major part since they are the main driver for running the supply chain. It is important to state the shelf life for the products and the variety of the portfolio. As already mentioned, this book is regarding the butter product category and more specifically the two brands, Kærgården and Lurpak. The shelf life is important, since it dictates for how long the products can be stored in warehouses, and thereby adds a degree of complexity to the supply chain, as inventory cannot just be built up. Furthermore, it creates a natural flow of goods through the supply chain since the products need to be handled with First-in-First-Out (FIFO) handling in the warehouses due to the shelf life. As already mentioned, the model needs to be simplified due to

limitations of time to build the model and complexity of the supply chain system, meaning that all the Lurpak and Kærgården products to the German, Danish and UK market are divided into five different product categories; Lurpak A, Lurpak B, Lurpak_C, Kærgården_A and Kærgården_B These five different products do not necessarily have a similar shelf life. However, the shelf life has been aggregated to fit the five categories and in order to reduce the complexity of the model. This means that each of the five product categories has a common shelf life.

#### Behavioural Tables

The behavioural tables describe the "how's" and "why's" in the supply chain system. As already mentioned, the customer orders of the supply chain have in regards to the time scope been reduced to consisting of one week of demand data. The input is pulling the strings of the supply chain. The next behavioural table of the model is customer sourcing policies. Briefly explained, the policies are regarding where the customers are supplied, with which products from which warehouse.

The internal policies of Arla consist of production, inventory and transportation. These policies describe the behaviour of the three areas. The production policies are describing which products are produced at which sites and the lead times for these products. To exemplify, the products of Kærgården are both produced at the German and Danish dairies. The inventory policies dictate which products can be stored were. In other words, they describe which warehouses can store products. The inventory policies also define the required service level of the supply. The last policy of the behavioural tables is the transport policies. These policies dictate by which mode the products are transported and from which source to which destination. These transport policies contain every possible route from a source to a destination, thus also from production sites to warehouses.

## 7.2 Visualisation of the Digital Supply Chain

As both the physical description as well as the process of the digital development have been described, it is possible to show visualisations of how the digital twin of the butter supply chain for the German, Danish and UK market looks like. The visualisations show both the input data that has been used for the model, as well as a geocode map showing the locations of both dairies, warehouses and customers. The input table is created based on the above information on physical elements. The behavioural tables are not included in this table, since these data are relatively big. It has been chosen to visualise the tables based on the products, since these are the general factor for the model, as these are the main reason for having the supply chain. The two visualisations are the result of the above investigation of the current physical supply chain system and also the result of the process of developing a digital twin of the physical space.

| *Products* | Lurpak_A | Lurpak_B | Lurpak_C | Kærgården_A | Kærgården_B |
|---|---|---|---|---|---|
| *Sites* | • Dairy_1<br>• DK_WH_4<br>• DK_WH_3<br>• DK_WH_2<br>• DK_WH_1<br>• UK_WH_2<br>• UK_WH_1<br>• DE_WH_1<br>• DE_WH_2 | • Dairy_1<br>• UK_WH_2<br>• UK_WH_1 | • Dairy_1<br>• DK_WH_4<br>• DK_WH_3<br>• DK_WH_2<br>• DK_WH_1<br>• UK_WH_2<br>• UK_WH_1 | • Dairy_1<br>• Dairy_2<br>• DK_WH_4<br>• DK_WH_3<br>• DK_WH_2<br>• DK_WH_1<br>• DE_WH_1<br>• DE_WH_2 | • Dairy_1<br>• Dairy_2<br>• DK_WH_4<br>• DK_WH_3<br>• DK_WH_2<br>• DK_WH_1<br>• DE_WH_1<br>• DE_WH_2 |
| *Custom-ers* | • Germany north<br>• Germany west and south<br>• Denmark north<br>• Denmark south<br>• Denmark Zealand<br>• Denmark Co-penhagen | • UK north<br>• UK south | • UK north<br>• UK south<br>• Denmark north<br>• Denmark south<br>• Denmark Zea-land<br>• Denmark Co-penhagen | • Germany north<br>• Germany west and south<br>• Denmark north<br>• Denmark south<br>• Denmark Zea-land<br>• Denmark Co-penhagen | • Germany north<br>• Germany west and south<br>• Denmark north<br>• Denmark south<br>• Denmark Zea-land<br>• Denmark Co-penhagen |
| *Transpor-tation mode* | • By truck | • By truck | • By truck | • By truck | • By truck |

*Figure 15, Input table for SCG, own production*

Above is the input table with the physical elements, beneath is the visualised supply chain map. In the map the points visualised by green triangles, blue dots and purple triangles are visualising dairies, customers and warehouses, respectively.

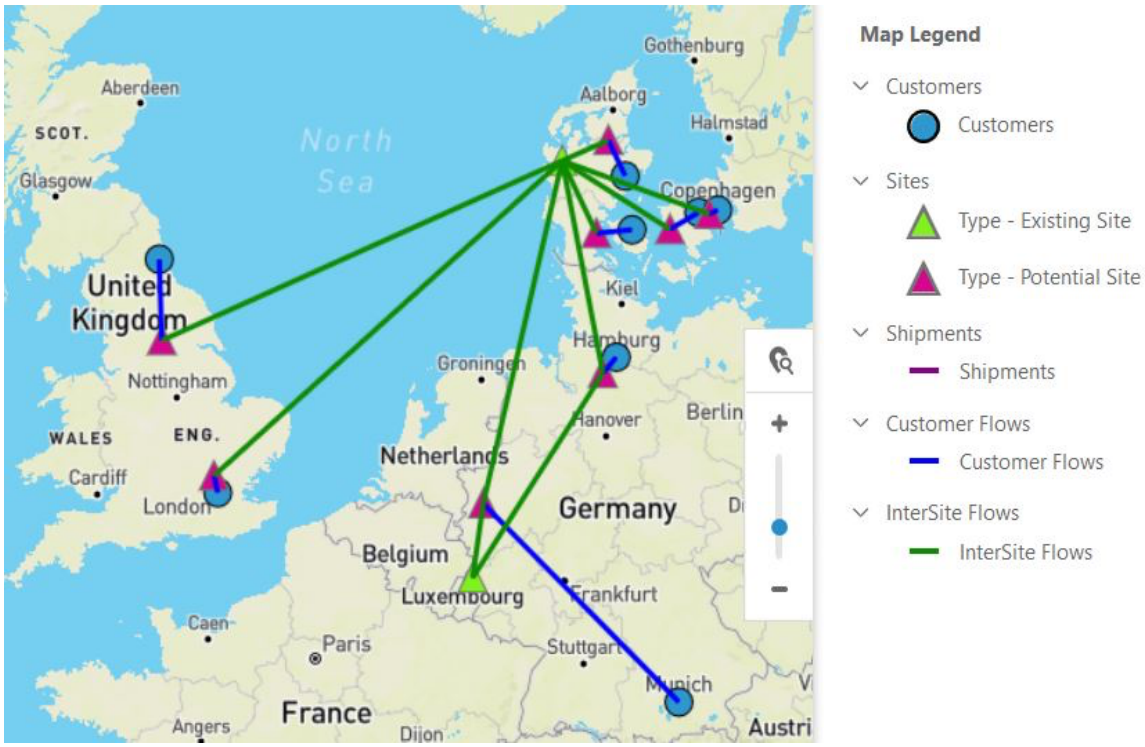


*Figure 16, Butter Supply Chain digital twin picture, own production*

The model is based on knowledge acquired from interviews and also numeric quantitative data provided by Arla. As mentioned in the introduction to this chapter, the model is considered as the

AS-IS of the current supply chain and thereby a digital twin to the physical supply chain. As described, the model is relatively limited since the data quality and accessibility at Arla has been limited

In the following chapter, the AS-IS model will be the basis when developing scenarios. The AS-IS model will have constraints added on, which are assumed to come from the events causing SCD, and are generated based on the building of scenarios. Based on the AS-IS model and the constraints added on, it will be investigated how to accommodate supply chain disruptions and thereby how to enhance supply chain resilience.

# 8 Running Scenarios

To investigate how different disruptions will affect the supply chain of Arla, four different scenarios have been created. A thoroughly presentation and assessment of these will be provided in the following sections. Also, the results of running the scenarios through SCG as well as suggestions for how to deal with these scenarios will be presented.

As mentioned in section 5, there are different solving methods from which to choose when SCG works with a supply chain model. For the cases of the following scenarios, the network optimisation solving method has been chosen. One would say that the simulation method might sound like the most suitable solution, but according to Participant C, the simulation method only gives an impression of how the supply chain runs with the current set-up. However, using the network optimisation method, SCG is able to take problems and solve them. As SCG needs a factor to base the network optimisation on, a cost-factor has been inserted into the model. The cost-factor does not reflect the reality, but is assumed relative to it. The scenarios built are causing issues for the supply chain, and for the research it makes sense to create an artefact which is able to suggest solutions to these problems and thereby shed light on how to enhance the supply chain resilience towards the disruptions caused by the events.

In order to run the scenarios properly in SCG and get the best possible outputs, SCG needs predefined problems based on the scenarios to do the network optimisation. This means that for each scenario, implications must be detected and these implications are then the basis for the problem that needs to be solved by SCG. Thus, questions which need to be answered must be asked to apply the SCG software properly (Participant C). It is important to state that creating scenarios, implications, and problems like this can be considered as “qualifying guessing”, and is thus not necessarily mirroring the reality to a full extent; there is a probability of the events described in the scenarios never happening.

With Figure 10 in mind, the scenarios built in this chapter are based on the five building blocks. This means that the scenarios will be created based on narrative stories. Also, learnings will be an important factor when developing the scenarios. The learnings and accordingly adjustments to the scenarios will happen iteratively. The mental modes are about to challenge ones understanding of reality. This means that scenarios not necessarily mean to be according to, for instance, interviews, as scenarios should shake the normal. In other words, worst case scenarios of different events are a possibility even if not the reality. Decisions and performance are when SCG does its work. These two blocks are where the model creates inputs and insight for decisions on how to react on events in the scenarios, as well as describes the performance which the reaction to events will entail.

As Figure 11, the process for building scenarios, has defined the development of scenarios, the scenarios are developed and run based on these processes. The sections within each scenario

can be linked to these processes and are described as; Narrative of scenarios, Possible implications, Problems to solve, Results, and Comments. Going through these four sections covers very well the six processes of scenario planning described in Figure 11. To dig into the process, focal issues are first of all identified, in other words the scope and decision variables are developed. This step is where the event causing the SCD is identified. Next is stakeholders and actors. This is identifying the relevant actors of the event. Both whom the event will affect and who are causing the event. Third step in developing the scenarios is to identify the relationship between the stakeholders and how they are related to the focal issue, or in other words, the event. Last step in developing the scenario, is to identify key uncertainties, or alternatives to the focal issues. This means to decide which are the possible reactions to the event of the scenario. The last step, running scenario, is where SCG does the job. By entering the scenario that is built into the SCG, it is possible for the software to run and give a proposal for a solution for the event happening, based on the data it is fed with.

The scenarios are developed based on a brainstorm session and on knowledge and experience of the current environment in which the supply chain operates. The brainstorm session has been done in two parts; alone and together with colleagues at Arla. The selection of members for inputs to the scenarios has been done by a random selection and without notice for the participants on beforehand, in order to make the scenarios as plausible, realistic and on the spur of the moment as possible.

## 8.1 Covid-19 Lockdown – A Lockdown of the Society due to a Global Pandemic

Currently, there is a pandemic going on all over the world. The Covid-19 has already caused more lockdowns of the society. As the disease is still running in the society, the possibility of further lockdowns of the society is present. Since societies around Europe have already experienced lockdowns in the spring and autumn of 2020, there is a greater understanding of the implications, lockdowns entail. Experienced from data of demand through 2020, there was an increase in demand of butter in the beginning of the first lockdown period in Denmark. A similar increase is a possibility when similar lockdowns hit the society again.

An event like this is only to some extent difficult to foresee since, as mentioned, experience says that lockdowns are governmental instruments used to navigate in the pandemic. This also means, that the scenario cannot be considered as a black swan, since it is a known possibility that might happen. In the spring of 2020, the lockdown was impossible to prepare for since it came out of nowhere. Knowing and having experience of a lockdown it is to a higher extent possible to use the experience to see trends in for instance infections, which might lead to similar lockdowns and thereby prepare the supply chain for a disruption.

To sum up the scenario and pinpoint the important focal issues, actors, etc., the scenario is regarding the event of new lockdowns happening to the society. These will first of all affect the consumers. Furthermore, they will obviously affect the supply chain, as they are considered a SCD. The actors of the supply chain that might be hit of such events would possibly be the production, the warehouses and the outbound transportation.

### 8.1.1 Possible Implications

If a lockdown of the society happens it has implications on the supply chain. This section will explain and simplify the possible implications caused by a possible lockdown in the society. The above section has already touched upon it, but to concretise the implications could be; *Supply difficulties and increase in demand.*

It is important to state that the implications are discovered based on assumptions and experience, as well as relevant inputs. The two implications seem to be conflicting and thereby difficult to being both fulfilled. However, the supply chain needs to be able to cope with these two in order to accommodate the disruption. The implications of the lockdown will mean that adjustments of the supply chain set-up or actions are needed. According to the theory on SCRES, these adjustments can be of different kinds. Both preparation and reaction for a disruption like this are a possibility. It is easier to understand the possible actions for the disruption when the implications have been discovered. The implications of these disruptions are the main driver for creating SCRES to be able to accommodate the possible event of a society lockdown due to a pandemic.

### 8.1.2 Problem to solve

As mentioned, the simpler way to use SCG is to define a problem that needs to be solved in a Network Optimisation method. The most accurate way to do this is to define a problem from the narrative scenario and implications. In other words, the AS-IS model will get constrains added on, which need to be reacted on. What the SCG will do, is to come up with a solution to the problem. Translating this to the theory of SCD and SCRES, the problem that needs to be solved in this model is what the disruption is causing. The SCRES can be deduced from the solution, to the problem, SCG suggests when running the model. The problem that arises based on the event and that needs to be solved in this scenario is:

How should the supply chain network react when the demand of all products to Denmark increases with 10% while capacity of production is reduced by 5%?

This problem is the result of what the event of another Covid-19 lockdown in the society is assumed to cause. Also, the above problem can be considered as the predicted supply chain disruption of the scenario. The problem contains the constraints which need to be set in the model, in order for SCG to come up with a solution to this disruption. Furthermore, by adding the constraints to the AS-IS model it is possible to compare the scenario of a Covid-19 lockdown with the "baseline" AS-IS model.

### 8.1.3 Results from Supply Chain Guru

In order to get SCG's suggestion to a solution to the problem caused by the event of a new Covid-19 lockdown, the constraints have been added to SCG by using the feature "Add Scenario". In adding scenario, the constraints based on the problem and implications of the problem can be added. The constraints that are added are; +10% increase of demand to the Danish market and -5% reduction of the capacity at the Danish dairy.

The model is then run with the constraints and SCG is suggesting a solution to these constraints. The visualised supply chain map with overview of flow of goods is shown beneath.

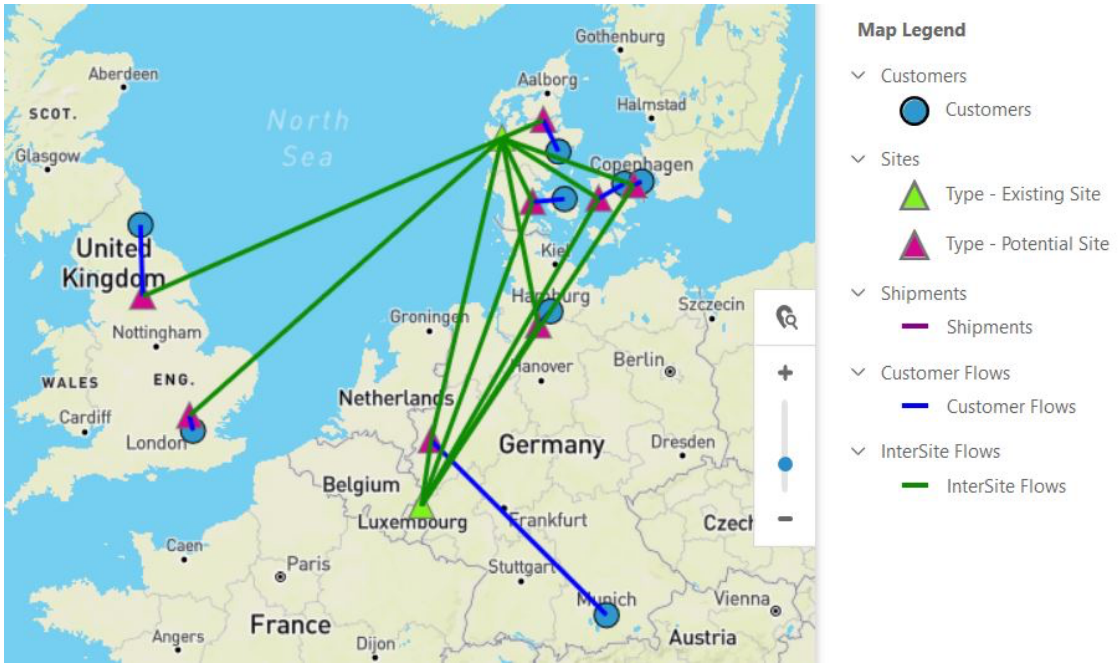


*Figure 17, SCG suggestion, Covid-19 lockdown, own production*

The map shows that InterSite flows have been added between the dairy in Germany and the Danish market. Only looking at the map gives a good overview of how the physical network will be affected, however, to get a better understanding of the actual initiatives that need to be done, the numeric results present a better picture of these.

| Analysis | Site | Destination | Units outbound | In transit inventory | Products |
|---|---|---|---|---|---|
| Baseline | Dairy_1 | DK_WH_1<br>DK_WH_2<br>DK_WH_3<br>DK_WH_4<br>DE_WH_1<br>DE_WH_2 | 43,357,257 | 1,043,672 | Kærgården |
| | Dairy_2 | DE_WH_1<br>DE_WH_2 | 71,248,211 | 1,900,706 | Kærgården |
| Covid-19 | Dairy_1 | DK_WH_1<br>DK_WH_2<br>DK_WH_3<br>DK_WH_4 | 26,760,137 | 541,521 | Kærgården |
| | Dairy_2 | DK_WH_2<br>DK_WH_3<br>DK_WH_4<br>DE_WH_1<br>DE_WH_2 | 87,845,342 | 2,778,472 | Kærgården |

*Figure 18, Summary of SCG suggestion, Covid-19 lockdown, own production*

Digging into the results and considering the UK market in this scenario, it would not be affected by a Covid-19 lockdown in Denmark. Upstream in the supply chain, neither the German market is hit by the lockdown in Denmark. Considering the flow of goods in-between the sites in the model, SCG suggests that the warehouses and dairies take action if the event hits. SCG suggests to move the production of Kærgården_B for the Danish customers in South, Zealand and Copenhagen to the dairy in Germany and ship it from Germany to the three warehouses in DK_WH_2, DK_WH_3 and DK_WH_4. The reduced capacity also means, that the general inventory level of the warehouses in Denmark decreases. This is an obvious result of having a lower number of products shipped from the dairy. The increased demand on the Danish market and reduced capacity has led to that the capacity of the Danish dairy not being able to cope with production of all the three markets,

which means that some productions have been moved to Germany. In general the analysis shows that approximately 38% of the production of Kærgården at the Danish dairy has been moved to the German site.

### 8.1.4 The Scenario relative to Supply Chain Resilience

Comparing the results from SCG to SCRES and Figure 9, the suggestions to react on the event are quite similar to what SCRES has been defined as. As already touched upon, the resilience definitions are both readiness, recovery, response, etc, where building and running this scenario would be either readiness or response. This means that running the scenario can either be done before the lockdown is warned of or after it has started to make decisions on how to react to the new reality. The way SCG is used is dependent on how prepared Arla is to focus on SCRES. If data is acquired and the AS-IS model is ready, scenarios with constraints can be run quite fast, and readiness can be ensured. If the model is not ready whenever the event hits, relatively quick response can be ensured by creating the AS-IS model and adding the known constraints, which will then be used when SCG makes proposals for how to react to the event of a Covid-19 lockdown.

Considering the SCRES initiatives described in Figure 9, more of them are present in the scenario of a Covid-19 lockdown. First of all, obviously the supply chain mapping is done. As already mentioned in the theoretical framework, supply chain mapping creates transparency throughout the supply chain and visualises potentially exposed parts of the supply chain. In this scenario, it can relatively easy be seen in the supply chain map, that the Danish market as well as the Danish production site will be exposed if a lockdown hits Denmark. By having the supply chain map, it is possible to easily see possible reactions to this. Increase of inventory is an initiative which SCG suggests to do. In the above section, SCG suggests that increasing the inventory of the warehouses will help cope with the decreased capacity and thereby still be able to meet the demand. An expansion of the supplier base for the Danish market has been suggested to be increased as well. In the AS-IS model and the current supply chain set-up, the Danish market gets its supply from the dairy in Denmark. SCG suggests to expand the supplier base by also getting supplies from the dairy in Germany. By doing so, the exposure of the market is decreased, since a decrease in the capacity in Denmark would mean that the supply and demand balance can be sustained by supplying from Germany as well.

## 8.2 Brexit – United Kingdom leaving the European Union without a Deal

The 23rd of June 2016, the Brits voted for the United Kingdom to leave the European Union. UK leaving the EU brings a lot of uncertainty as well as negotiations on trade agreements between UK and EU. These trade agreements and whether a deal will be reached or not has a great consequence on exports to the UK. Also, imports from the UK are affected by the negotiations. There are several possible outputs of the negotiations between UK and EU; they can end up with an agreement on trade deals similar to the one between the countries which are EU members, and they can end up with no deal, leading to high taxes on products imported from and exported to the UK. UK leaving the EU without a deal on trades will most likely also cause an inflation of the sterling pound, meaning that demand will probably be affected by this inflation. An event like this is relatively easy to foresee, as the result of the vote has been known since 2016, and therefore preparations for the different possible outcomes of the exit have been possible to do.

According to Participant G the majority of the production from the dairy in Denmark is shipped to the UK. This clarifies that the Brexit and trade negotiations can have a big impact on the butter supply chain for Arla, since approximately half of all volumes from the dairy in Denmark is shipped to the UK.

Summing up the scenario, the focal issue is the event of UK leaving the EU without a deal, causing a SCD. The actors involved in this scenario are both consumers, transportation to the UK, the dairy of Denmark, as well as the organisation of Arla in total, financial-wise. The next section dives into how the different actors are affected.

### 8.2.1 Possible Implications

Working with the worst-case scenario of Brexit, UK leaving the EU without a deal, it brings possible implications for the butter supply chain of Arla. The implications will have an effect on the supply chain both operationally, financially and behavioural-wise, as the identified implications are; *Extended lead time for export to the UK, Variation in demand due to inflation, and Higher taxes on exports to the UK*.

The implications are identified based on assumptions and worst-case scenarios described by different researchers in the field, such as Amadeo (2020). Further, internal communication from Arla has been used as inspiration for finding possible implications. To dig into the implications and what directly caused them, the extended lead time for export to the UK can be caused by customs at the UK border, meaning that the freedom of movement between the UK and EU is limited, and the waiting time for trucks at the border is assumed to take longer. It is also assumed that no deal would mean that the demand of imported butter will vary, due to inflation of the pound sterling. Also, prices of imported products may rise, compared to locally produced products, also resulting in a varying demand. Last but not least, higher taxes on exported products to the UK are to be expected, if the UK leaves the EU without a trade agreement.

### 8.2.2 Problem to solve

As the event of this scenario is known, and the implications causing the disruption are known as well, the next step is to identify the problem to solve for SCG. As mentioned in the first scenario, the SCG needs a problem to be solved, when working with Network Optimisation, as in this case. Therefore, the problem assumed to arise with Brexit without a deal needs to be clarified and pinpointed, as the constraints in this problem are to be added to the AS-IS model in order for the SCG to analyse a solution to the problem. The solution to the problem can be considered as a possible initiative to create SCRES to the event happening. Based on the narrative scenario and the possible implications, the problem within this scenario is:

How can the supply chain react to the UK leaving the EU, leading an extra 1 day of lead time to and variation in demand up to 20% on the British market?

This problem is inserted as constraints into the AS-IS model that has been built. Then it is possible to investigate how to deal with the assumed problem of the UK leaving EU without trade agreements. SCG will provide solutions to the problem, which can indicate how SCRES can be established for a disruption like the one in this scenario. In the following section the problem has been run in SCG and the results of SCG will be presented.

### 8.2.3 Results from Supply Chain Guru

To solve the problem in SCG, the constraints based on the implications have been added. The constraints added to the AS-IS model, in order for SCG to solve the problem, are a decrease in demand of 20% due to higher prices on imported products for the British consumer, and 1 day extra lead time when crossing the border to the United Kingdom. The constraints are the basis for understanding the implications of the UK leaving the EU without a deal on the supply chain; and SCG has come up with a suggestion for how to cope.

Beneath a visualisation of the suggested supply chain from SCG is provided. The map is visualising the flow of goods suggested by the software with the assumed constraints of the UK leaving the EU.

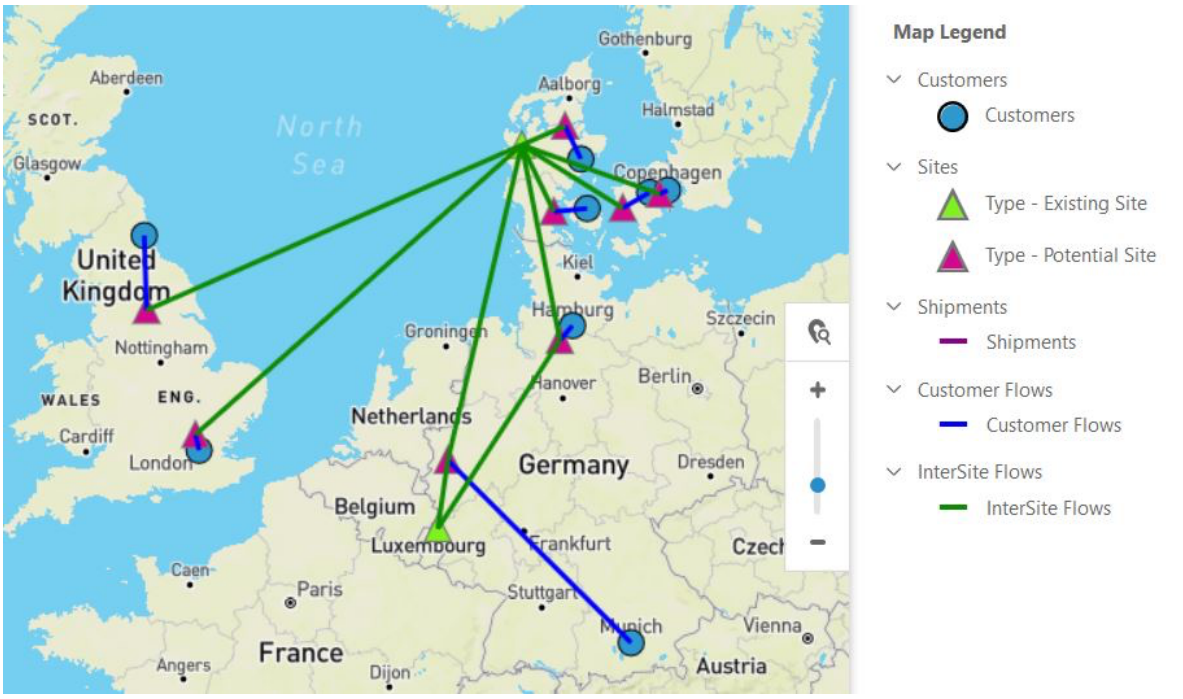


*Figure 19, SCG suggestion, Brexit without deal, own production*

Looking at the map and the flow of goods, there is no change from the AS-IS model. This makes good sense, since the market affected by the Brexit is the UK market, and the German and Danish markets stay the same. However, by looking into the numeric results, differences in the supply chain when comparing the AS-IS to the scenario are clear. A summary of the results from the analysis is presented beneath.

| Analysis | Site | Destination | Units outbound | In transit inventory | Products |
|---|---|---|---|---|---|
| Baseline | Dairy_1 | UK_WH_1 | 40,308,194 | 3,342,204 | Lurpak |
| | UK_WH_1 | UK south | 39,378,044 | 131,261 | Lurpak |
| | UK_WH_2 | UK north | 930,150 | 13,517 | Lurpak |
| Brexit | Dairy_2 | UK_WH_1<br>UK_WH_2 | 32,246,555 | 3,247,619 | Lurpak |
| | UK_WH_1 | UK south | 31,502,435 | 127,548 | Lurpak |
| | UK_WH_2 | UK north | 744,120 | 13,133 | Lurpak |

*Figure 20, Summary of SCG suggestion, Brexit without deal, own production*

SCG suggests to keep stock of products, approximately 10%, for the UK market in the Danish site, in order to be able to increase the fill rate of the trucks shipped to the UK. The extra lead time also means that the average inventory level at the warehouses in UK is increased, since an extra day of supply needs to be kept on inventory, as the flexibility of having one day of lead time is reduced. Despite having 20% fewer units outbound, the warehouse inventory levels have increased with 3%. With more data it is assumed that the general safety stock would be increased in the warehouses as well since adding to the lead time means less flexibility. Besides this, the products produced at the dairy in Denmark have been reduced. Since the demand from the British market has been reduced by 20%, there is spare capacity at hand. This can be considered as both good and bad since the production cost per unit is higher due to the fixed costs, but on the other hand the surplus production can be used as a buffer in case of an unforeseen event.

### 8.2.4 The Scenario relative to Supply Chain Resilience

The results from SCG on the problem occurring if the UK leaves EU without a trade agreement can be considered as creating SCRES considering theory. Scenario planning like in this example can be considered as a way to prepare for the possible disruption of Brexit. As mentioned, Arla is already scenario planning for Brexit and the financial outcomes of the different possibilities. By using SCG Arla is able to do scenario planning on the supply chain as well. In this example, a worst-case scenario example has been stated and run through SCG to be able to prepare the supply chain for this scenario. By knowing how the supply chain reacts to the event, it is possible for Arla to create elasticity and robustness to prepare the supply chain for Brexit.

Looking at the initiatives in Figure 9, some of these can be compared to the suggestion SCG has proposed. The supply chain map was drawn already as the AS-IS model, but the proposed supply chain adjustment provides a new map for further understanding of the supply chain. As this model is quite simplified compared to the physical supply chain, the map does not show the full extent of the supply chain network. If all the customers of the supply chain were visualised, the supply chain map would provide a very extensive view on which parts of the supply chain downstream would be exposed by Brexit due to more transparency of the chain. Additional to the supply chain map, an increase of the inventory is suggested, since SCG foresees that the reduced flexibility due to customs delays will lead to a need for more inventory. In general, Brexit with no deal will presumably lead to a SCD in the sense that demand would decrease. A decrease in the demand will not make SCG propose insights of how to cope with this and maintain the sales to the market, therefore it might be difficult to predict how to cope with this SCD sales-wise, as this is out of scope for SCG.

## 8.3 Conflagration at dairy – Breakdown at Dairy due to Fire

An event that will lead to a disruption as well, is a possible conflagration at a dairy. Compared to the two above scenarios which are both considered white swans, this scenario is more considered a black swan. Events like this are impossible to foresee and thus very difficult to prepare for. Referring to Figure 6, conflagration at a dairy would be located in the bottom right corner. The probability of an event like this happening is very low, but the impact on the supply chain would be huge. The assumption of low probability for an event like this stems from experience of former conflagration on dairies or the lack of it.

If a conflagration at a dairy happens in the butter supply chain it would lead to great disruptions to the supply chain, bearing in mind that the supply chain contains two production sites. This scenario is built around a breakdown of one of the dairies due to a fire. The dairy involved in the fire is the one in Denmark supplying products to all of the three markets involved in this analysis. This means that a breakdown of the dairy in Denmark would affect the whole supply chain of butter and different initiatives would most likely be necessary to still be able to meet the demand from the markets. As mentioned, a black swan like the event in this scenario will be difficult to prepare for, and scenario planning will probably be more of preparing for response and recovering from the event, than preparations for the actual event to happen.

Pinpointing the focal issues of this scenario, it is the event of a conflagration happening on a key production site. The actors involved in this scenario would more or less be the whole supply chain, except the customers, since a sudden breakdown of this kind would disrupt the whole supply chain. The following section will clarify the implication of an event like this happening.

### 8.3.1 Possible Implication

If a conflagration at the Danish dairy should happen it will lead to implications for the supply chain of butter. The implications will most likely affect every physical aspect of the supply chain. For this scenario the possible implication is; *Temporary decrease of capacity at the Danish dairy.*

This implication is easy to foresee, if the event should happen. The implication is obvious as a fire in a diary will most likely imply severe damage to the site and a possible breakdown of production lines due to repairs of the damages. The difficult part of the implication is to assess to which extent the decrease of capacity will be. The decrease of capacity will most likely hit both the Danish and the British markets quite hard, as the main supply to these markets comes from the dairy in Denmark. This implication is a rather complex issue for the supply chain since both Kærgården and Lurpak products are produced at the Danish dairy, while the production in Germany is only producing Kærgården and there is thus no alternative production for Lurpak.

### 8.3.2 Problem to solve

This scenario differentiates from the two previous ones. The two previous scenarios are what we can consider a white swan, while this one is more of a black swan. This also means that the problem linked with the event happening is difficult to predict and determine. However, a problem can be set up based on the assumed implication for SCG to solve. As mentioned in the introduction to this chapter, some of the scenario planning is based on "qualified guessing", which will be the case here as there is no further experience of an event like in this scenario and it is difficult to predict what happens if a conflagration happens at the dairy in Denmark. Based on assumptions and the implication, the problem that needs to be solved is:

What actions are needed in the supply chain network in case of a temporary breakdown of a production line in a key dairy?

Like the previous scenarios, this problem is the basis for the constraints added to the AS-IS model. As the two previous scenarios could provide preparation foundation, this scenario will more look into how to react if a conflagration happens. This means that the solution from SCG is probably not a 1:1 solution ready for use, as there are big uncertainties of the implications from this event, or the problem to solve, being accurate. However, by being able to quickly identify the problem, SCG could increase the response time.

### 8.3.3 Results from Supply Chain Guru

In order to get SCG to run the scenario of a conflagration leading to a breakdown at the Danish dairy, a constraint has been added to the AS-IS model. The constraint consists of a reduced production capacity of 25% of the dairy. Inserting the constraint to the AS-IS model and running the scenario, SCG comes up with a suggestion for how the supply chain can cope with an event of conflagration and breakdown of a production line. If the breakdown is bigger or smaller, the capacity reduction can be changed accordingly in the constraint, and SCG will suggest a new solution with insights.

A supply chain map visualises how SCG suggests the supply chain set-up should react to this SCD. Also, the map shows how the flow of goods will be affected in the case of an event like a conflagration.

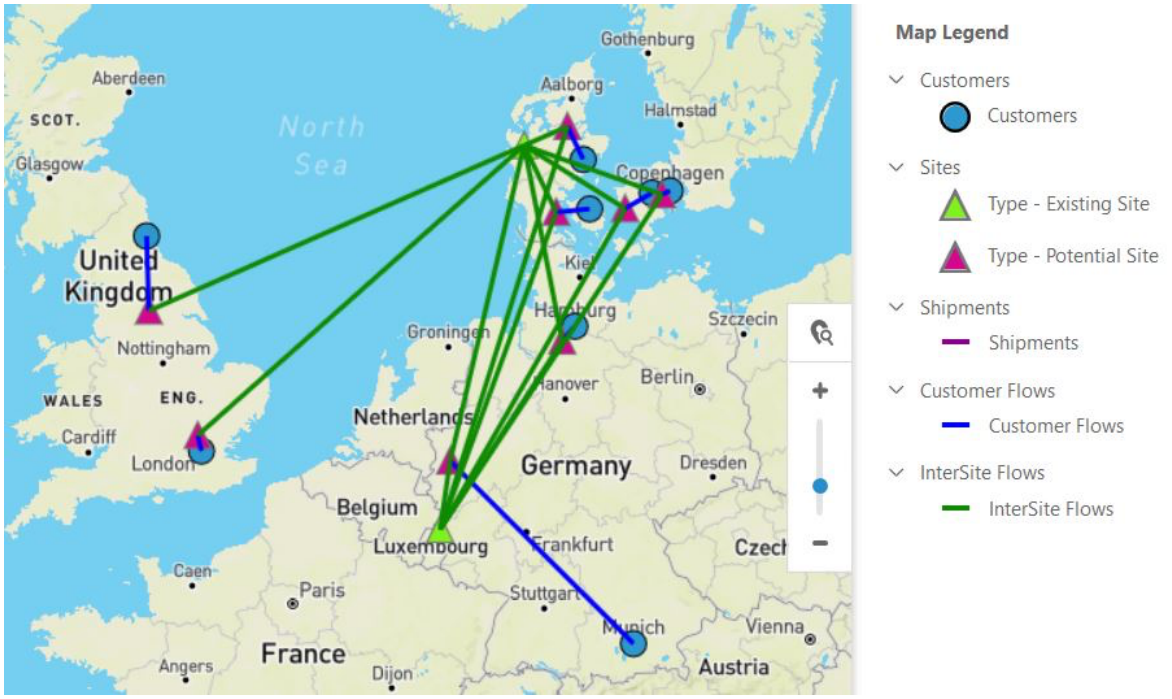


*Figure 21, SCG suggestion, Conflagration in dairy, own production*

By just looking at the map and comparing it to the map of the AS-IS model it is clear that SCG suggests a change in flow of goods. This was to be expected, as taking away one quarter of the total capacity from one production site supplying all markets will cause major problems. The map shows that SCG suggests to start supplying the four customers in the Danish market with products from Germany. Looking further into the suggested solution from SCG, a summary of the results has been provided beneath.

| Analysis | Site | Destination | Units outbound | In transit inventory | Products |
|---|---|---|---|---|---|
| Baseline | Dairy_1 | DK_WH_1<br>DK_WH_2<br>DK_WH_3<br>DK_WH_4<br>DE_WH_1<br>DE_WH_2 | 43,357,257 | 1,043,672 | Kærgården |
| | Dairy_2 | DE_WH_1<br>DE_WH_2 | 71,248,211 | 1,900,706 | Kærgården |
| Conflagration | Dairy_1 | DK_WH_1<br>DK_WH_2 | 1,737,285 | 18,095 | Kærgården_A |
| | Dairy_2 | DK_WH_1<br>DK_WH_2<br>DK_WH_3<br>DK_WH_4<br>DE_WH_1<br>DE_WH_2 | 112,868,193 | 4,593,867 | Kærgården |

*Figure 22, Summary of SCG suggestion, Conflagration in dairy, own production*

From the warehouses to the customers the flow and supply chain stays the same. The demand is the same, and the service level is not affected by the solution provided by SCG. However, looking into the interflow between the sites there has been a rather big change, as the map tells. The numeric data shows that the supply stays the same, but the flow has changed. In the AS-IS model the supply of Kærgården for the Danish market was produced in Denmark. The decrease in capacity has meant that a major part of the production of Kærgården has been moved to Germany. This is a result of the dairy in Denmark being the only site producing Lurpak, which means that the

production of Lurpak cannot be decreased or moved. Looking into how large a part of the production of Kærgården has been moved to Germany, approximately 98.5% of the production of Kærgården is to be produced in Germany in order to still be able to meet the demand for both Lurpak and Kærgården on the three markets. The only Kærgården left in Denmark is the A variant for DK_WH_1 and DK_WH_2. Moving the production of Kærgården also means that the lead time of Kærgården has been increased. This does not seem to be an issue to operate the supply chain, however, in SCG's proposal.

### 8.3.4 The Scenario relative to Supply Chain Resilience

Experiencing an event like this scenario is difficult to foresee or prepare for. The black swan happening is therefore about responding and recovery. A conflagration in a dairy is difficult to prepare for, and supply chain will probably never be ready for such an event. Therefore, the use of SCG in this case is directed towards getting a solution for how to either recover the supply chain from a breakdown on a key production site, or to respond to the disruption. The response needed for an event like needs to be fast. By preparing for the software with an AS-IS model with loads of data, it is possible to enter the constraints experience with the event and relatively fast get SCG to identify different options for how to cope with the disruption, and still be able to balance the demand and supply as good as possible. Also, the reaction to the disruption will be based on data and rational decision, which can avoid the supply chain from shattered.

The initiatives of SCRES from Figure 9 can be compared to the suggestion from SCG. Like the previous three scenarios, the tool of supply chain mapping is very useful for a SCD like this. When mapping the supply chain, a transparency is obtained and transparency increases the precondition for reacting to disruptions. Missing transparency makes it difficult to react quickly, and the supply chain can end up being in a state of disruption for a long time. Having visualised the supply chain in a map, it is relatively easy to see where in the supply chain there are opportunities to react, for instance like in this example, it becomes clear that there is spare capacity in Germany. This means production can be moved from Denmark to Germany if facing a breakdown like a conflagration will entail. As this kind of disruption is considered a black swan it is hard to make initiatives which can lead to SCRES. Some initiatives that can help accommodate a SCD like this are to increase inventory and have spare production capacity. However, a black swan is very rare, and having high inventories and spare capacity can be considered as a high cost for "security". The setup of creating initiatives for black swans is similar to having an insurance, as a security for unforeseen events, which might or might not happen. This can be costly to protect oneself from, when considering Figure 6 and the probability of a SCD happening. Therefore, creating the best possible circumstances for reacting to a SCD might be a better solution, for instance by using SCG.

## 8.4 Political Regulations on Transport – Trucks are no longer allowed to drive in Weekends

At the moment, trucks can drive on the highways every hour of the day, all year round in Denmark. In 2019, the government of Germany banned trucks from driving on the highways on Sundays and holidays. Furthermore, in summer, from 1st of July to 31st of August, the trucks are not allowed to drive on the highways on Saturdays (https://trans.info/en/bans-for-trucks-in-germany-in-2019-121175). A scenario developed for this analysis is that the Danish government applies similar restrictions to the Danish highways as seen in Germany. There could be more reasons for the Danish government to regulate truck transportation. The current environmental focus could lead to the government restricting the number of vehicles on the roads by, for instance, banning trucks driving in weekends. Also, by taking away trucks from the roads, traffic will decrease significantly, which could also be an objective for the government.

An event like this would cause a disruption to the supply chain of butter of Arla, since most of the produced volumes are shipped from the dairy in Denmark. The event that this scenario is built on, is considered a white swan (It is predictable that this might happen). Furthermore, the reaction time to a regulation of this kind would most probably be quite long (regulations take a long time from being proposed to being introduced, to being initiated). This means that Arla would be able to start preparing for the new reality with not being able to have trucks on the roads in the weekends. However, SCG would still be a great support tool to come up with solutions for how to cope with this event.

To sum up and pinpoint, the focal issue in this scenario is the event of introducing transport regulations for trucks in Denmark. The actors affected would most likely be the warehouses, the Danish dairy and the transportation in-between warehouses and dairies. The following section describes more how these actors can be affected as the possible implication of the event will be described.

### 8.4.1 Possible Implication

The implication of the scenario of regulations on transport is already to some extent described in the section above. In this section, the possible implication is described more thoroughly to get an understanding of the consequences of the scenario. The assumed main implication of regulations of transport is; *Shipping capacity decreased from seven to five days a week.*

This implication can have a major impact on the supply chain of butter. Since the production in Denmark is running in weekly cycles it will have an impact, taking out two of seven days for shipping. It would probably mean that the Danish dairy's inventory level will increase, inventory in the warehouses will increase, and the flexibility of the supply chain will decrease. Having less days to operate the shipping will also lead to the loads being bigger for each shipment, assuming that the demand will not change. Fortunately, the shelf life of the products is relatively long, having in mind it is food products, meaning that the possible two days of no movement will not have that great of an impact for the total shelf life of the products. The implication of regulations on transport will in general hit every market, since the Danish dairy is the supplier. The German market might, however, be able to shift their allocation of production from Denmark to Germany, where it is possible to ship on Saturdays.

### 8.4.2 Problem to solve

This scenario contains a quite obvious problem to the AS-IS model. The event of this scenario is easy to understand, and as for the second scenario, the event will come with a warning period, as political regulations will not happen from day to day. This means, that a SCD like this is considered a white swan. The defined problem is, again, a result of the narrative scenario and the assumed implication coming from the event. The constraints added to the AS-IS model are also relatively simple to add, and the solution provided by SCG should be one of the more predictable solutions. The problem for this scenario is:

How can the supply chain network accommodate the truck-free weekends in Denmark without compromising the service level?

The problem that SCG will come with a suggestion to solve can help Arla prepare for how to operate their supply chain if a traffic regulation of this kind is presented. This SCD is not considered having as big an impact as some of the others, which also means that the consequences of the event will not be huge. However, by solving the problem, SCG can still suggest the best possible solution to

the problem, based on the inputs provided to the model. This also means that the SCRES is reacting on a disruption, rather considered as preparing for a possible SCD, due to the warning time interconnected with political regulations.

### 8.4.3 Results from Supply Chain Guru

To get SCG to run the scenario, constraints have been added to the AS-IS model. The total period of the model has been divided into weekdays and weekends, in order to separate the two and start differentiating the transportation of the periods. By adding this constraint, it is not possible to ship products from the warehouses in Denmark in the weekends, meaning that the Danish customers will not get their demand fulfilled in weekends. As a result, the demand is moved from the weekends to Fridays before the respective weekends.

The map beneath visualises the supply chain set-up suggested by SCG to solve the problem and implications if transport regulations are accepted.

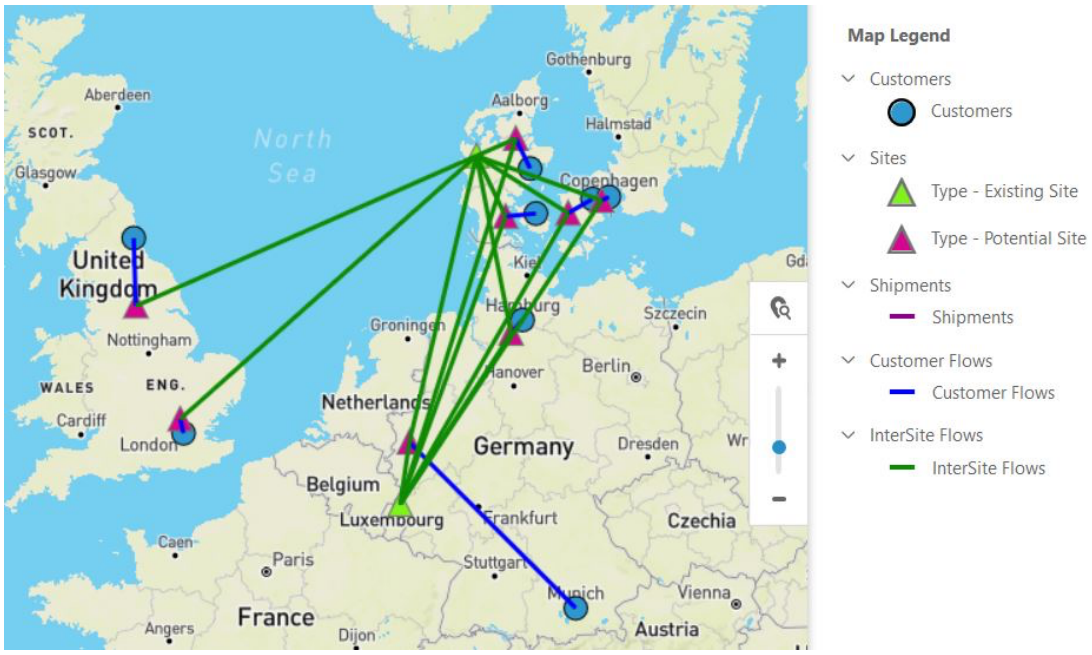


*Figure 23, SCG suggestions, Transport regulations, own production*

Comparing the map to the AS-IS model in Figure 16, it is seen that it is suggested that the dairy in Germany starts producing Kærgården for the Danish market as well, and for all four warehouses. The flow to the UK is, like the previous four scenarios, similar to the AS-IS since the only opportunity for production to the UK is the Danish dairy. The table beneath gives a more detailed insight in how SCG suggests to operate the supply chain.

| Analysis | Site | Destination | Units outbound | In transit inventory | Products |
|---|---|---|---|---|---|
| Baseline | Dairy_1 | DK_WH_1<br>DK_WH_2<br>DK_WH_3<br>DK_WH_4<br>DE_WH_1<br>DE_WH_2<br>UK_WH_1<br>UK_WH_2 | 125,789,864 | 5,279,084 | Lurpak & Kærgården |
| | Dairy_2 | DE_WH_1<br>DE_WH_2 | 71,248,221 | 1,900,706 | Kærgården |
| | UK_WH_1 | UK south | 39,378,044 | 131,261 | Lurpak |
| | UK_WH_2 | UK north | 930,150 | 13,517 | Lurpak |
| Transport regulations | Dairy_1 | DK_WH_1<br>DK_WH_2<br>DK_WH_3<br>DK_WH_4<br>UK_WH_1<br>UK_WH_2 | 88,225,043 | 6,557,757 | Lurpak |
| | Dairy_2 | DK_WH_1<br>DK_WH_2<br>DK_WH_3<br>DK_WH_4<br>DE_WH_1<br>DE_WH_2 | 108,813,042 | 8,471,817 | Kærgården |
| | UK_WH_1 | UK south | 39,378,044 | 246,011 | Lurpak |
| | UK_WH_2 | UK north | 930,150 | 32,007 | Lurpak |

*Figure 24, Summary of SCG suggestion, Transport regulations, own production*

Looking at the numbers in the above summary of the analysis, it can be seen that the inventory levels of the warehouses in UK have increased with more than the double on units in inventory. This is a result that there would be no possibilities for shipments in the weekend, meaning that the demand for the weekend in the UK would need to be stored in the warehouses already by Friday and cover the whole weekend as well as the Monday and Tuesday demands. As seen in the map, some production has been moved from Denmark to Germany. Looking into the numeric results, it is seen that actually all Kærgården for the Danish market is now produced in Germany as well as kept on stock in Germany during the weekend. This means that SCG suggests to solely supply Lurpak from Denmark and Kærgården from Germany. SCG also suggests to increase the inventory level of the warehouses in Denmark. This is an obvious initiative since the demand on Fridays is now covering two more days of demand from the consumers, meaning that the average inventory level will increase, since more is shipped outbound on Friday mornings. Also, the inventory relative to the outbound of the Danish dairy has increased, as products need to be stored that cannot be shipped straight away, when produced in the weekends. This refers to Lurpak for all of the three markets.

### 8.4.4 The Scenario relative to Supply Chain Resilience

As mentioned, when narrating the scenario, a warning period would most likely be notified, if political regulations on transport were introduced. Because of the warning period, the disruption cannot be considered a black swan. This means that the overall focus to create SCRES for a SCD like this is regarding preparation and readiness. Arla has an opportunity to run different scenarios before the regulations become effective. Using SCG, Arla would be able to enter the constraints attached to this regulation and get insights and suggestions from SCG on how to operate the supply chain when these regulations would become effective. A SCD that is not sudden is obviously easier to handle for a supply chain, as the systems and actors in the supply chain are prepared.

The solution from SCG can be linked to the initiatives in Figure 9 like all the other scenarios. Having the supply chain drawn in a supply chain map gives a clearer and better overview of the different actors and stakeholders in the supply chain. For a scenario like this it makes good sense to get this overview, as it gives a clear view of which parts of the supply chain are affected by transportation in Denmark. Thereby the exposure point can be pointed out. The transparency of the supply chain makes it possible to look into several different opportunities for solutions than the data-based ones from SCG. SCG is also suggesting to relocate the supply for the German market from Denmark to Germany. By doing so, the flow of goods to the market can be sustained. The proposed adjustment from SCG can also be considered as some kind of regionalising of the supply chain, meaning that the supply of butter for the German market is solely sourced from the dairy in Germany, resulting in an emphasis on nearshoring. Supply chain regionalising is also considered, by theory, as a way to ensure SCRES. In this example it is a way to accommodate the political changes made-up for this scenario, and thereby ensuring that if political regulations were introduced, supply for other markets would not be affected. In this case the UK market would obviously be affected as well, as all supply of Lurpak comes from Denmark. However, like in the Brexit scenario, a Greenfield analysis would maybe be sufficient to see whether it would make sense to regionalise the supply chain of Lurpak and open a production in the UK.

## 8.5 Summary

During the analysis, the theory defined in the theoretical framework has been put into context relating to the case of Arla's butter supply chain. The recorded supply chain is based on data from different planning departments within the supply chain and is visualised in Figure 13. The knowledge and understanding of the physical supply chain were the basis for creating the digital twin of the supply chain. In order to create a digital supply chain, a software from Llamasoft called Supply Chain Guru is used. The software is a tool used for supply chain design and is able to, by using a lot of data, to optimise supply chains or give data-based insight for the decision-making regarding supply chain designs. By using the knowledge, understanding and data of the current physical supply chain along with the Supply Chain Guru, a digital supply chain was created. The purpose of creating a digital twin of the supply chain is to be able to investigate whether scenario planning can be used to create supply chain resilience, as it has been stated in the theoretical framework.

When doing scenario planning, it is of advantage to have a twin of the physical system in which to do testing of the scenarios. The digital supply chain is used for exactly this. In the theoretical framework, knowledge on what a scenario actually is and how to do scenario planning was acquired. The scenarios in this e-book were developed based on the different steps according to Figure 10 and Figure 11. In order to use Supply Chain Guru most beneficially, it was decided to use the solving method of Network Optimisation. Therefore, when narrating the scenarios and event, implications and problems were discovered. The implications and problems were then translated into constraints which were added to the AS-IS model of the digital supply chain. By doing so Supply Chain Guru was able to come up with suggestions for how to cope with the problems occurring from the events described in the four scenarios as well as providing deep insight in the significance to the supply chain of the suggested solutions.

The development of the scenarios was done with the theory of black swan and white swan in mind. This means that the four scenarios consist of both events that can be foreseen and events that cannot be foreseen and which has a more shocking effect. The four scenarios that have been developed are*; Covid-19 lockdown, Brexit with no deal, Conflagration at a dairy, and Political regulations on transport.* The four scenarios consist of problems which disrupt the supply chain of BSM. SCG has then created solutions to accommodate the disruptions and clarify how to create resiliency in the supply chain regarding the specific disruption. For the Covid-19 lockdown SCG

suggests to start sourcing Kærgården for the Danish market from Germany as well, and thus focussing on increasing the supplier base. For Brexit, SCG suggests to increase the fill rate for each transportation, which means an increase of the inventory in Danish dairy. For the scenario of a conflagration happening, SCG proposes to move the production of Kærgården to Germany, and thereby focussing the production in Denmark on what is solely produced at the dairy affected by the breakdown. In the last scenario of transport regulations, SCG suggests to centralise the production of Kærgården to the German dairy, and then ship the Kærgården products to the Danish warehouses from here. Also, SCG suggests to increase the inventory levels at the Danish and English warehouses, since the inventory level should be able to cover the demand for the weekend as well.

A table has been created to summarise the scenarios and the suggested action by SCG. The table summarises the above analysis briefly and presents the main outputs.

| Scenario | Type of disruption | Implications | Problem | Solution | Compared to SCRES |
|---|---|---|---|---|---|
| *Covid-19 lockdown* | White swan | Supply difficulties and increase in demand. | How should the supply chain network react when the demand of all products to Denmark increases with 10% while capacity of production is reduced by 5%? | Production of Kærgården_B has been moved to Germany solely, and the inventory levels on the Danish dairy have been increased. | Ensuring readiness or response. Depending on the reaction time |
| *Brexit – No deal* | White swan | Extended lead time for exports to the UK, Variation in demand due to inflation, and higher taxes on exports to the UK. | How can the supply chain react to the UK leaving the EU, leading an extra 1 day of lead time to and variation in demand up to 20% on the British market? | Inventory levels in the UK warehouses have been increased as well as the inventory levels at the Danish dairy. | Preparing for the Brexit by increasing the readiness of the supply chain. |
| *Conflagration on dairy* | Black swan | Temporary decrease of capacity at dairy_1. | What actions are needed in the supply chain network if there is a temporary breakdown of a production line in a key dairy? | All production that can be produced elsewhere than Denmark has been moved to Germany. | Reaction and ensuring quick response and best possible recovery. |
| *Political regulations on transport* | White swan | Shipping capacity decreased from seven to five days a week. | How can the supply chain network accommodate truck-free weekends in Denmark without compromising the service level? | The production of all Kærgården is moved to Germany. The general inventory levels in UK and Denmark have increased and the demand from the Danish market on Fridays has increased | Preparing for the political regulations and ensure readiness by for instance re-engineering the supply chain. |

*Figure 25, Summary of scenarios, own production*

Concluding on the analysis, SCG has been used to enhance supply chain resilience, by increasing both readiness and preparedness for disruptions, as well as the ability to quickly respond to supply chain disruptions and recover from them. In the following chapter, it will be discussed how scenario planning is enhancing supply chain resilience along with what kind of supply chain resilience scenario planning can support. Furthermore, paradoxes of supply chain resilience will be discussed.

# 9 Discussion & Reflection

Through this chapter the results of the analysis compared to the theory of this book will be discussed and reflected upon. The analysis of scenario planning in the butter supply chain will be the basis for the discussions of how scenario planning can enhance SCRES, to identify the prerequisites for using a supply chain design tool, as well as the paradoxes of working with SCRES. The chapter will be divided into sections and themes which discuss the results from the analysis against the theory that was presented in Chapter 3. Some of the themes throughout this chapter are how the results from the analysis can be compared to the theory of SCRES, and how the digital twin is used compared to how the theory says it should be used.

## 9.1 Enhancing Supply Chain Resilience

In the theoretical framework, Chapter 3, it was investigated what SCRES actually is and what it contains. It was found, that SCRES consists of more initiatives, strategies and definitions. This also means, that it can be difficult to say exactly what SCRES is and when it has been obtained. As Taleb (2010) mentioned in his book, about the black and white swan, there are two different kinds of disruptions. It is difficult to react or prepare in the same way for the two disruptions. Whereas it is possible to react on the white swan, it is much more difficult to prepare for the black swan, probably close to impossible to prepare for. To exemplify, a black swan like a fire in a dairy is not possible to foresee. Not being able to foresee an event obviously makes it different to prepare for. The question is whether it is possible to ever foresee and prepare for a black swan. Safety stocks and other tools are used to cover for minor disruptions or problems, but bigger disruptions with major impacts, like some of the events described in Figure 5, are difficult to prepare for. The physical aspects of supply chains are of a size where it is difficult to acquire backups just waiting for an event that might happen. As Christopher (2005) and Lambert (2008) state, lead-time and cost are the two heavy factors of the physical supply chain, having excess capacity and working with backup for a possible event that might happen can be conflicting, when trying to optimise these two factors.

However, by investigating the theory and considering the disruptions that come with a great shock effect it is possible to some extent prepare for the events, by using initiatives which prepare the supply chain and make the best possible conditions available to meet unforeseen events in the future. Considering Figure 9, Lund (2020), Cranfield University (2003) and Ponomarov (2009), some of the initiatives which will contribute to robustness of the supply chain are Supply Chain Mapping, Improve collaboration with suppliers, Expansion of supplier base. These come with costs, which will be discussed in more detail in section 9.6. Looking at the SCRES strategies, the strategies of re-engineering of supply chain and minimising exposure to shock are ways to prepare for black swans as well. Again, creating strategies like these is difficult as black swans cannot be foreseen and no one knows which implications a black swan might lead to. Therefore, it can be difficult for companies to, for instance, re-engineer their supply chain based on something they do not know yet.

On the other hand, the white swan is to a higher extent about the preparedness and readiness aspect of SCRES. The events created in the analysis were mainly white swans; disruptions and events that to some extend are possible to foresee and prepare for. These events often come with a warning period, which can be a lifeline for companies to prepare themselves for the events. For instance, re-engineering of the supply chain can be done if a company is aware of regulations, political events etc. that will happen on a market they are operating on. Being able to prepare for

events that disrupt the supply chain makes it much easier to work with SCRES and the opportunities for making thought-through decisions are better than with the black swans which require quick decisions to recover or react.

As the analysis showed different types of disruptions and different ways to handle these, it is interesting to reflect upon SCRES and what it actually is. Through this book, different views and theories on resiliency have been presented. Resiliency has, in theory, been described as both preparing for the future by creating robustness and elasticity, and as being able to react to and recover from events. These definitions depend very much on the case in which the resiliency is used. Based on the interviews conducted, especially Participant C, the understanding of resiliency was that it is about reacting on disruptions that might happen. Considering the theoretical framework and the analysis, the ability to react can be increased by looking into the initiatives of the analysis of the case company Arla. Also, according to Stecke (2009), resiliency is about to prepare for events. This can also be seen by looking into the SCRES house and by taking stand in the chapter 5 where the analysis on how to prepare a supply chain for different events has been conducted.

The following section will dig deeper into the discussion and discuss how the theory of scenario planning can be used in regards to SCRES, using the results from the analysis as a foundation. Based on the already discussed topic, SCRES, the discussion will follow in how to a greater extend use a digital twin to further emphasise on SCRES.

## 9.2 Scenario Planning as Enabler for Supply Chain Resilience

As the analysis has shown, scenario planning can be used to enable SCRES in different ways based on the kind of disruption. The scenario planning is obviously more usable for some events than for others. Events that cannot be foreseen and are rather improbable, in other words black swans, are difficult to do scenario planning on, since the implications of such events can be difficult to identify. For instance, would it make sense, before 2001, to do scenario planning off a terror attack hitting? Probably not. On the other hand, dealing with white swans, scenario planning is much more useful and can provide multiple plans for how to deal with the disruption. The analysis has provided examples on how scenario planning can be used to prepare the supply chain for white swans and thereby increase the SCRES. Both the scenario with Brexit and the scenario with political regulations on transport describe and show very well how scenario planning can be used to make plans for how to deal with disruptions. Whenever the Brexit will be realised, the scenario planning has led to Arla being prepared for how to react if the UK leaves the EU without trade agreements, and how to cope with this.

Even if scenario planning may not make sense in connection with certain shocking events, it may in future be more widely used to prepare the supply chain for events, that are neither clear nor obvious. The example from theory when Schoemaker (1991) described how scenario planning was used on a black swan within Shell Oil, is a very good example of this. The scenario about conflagration in a dairy is another good example. This event would come like a bolt from the blue, but by having already done the scenario planning Arla will have contingency plans for how to react on it. It can, of course, be difficult to develop scenarios in advance on big epoch-making events like some of those described in figure 5. Events like these are considered black swans, and they therefore backup the point of scenario planning being more usable for white swans. The following three subsections will reflect on how digitalisation of the supply chain contributes to scenario planning through the digital twin and how SCG to a greater extent than in the analysis can be used for SCRES. Lastly, a general discussion on scenario planning and its possible downsides will round off the section.

## 9.3 Digital Twins of Supply Chains

Doing scenario planning like it has been done in this book, on a digital twin, it is interesting to discuss how a digitalisation of the supply chain can support SCRES. In Chapter 4 the digital twin of the supply chain was developed. As mentioned, and by Uhlemann's (2017) definition of a digital twin, the digital twin of a supply chain system is to create a virtual copy of the physical supply chain network. When working in virtual spaces data is key, and the culture around data is the most important in doing so. Starting to rely even more on data will probably require a transition, since reliability to the data must be ensured and the persons within Arla will have to start depending on whatever the data says. This also means, that the digital twin is not a possibility for everyone. A lot of understanding of the physical supply chain is required when building a virtual space, and general costs and lead-times are required to be able to use the twin to see implications within the supply chain. Additional to the understanding of one's supply chain, building a digital twin takes time as well. Considering the IKEA case, a whole new organisation within supply chain design tools was developed to build the digital twin due to the great complexity in building a digital twin.

In this book, the butter supply chain for three close markets is in scope, meaning that the supply chain set-up is very simplified. Building a digital twin of the supply chains full scale would, as mentioned, be very difficult and time-consuming. Both due to the number of products flowing through the supply chain, but also due to the high number of customers. Customers consist of almost every grocery store, as well as restaurants and bakeries etc. This means that the environment Arla is operating in, not just organisational, is very complex and that a creation of a virtual space of this will probably take as much time, as it did for IKEA. However, the possible positive outcome of having a digital twin of the supply chain will be worth it considering SCRES. One initiative, described by Choi (2020), within SCG is supply chain mapping. By creating a thorough digital twin of the supply chain, Arla can draw an extremely detailed map of their supply chain and thus create valuable insights as well as transparency throughout the supply chain which will make it easier to react on or prepare for events causing disruptions in the supply chain.

Also, as shown in the analysis, creating a digital twin of the supply chain will create a whole new possibility for scenario planning, since it is then possible to see the actual reaction of the scenario on the supply chain, without actually affecting it. This can give highly valuable insights and understanding when making decisions based on the scenario planning.

When discussing the area of digitalisation of the supply chain, it is obvious to reflect on the role which SCG plays in enabling SCRES and how it can be used to work with SCRES further than what was done in the analysis.

## 9.4 Supply Chain Guru as an Enabler for Supply Chain Resilience

SCG has been the main driver when developing the digital twin for the analysis. Considering Section 5 and the five solving methods, the network optimization method was used to solve problems occurring from events causing disruptions to the supply chain. This method worked well as implications and problems of the events were identified and constraints to the AS-IS model were added. Based on this, SCG came up with a solution on how to react to the problem and optimise in the most cost-efficient way. As found in the analysis, this can help to increase SCRES, as SCG's solutions to the problems from the events can be translated into SCRES initiatives. SCG can be used both for reaction to black swans and preparations for white swans. Considering the white swans and events that can be foreseen or which have a warning period, SCG was used to run scenarios on the problems that might occur. This means that SCG was coming up with suggestions for how to proact to events and prepare for whenever they would happen. SCG in relation to black swans was used to react on the event. Having an AS-IS model in form of a digital twin, makes it possible

to quickly add the constraints from an event with chock effect, and thus make a basis for a possible fast reaction to the event, based on the solution which SCG comes up with.

However, not only network optimisation can be used in SCG to create SCRES. As mentioned in the scenario with Brexit, a possible solution of creating a new dairy in UK to accommodate the implications of Brexit would be a possibility. Considering the house of SCG and Cranfield Universities' practical guide (2003), a solution like this would be a re-engineering of the supply chain. The network optimisation method will not suggest a solution like this, but by adding a Greenfield optimisation, the solution can be assessed and SCG can suggest whether this will make sense. Putting in a Greenfield analysis of a possible dairy in the UK producing Lurpak would make it possible for Arla to compare this solution with the one SCG gave in the analysis. This would require a lot of different data, when taking into consideration it is about establishing a new production site, and it would further demand a lot of time and resources, but it would, however, still contribute to the decision making on doing so. Looking at the initiatives of SCRES, regionalising of the supply chain and expansion of the supplier base can be looked into by using the feature of Greenfield analysis as well. By comparing different possible suppliers and sites, valuable insight can be given in order to work with these two initiatives.

Despite all the possibilities and benefits of using SCG to create SCRES, there are also some important points that need to be taken into consideration. The time spent on creating the digital twin in SCG can, according to Participant I, be split into two categories; working with data and building a model. During the interview, Participant I said that the time allocation is probably like the Pareto theory, 80/20. In this case 80% of the time is finding data, standardising data and preparing data, whereas 20% of the time is spent on building the model and running the optimisations. This gives a quite good indication, like discussed earlier, that building a digital twin of the supply chain is not for everyone. The chart beneath visualises the time.

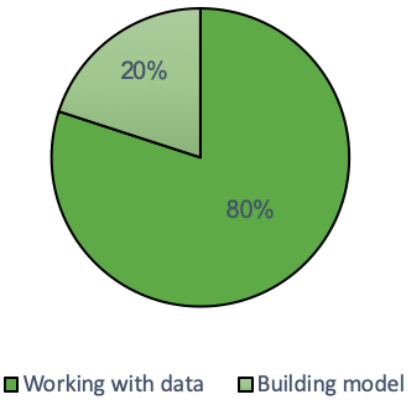


*Figure 26, Chart of time distribution for building SCG models, Participant I*

Beside spending a lot of time on finding and preparing data for SCG, there is another point to be considered. This is one downside that needs to be taken into consideration when working with SCG in order to create resiliency. When SCG suggests an optimisation, or in this case a solution to a problem, it only suggests one solution, which is the possible best from a classical cost perspective, like in SCM. This means that the decision makers need to be aware of the fact that SCG does not take soft factors into account and therefore there may be more suitable solutions based on these. This means that SCG will suggest the best solution based on data input, but whenever making decisions of how to react on or prepare the supply chain for future events it might not be beneficial

to base the decisions solely on SCG's suggestion. SCG is still suggesting a valid solution, however, based on the hardcore facts and data, while the softcore facts should come from other sources.

## 9.5 Reflections on Scenario Planning

To create SCRES based on scenario planning, there are some pitfalls which need attention. As described in the theoretical framework, scenario planning is based on different processes described in Figure 11. Looking into each process, there is a huge amount of work that needs to be done. A lot of the work is about identifying different things, for instance focal issues and stakeholders. It is difficult to do so, as there is a need to ensure that for instance every stakeholder is identified. Missing one could lead to consequences not only for them but for the whole planning based on the scenario. Also, there is another specific problem to be aware of when doing scenario planning. The scenarios are very much based on narratives, meaning that the planning will be done based on one's mindset and beliefs of what might happen. In the analysis, the scenarios have been developed through brainstorming and inputs from surroundings, but one cannot be sure whether the scenarios will actually happen or not. In other words, scenario planning is to some extent "qualified guessing". Considering the building blocks of Figure 10, experiences and learnings are a part of developing the scenario stories, which means that the scenarios are not solely developed on guessing what might happen in the future, but also on facts and trends describing what might happen.

Developing scenarios would probably be more sufficient to do in groups of experts. As scenario stories are "best man's guess", it makes sense to bring people who know most about certain themes to the table. Take for instance the Brexit scenario of the analysis, there are people at Arla who are closely following the developments of the negotiations between the UK and EU. It would make good sense to involve these people in developing the scenarios, together with people involved in the exports and production of Lurpak. Creating "experts' groups" will validate the scenarios to a much higher extent as their "guessing" is done by someone who have a better knowledge for doing so. It is important to state that scenario planning as a matter of course can end up being a waste of time, as the scenario developed will possibly never happen and therefore the work in running the scenarios and do the planning can end up being to no avail.

As this book has researched how SCRES can be enhanced through scenario planning, it makes sense to investigate what consequences SCRES might bring. It is, however, even more interesting to translate the consequences into paradoxes and see how these might be useful to balance the supply chain. The following section will discuss some of these and compare them with theory, to reflect on how it will affect the supply chain.

## 9.6 Supply Chain Resilience as a Paradox

With the holistic view in mind, there are consequences of working towards a more resilient supply chain. Instead of looking at the implications as consequences or possible trade-offs, it is of more interest to see them as paradoxes which can be used for advantages. As already described in the theoretical framework, paradoxes are about balancing competing demands. Figure 9 showed the strategies and initiatives of SCRES. Common for more of the initiatives is that they may not be the most optimal initiatives cost-wise for the supply chain. For instance, increase inventory, regionalising supply chain, nearshoring of supplier base are a new way to run the supply chain from the recently more popular low-cost behaviour, where suppliers and the supply chain are outsourced to low-cost countries and inventory is optimised to not contain more than the absolutely necessary. Taking the example of nearshoring or outsourcing long distance of the supply chain, the typical choice would be either/or. The paradox theory says that both/and is a more rational way to see

these competing demands. Having a both nearshoring and outsourcing supply chain seems difficult, but an example of this is Zara. Zara have both nearshored and outsourced their supply chain, and at the same time expanded their supplier base. This is done by producing the low cost, high volume products in low-cost countries, while producing the lower volumes and expensive products close to the market (Ferdows, 2004).

In the example above, the paradox of nearshoring versus long distance outsourcing has created a competitive advantage for Zara, as they can both react quickly to disruptions and have a low-cost production. Putting the example into context with SCRES and reflecting on the paradox of SCRES, the Zara case shows that nearshoring the supply does not necessarily need to abandon the supply from outsourcing to low-cost countries. In general, awareness of paradox theory when working with SCRES can bring competitive advantage to companies, in this case Arla. The paradox of nearshoring and outsourcing to long distance suppliers serves both of the two competing demands; having resilience in the supply chain and using low-cost suppliers. Having more suppliers will raise the cost and increase the need for and attention to supplier collaboration, but if a SCD should happen it is possible to switch between the suppliers and thereby be able to increase resiliency to this disruption. Awareness of the paradoxes, rather than seeing them as trade-offs, will enable companies to use the SCRES strategies and initiatives as a way for future accommodation of disruptions, at the same time as they can still be used for cost-efficient supply chain set-ups since awareness of resilience is created.

Using scenario planning would not necessarily mean that Arla will compromise or experience trade-offs with the current supply chain, as scenario planning will show different insights in for instance SCRES initiatives or strategies. Thus, the paradoxes of the strategy or initiative can be identified quickly, and the best possible way to balance the competing demands is clarified. Comparing the Arla case to the Toyota example from the theoretical framework, it is possible to draw some of the same lines. According to Takeuchi (2008) Toyota aims for stability, but calls for paranoia. In this case, drawing the supply chain in detail is a way to stabilise, standardise and cost-optimise the supply chain, but it is still used as a tool to be prepared for whenever an event causing a disruption might hit. This means that having a detailed twin of the supply chain in a sense is due to paranoia and used for creating contingency plans. Also, Toyota is operationally efficient, but full of redundancy. By using SCG to ensure SCRES, the same goes for Arla. SCG aims to cost-optimise the supply chain and make it as efficient as possible, but on the other hand redundancy is needed to be able to react whenever an event hit. Considering these two paradoxes for the supply chain of butter at Arla and in regard to scenario planning in SCG, is a way to ensure SCRES while still operating the supply chain efficiently and standardised.

# 10 Conclusion

Supply chains are becoming increasingly vulnerable with the globalisation, outsourcing-trends and the search to be continuously cost-efficient as a driver these past years. To reduce the vulnerability to disruptions, supply chain resilience must be enhanced. This book is based on a master's thesis which aims to investigate how supply chain resilience can be used to accommodate supply chain disruptions through scenario planning, with the overall goal to answer; *"How can supply chain resilience be enhanced through scenario planning?"*. The research has been conducted with Arla Foods as case company and with their butter supply chain as focus. The research is scoped around what scenarios are and what scenario planning is, how a digital twin of the supply chain can be developed, how Arla's supply chain reacts to disruptions, and what the implications of supply chain resilience are.

To look into the theoretical framework, it was described as an onion model, with the supply chain management in the center, and layers added. In total, the theoretical framework consists of six areas; Supply chain management, Supply chain disruptions, Supply chain resilience, Scenario planning, Digital twin, and Paradox theory. Since the research was aimed at understanding what scenario planning is and how it can be used in regards to supply chain resilience, these were defined in the theoretical framework. Supply chain resilience is focussing on three different factors; readiness for a disruption, response to a disruption, and recovery from a disruption. Resiliency can be enhanced through either different strategies, such as re-engineering of supply chain and minimising exposure to shock, through initiatives such as supply chain mapping, regionalising supply chain, expand supplier base, etc. Scenario planning is, in short, planning based on developed narrative scenarios of future events that might happen. To do the scenario planning within a digital twin it was necessary to understand what this was as well. The digital twin is a virtual space mirroring a physical space. In this case, the digital twin is a virtual reflection of the physical supply chain system.

When the theoretical framework is defined, it is important to understand the current physical space in order to build the digital twin. The current set-up of Arla's butter supply chain for the three markets of Denmark, Germany and United Kingdom is supplied from two dairies in Denmark and Germany. The products are sent to warehouses located in the three countries, from where they are shipped further on to the customers. When knowing the physical space, it was possible to build the digital twin of the butter supply chain. The software Supply Chain Guru was used to build the AS-IS model of the supply chain. Supply Chain Guru was fed with different data which describes transportation, production sites, warehouses, customers etc. of the supply chain, as well as the demand and supply of the supply chain. Finding these data and putting them into the software was the main driver in developing the digital twin.

As the digital twin of the supply chain has been developed, scenarios were developed to run them and to investigate whether the scenario planning can be used to increase supply chain resilience. The four scenarios which were developed to be run in the AS-IS model, were;

- Covid-19 lockdown – A lockdown of the society due to a global pandemic
- Brexit – United Kingdom leaving the European Union without a deal
- Conflagration at a dairy – Breakdown at a dairy due to fire
- Political regulations on transport – Trucks are no longer allowed to drive in weekends

The scenarios represented different kinds of supply chain disruptions, as both black swans and white swans were used as a scenario. Supply Chain Guru used the problems which were identified in the scenarios as constraints for the AS-IS model, to suggests how to deal with these events in

the supply chain as well as how the supply chain would react to these disruptions. Supply Chain Guru came up with different kinds of solutions for the scenarios, which can all be considered as initiatives to create supply chain resilience. Therefore, it can be concluded that scenario planning to a great extent can be used to enhance supply chain resilience, since the preliminary work of building a digital twin of the supply chain increases the readiness for a disruption, enhances the possibilities for weighing up a faster response to a disruption, and creates basis for a faster way to recover from disruptions. Doing scenario planning through a digital twin creates basis for preparing better the supply chain for the unknown future.

To sum up, in this book, based on a master's thesis a digital twin of Arla's butter supply chain was developed and used for scenario planning. The scenario planning is aimed to predict events in the future and to plan for how to either prepare for the possible disruptions or to react on them. In general, by being able to do decision making based on data whenever disruptions threaten the supply chain, makes the process of making the decision faster, as well as it makes the solution more well-founded. Making decisions based on data and being able to develop fast contingency plans through scenario planning, companies will definitely be more prepared for future events awaiting to strike and disrupt supply chains world-wide.

# 11 Further Reflections

As it has now been concluded how supply chain resilience can be enhanced through scenario planning it makes sense to put it further into perspective, and open up for how it can be applied in the future. Looking into the future, it is interesting to consider what it takes for companies to work with supply chain resilience through scenario planning. The requirements of data governance and to the organisational culture when working with data in one's supply chain are great. It takes a lot for companies to create an organisational culture where decisions are to a higher extent based on data rather than gut feeling or experience. Having opened up for using digital twins to do scenario planning and thus increasing the resiliency of supply chain can be a stepping stone for companies to start their journey in using data in a wider perspective. Having a digital twin of the supply chain also provides basis for insight and optimisation opportunities throughout the whole supply chain. For instance, procurement can to a much higher extent be data-based, when costs and lead-times can be added to a digital model of the supply chain and the consequences of each possible supplier can be simulated and thereby a much broader end-to-end view on the supply chain is ensured.

Moving back to how supply chain resilience through scenario planning can be used in businesses in the future, it can be considered as a kind of shift in paradigm. Maintaining the master data and data continuously enables huge opportunities for using digital twins of supply chains to a greater extent in both strategic, tactical and operational planning. Would it make sense to include Supply Chain Guru in S&OP planning? By having a digital twin, the discussions and insight in supply chain planning can follow based on data and it will be possible to test different scenarios to assess which plan is the most suitable. This example shows the opportunities, which companies with functional data governance have and how physical systems can be translated into virtual spaces to a higher degree to be able to drive businesses on data.

Through the book it has been looked into how to recover from, or prepare for supply chain disruptions and use it to get back normal. It might be interesting to open up on using disruptions as a stepping stone for optimisation and development. Whenever the situation is shaken by a disruption, it could make sense to consider how the disruption can be the beginning of a change of the current state of things and thus challenge the old normal and turn the disruption into a positive push in a new direction instead of returning to the old normal.

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# 13 Appendix 1 – Overview of literature used for theoretical framework

An overview of the literature used for the theoretical framework

| Theoretical area | References | Topic |
|---|---|---|
| Supply Chain Management | Blackstock, 2008 | Keynote speech on conference, about supply chain at International Association of Food Industry Suppliers |
| | Christopher, 2005 | Foundational theoretical introduction to Supply Chain Management in a text book |
| | Lambert, 1998 | Foundational theoretical introduction to Supply Chain Management |
| | Lambert, 2008 | Introduction to Supply Chain Management and the Global Supply Chain Framework (GSCF) |
| Supply Chain Disruption | Alcantara, 2017 | Statistical information about Supply Chain Disruption |
| | Bugert, 2018 | A review of different Supply Chain Disruptions and general definitions on these |
| | Choi, 2020 | Covid-19 and the Supply Chain Disruption it has caused |
| | Chopra, 2004 | Accommodating Supply Chain Disruptions in order to avoid supply chain breakdowns |
| | Christopher, 2005 | Foundational theoretical introduction to Supply Chain Management in a text book |
| | Knemeyer, 2009 | Planning for the unknown future in a proactive way within supply chains |
| | Lund, 2020 | Resiliency in value chains. Where they come from and how to deal with them |
| | Stecke, 2009 | Supply Chain Disruptions in general. Factors that cause them, examples on events and vulnerability as a factor |
| | Taleb, 2010 | Black swan theory |
| | Wucker, 2020 | Black swan theory |
| Supply Chain Resilience | Cranfield University, 2003 | Practical guide to establish Supply Chain Resilience |
| | Hohenstein, 2015 | Research on what Supply Chain Resilience is. Review on previous research on the topic |
| | Knemeyer, 2009 | Planning for the unknown future in a proactive way within supply chains |
| | Lund, 2020 | Resiliency in value chains. Where they come from and how to deal with them |
| | Ponomarov, 2009 | Foundational introduction to Supply Chain Resilience |
| | Stecke, 2009 | Supply Chain Disruptions in general. Factors that cause them, examples on events and vulnerability as a factor |
| | Swink, 2020 | Building Supply Chain Resilience through experience. Also, the 5S framework for Supply Chain Resilience |
| Scenario Planning | Chermack, 2003 | General study on what Scenario Planning is and the building blocks of Scenario Planning |
| | Peterson, 2003 | Scenario Planning as a tool. General introduction to Scenario Planning |
| | Schoemaker, 1991 | Historical example on how Scenario Planning has been used previously |

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|---|---|---|
| Digital Twin | Colota, 2016 | Foundational introduction to the fourth industrial revolution, Industry 4.0 |
| | Parrott, 2017 | The Digital Twin and how it is related to Industry 4.0 |
| | Schleich, 2017 | Examples on Digital Twins and how they have been used before |
| | Tao, 2017 | Previous use of Digital Twins in manufacturing and systems |
| | Uhlemann, 2017 | Foundational introduction to Digital Twin technology |
| Paradox Theory | Cunha, 2019 | Foundational introduction to Paradox Theory |
| | De Wit, 2017 | Text book on strategy work within business and how to deal with paradox theory in relation to strategy development |
| | Pålsson, 2020 | Paradox theory in supply chain in relation to packaging |
| | Smith, 2016 | Introduction of the concept of competing demands and example of these |
| | Takeuchi, 2008 | Research on how Toyota has used Paradox Theory as a part of their business philosophy |