RAW MATERIALS
BUSINESS CONTINUITY PLAN
A Case Study at SABIC in Europe

2011, August
TU Delft, Management of Technology
Graduation Project
Raw Materials Business Continuity Plan

A Case Study at SABIC in Europe

PUBLIC VERSION

Graduation Project

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Graduation Date
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Summary

The high level complexity of today’s supply chains, their strive for ever increasing efficiency, and their global structure have rendered supply risk management more important than ever. These trends have been forcing companies to start taking measures against supply chain vulnerabilities, especially on the inbound side. A great deal of the risks on the inbound side of a firm is caused by the inability of a supplier to provide the purchasing company with the raw materials demanded. These kinds of supply disruptions may directly affect the profitability and even the very survival of a business. The risk sources that cause such disruptions become especially hard to detect as a company greatly grows its supply base and works in collaboration with a large number of suppliers. However, mitigating these supply risks is of great importance for companies, which heavily rely on the timely availability of their supplies. From this perspective, a business continuity plan for raw materials introduces the approach of identifying and mitigating supply risks, which are estimated/expected to have a high impact.

Given these conditions, SABIC in Europe is interested in adopting a risk management approach on its entire supply base, consisting of approximately 1500 raw materials, in order to achieve surety of supply for its production processes. SABIC in Europe is a major producer of plastics, chemicals and innovative plastics, and it is headquartered in Sittard and Bergen op Zoom, the Netherlands. Historically, the company has noted disruptions in its procurement operations due to various reasons including individual supplier failures, bottlenecks in the market, and force majeure conditions. At this point, it is important for SABIC in Europe to act proactively to have a business continuity plan for its raw materials in place, before the risks actually materialize. In that way, surety of supply can be achieved for its production activities. However, it is also given that SABIC in Europe has limited resources and time that can be dedicated to a business continuity plan; therefore, not all of the 1500 raw materials can be subject to it. This requires that a sub-group of raw materials, which are critical to SABIC in Europe’s business, needs to be prioritized for the business continuity plan.

To provide a solution to this problem, this research has been conducted in the form of a single case study facilitated by the European Procurement Department of SABIC in Europe, backed up by an extensive literature review. Besides literature review, the main data collection methods that have been utilized were interviews (i.e. semi-structured, structured and unstructured) with regional and global buyers of SABIC in Europe, and desk research at various departments including Procurement, Operational Procurement, Technology and Innovation, and Supply Chain Planning.

Given the problem statement, the main research question has been formulated as follows:

**MRQ: How can a business continuity plan be applied to SABIC in Europe’s supply base in order to increase the surety level of supply for critical raw materials?**
There are various risk management approaches in literature, which serve to increase surety level of supply of companies. These approaches usually follow a similar sequence to the following:

- Risk identification
- Risk assessment
- Risk treatment
- Risk monitoring

Considering the issue within the context of SABIC in Europe, a missing step in the approach above is the prioritization of raw materials for the business continuity plan, because it is not feasible to identify, assess and treat the risks of every raw material in the supply base of SABIC in Europe due to restricted resources and time. Keeping this remark in mind, the raw materials business continuity plan of SABIC in Europe should at least include the following steps: prioritization of critical raw materials, risk identification, risk assessment, and risk treatment. Risk monitoring has not been considered as a distinctive step in this aspect, as it would contribute to the business continuity plan in the long run and thus remained outside of the time scope of this project. In addition, it was crucial to elaborate the motivation behind implementing this project, in order to focus on the right points during the implementation of the research. Taking all these points into account, the following sub-questions have been formulated to determine the scope of the project in narrower terms:

*RQ1: What is the motivation for SABIC in Europe to have a business continuity plan for its raw materials?*

*RQ2: How can a sub-group of raw materials from the supply base of SABIC in Europe be prioritized for the business continuity plan according to their criticality for business?*

*RQ3: What are the supplier-related risk sources of high impact nature addressed by the prioritized raw materials?*

*RQ4: What are the risk reduction methods that can be used for the business continuity plan of the critical raw materials?*

In line with these research questions, five research blocks have been created, which have been carried out in sequential form through the course of the project. These research blocks are displayed below, and they will be explained with their research methodologies and outcomes.

- Motivation for the business continuity plan at SABIC in Europe (RQ1)
- Prioritization of critical raw materials (RQ2)
- Identification and assessment of supplier risk sources (RQ3)
- Identification of risk reduction methods (RQ4)
- Integration of outcomes: the business continuity plan and its application (MRQ)
The first research block, which deals with the motivation of this project, has been conducted by researching the nature and characteristics of supply disruptions in literature and at SABIC in Europe. Furthermore, the motivation behind implementing a business continuity plan for a purchasing firm has been researched in literature. Based on the outcome of these investigations, the motivation of this project for the company has been clarified.

Supply disruptions may lead to severe costs for purchasing companies by causing supply chain delays, which result in stock-outs of raw materials and thus inability to meet customer demand and cost increases. Major disruptions may even threaten the very survival of a business; therefore, adopting a solid risk management approach is crucial. However, it is also essential to justify the benefits that will be gained from adopting a risk management practice clearly. At this point, common approaches (e.g. expected value approach) have two major limitations: First, they assume that all relevant risk events and their estimated probabilities and impacts are known. Second, the impact of a supply disruption linearly affects the utility of a company; however, when major disruptions that could threaten the survival of a business are considered, the linearity assumption is not valid. A business continuity plan, on the other hand, covers exactly these two points: uncertainty on the probability and impact of risks, and high impact risks. Therefore, this business continuity plan has enabled SABIC in Europe to be proactive rather than reactive to major disruptions in the inbound supply chain, which are sourced by high impact supply risks. The motivation of this project was to enable critical raw materials to be identified and secured by taking measures beforehand or having b-plans at hand. In that aspect, the project was expected to contribute to security of supply within the company by aiming avoidance of major business disruptions and losses.

The second research block’s aim was to prioritize the critical raw materials of SABIC in Europe. But first, criteria that define criticality of a raw material needed to be developed. For that purpose, literature review and empirical research at SABIC in Europe have been done on criticality criteria. Once the suitable criteria have been selected, a tool has been developed to identify the critical raw materials of SABIC in Europe. Eventually, the outcome of the prioritization has been evaluated and validated.

Criticality criteria that have been found in literature were the following in order of decreasing frequency: Impacted profit/sales, purchase volume/spend, supply chain complexity, number of suppliers, supply characteristics, and impacted reputation. During the empirical research at SABIC in Europe, similar criticality criteria have been identified in order of decreasing importance: impacted sales, number of suppliers, product grade count (corresponding to supply chain complexity), impacted customers (corresponding to impacted reputation), number of purchasing plants (corresponding to supply chain complexity), etc. An essential difference in the perception of criticality in literature and at SABIC in Europe was on the purchase volume/spend criterion. In literature, this criterion has been suggested by several authors, although it has also
been rejected by some of them. In SABIC in Europe, this criterion was found to be misleading as low spend items might have major business impact.

As a result of the literature review and empirical research at SABIC in Europe, the sales impact of raw materials and their number of suppliers have been determined to be the primary criteria for criticality. Eventually for the sake of simplicity, raw materials with

- sales impact > €10M & single sourced,
- sales impact > €100M,

have been prioritized for the business continuity plan, corresponding to around 100 raw materials.

Additional interpretation on the criticality of items has been enabled by gathering data on other criticality criteria, including

- grade count linked to the raw material
- number of purchasing sites
- number of active suppliers
- other remarks (information on specific supply characteristics)

It is essential to note that the relationship between the spend and the business impact of an item has been found to be non-proportional. There were items with very low spend and major sales impact, and vice versa. The results of prioritization have also been validated by global category managers, who have not been directly involved in the development of criticality criteria.

The third research block covered the identification and assessment of supplier risks for the prioritized raw materials. For that purpose, supplier risks have been identified based on literature review and they were assessed according to their impact and probability at SABIC in Europe. Based on the results of this assessment, high impact risk sources have been selected, in accordance with the general approach of business continuity plans. Next, a procedure for generating risk profiles for prioritized raw materials has been developed in order to evaluate their risk exposure ratings.

In literature, 20 risk sources have been identified, which have been organized into four categories: business related risk sources, operational risk sources (these two make up the internal supplier risk sources), external supplier risk sources, and market risk sources. These risk sources have been evaluated at SABIC in Europe with regard to their probabilities, impacts and contexts; hereby, two risk sources have been added to the previous 20. As a result of this risk assessment, the following risk sources have been determined to have a high impact, and have therefore been subject to the rest of the research: poor financial health of the supplier, flexibility constraints of the supplier, market constraints, low number of qualified suppliers, high
lead time, supplier being under no legal liability, and geographical density of suppliers. These risk sources have created the basis for generating the risk profiles for prioritized raw materials. Risk profiles are tables that exhibit where the risks of individual raw materials are, and what their risk exposures are. Hereby, risk exposure is defined as a measure of the magnitude of a risk based on current values of probability and impact, regardless of the sales impact of the associated raw material. Next, metrics have been developed to measure the high impact risk sources. A rating scheme (over 1.0) has been developed for these risk sources, in order to evaluate raw materials’ risk exposure ratings. The weights associated with individual risk sources have been attached according to their impact and probability. Every prioritized raw material has been given a label according to its risk exposure percentage: low, medium or high. Moreover, a KPI has been developed to quantify and track the improvement that is achieved when a risk is reduced, which calculated in the following way:

\[ KPI: \text{Secured Business Value} = \Delta \text{Risk Exposure Rating} \times \text{Business Impact} \]

The main target is to reduce the risk exposure rating to a minimum of 40% for every critical item, given the limited time and resources that can be dedicated to risk management for raw materials.

The fourth research block was the identification of risk reduction methods as part of risk treatment. Risk sources have been identified through extensive literature review, which have been evaluated according to their advantages, downsides, applicability and other features. Based on the outcome of this evaluation, suitable risk sources for SABIC in Europe have been selected, in order to contribute to the action lists of prioritized raw materials, whereas action lists are groups of risk reduction methods specific to individual raw materials that are suitable for treating their supplier risks.

In literature, 17 risk reduction methods have been identified, which have been classified into three categories: operational buffers (i.e. strategies to build up reserves in order to reduce the impact of a disruption), mitigation plans (i.e. methods aimed at reducing the probability of the materialization of the risk) and contingency plans (i.e. procedures that are conducted once a disruption actually materializes in order to reduce its impact). These risk reduction methods have further been assessed at SABIC in Europe as explained above. Two methods, which were not identified in the literature review, have also been added to the list. The analysis on these risk sources resulted in the selection of the following risk reduction methods, as they are found to be more suitable in terms effectiveness and applicability: multi sourcing, identifying alternative sources of supply, keeping safety stocks, accurate demand forecasting, establishing increased coordination with supplier, contracting, standardization, and simplification. These risk reduction methods have been chosen to be considered when preparing the action lists of prioritized raw materials.
The last research block aimed to integrate the results of the previous research blocks in order to build the complete framework for the raw materials business continuity plan. Finally, this framework was applied to the supply base of SABIC in Europe. However, the size of the report allows the business continuity plan to be illustrated through five of the raw materials only. This framework is designed to be applied on an annual basis with updated data and evaluation. It is also considered for being extended to other regions of the company.

By integrating the outcome of the previous research blocks, a 3-step business continuity plan has been created:

- Prioritization of critical raw materials
- Risk profile generation for prioritized raw materials
- Preparation of action lists for prioritized raw materials

The criticality criteria have been applied to the supply base of SABIC in Europe, in order to prioritize critical raw materials for the business continuity plan. Next, high impact risk sources of these raw materials have been investigated in order to generate their risk profiles. Last, action lists consisting of suitable risk reduction methods have been prepared per prioritized items for managing their supply risks. The last step has been carried out only for a few raw materials due to the limited time span of the project.

The research has been conducted on SABIC in Europe’s specifics; however, the main outcome (the business continuity plan framework) can be adapted in a way to allow other firms to use it, provided that they have a similar supply base in terms of size, complexity, being global, etc. The design of the framework also allows flexibility on a case basis; but some parts of the business continuity plan might as well not fit other companies. For instance, other companies might perceive high impact risk sources (based on the risk assessment at SABIC in Europe) as lower impact. These kinds of variables/issues should be thought thoroughly before implementing the business continuity plan to another company.

This research has contributed to literature by conducting an extensive literature review on various topics like business continuity plans, criticality criteria for raw materials, supplier related risk sources, and their risk reduction methods, and by further enriching them through case studies. It has also been of managerial relevance as it was designed to increase the surety level of supply of SABIC in Europe, and will also serve as a solid input to other companies’ business continuity plans.
Preface

This master thesis is the public version of my graduation project, which slightly differs from the private version as it contained confidential information about SABIC in Europe. It is the outcome of six months of internship at SABIC in Europe and it indicates the final step of my active student life in the Management of Technology MSc Program in TU Delft. I have started the project in January 2011 after moving to Sittard and worked on the project mostly in Sittard and partially in Bergen op Zoom. I finished the project in July, as planned.

It has been a great experience for me to work in a dynamic and international environment offered by SABIC in Europe, where I learned a lot on strategic procurement activities and risk management practices. My greatest chance was that this project was partially defined before I entered the company. Therefore, my company supervisors have promoted the project greatly within the company, which enabled me to work both independently and with their total support behind. At the end, I really enjoyed working on this project.

I would like to take this opportunity to thank Dr. Paul Diepen and Luis Padron for giving me the opportunity to become part of their team. As my company supervisors, they have provided me with the guidance and support I needed throughout the project, as well as with a friendly working environment. I would also like to thank my other colleagues in SABIC in Europe for all their inputs into the project.

I would also like to thank Prof. Dr. Ir. Lorant Tavasszy for chairing my committee. Ir. Marcel Ludema deserves special thanks for his regular guidance in our meetings. Last, I would like to thank Dr. Sergey Filippov for his essential input at critical points of the project.

Finally, there are quite a few people I would like to thank for their great support in these six months. First, I would like to thank my parents for continuously sending me positive energy from Istanbul. Also, very special thanks go to my two brothers, Metin and Aydin, my cousin Ali, my girl friend Deniz, and all my other friends for being there for me throughout this period.
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1. Introduction

This first chapter of the research is intended to provide background information on the research topic, followed by introductory information on SABIC, SABIC in Europe, as well as on some key points on the strategic procurement activities of SABIC in Europe. It also introduces the problem statement, detailed explanation on research questions, the research framework and the deliverables of the research. At the end of the chapter, an overview of the structure for the rest of the report is provided.

1.1. Introduction to the Research Topic

Supply chain managers have only limited or incomplete information about their sources of supply. Therefore, risk management has been becoming an inevitable part of purchasing activities and supply chain management (Deane et al., 2009). The materialization of any risk, referred to as “supply chain disruption”, can be quite harmful and even catastrophic both for the supplier and for the buyer. Moreover, it might be difficult to identify and analyze these risks in terms of their probability and impact; they can directly affect the profitability and survival of a business. For that reason, supply chain risk management (SCRM), as a new and novel methodology, has gained importance. SCRM is “the management of supply chain risks through coordination or collaboration among the supply chain partners so as to ensure profitability and continuity” (Ellegaard, 2008). The challenge is to manage these risks by creating resilient supply chains. This means that supply chain design and management have to deal with the concept of supply chain resilience, defined as the ability of a system to quickly react to the undesired events when they happen (Christopher and Peck, 2008). However, creating resilient supply chains is more difficult than ever, because companies are operating under tougher conditions. In the past, firms were manufacturing in-house, sourcing locally and selling directly to customers; inbound risks were less diffused and easier to manage. Today, increased product and service complexity, and outsourcing of supply networks across international borders increase inbound risks in complex supply networks (Harland, 2003).

The focus of this research is on the inbound side of the supply chain, namely the supply part, and on high impact risks that cause severe supply disruptions. In order to address supply risk of this type, many managers are now adopting an approach called “business continuity planning” (BCP). Due to their nature, these disruptions are difficult to predict; however, when they occur, they have a significant impact on the associated business lines and supply chain (Zsidisin et al., 2005).

The supply risk is defined as ‘the potential occurrence of an incident associated with inbound supply from individual supplier failures or the supply market, in which its outcomes result in the inability of the purchasing firm to meet customer demand’ (Zsidisin, 2003). For the supply management activities, which include the sourcing of raw materials and components, as well as supplier selection and contracting, purchasers and supply chain managers are required to make a range of risky business decisions. However, most companies do not invest the required time or resources for mitigating supply chain risks. Repenning and Sterman (2001) suggest that firms rarely invest in improvement programs in a proactive manner because ‘nobody gets credit for fixing problems that never happened’. If a risk never materializes, it becomes very difficult to justify the time spent on risk assessments, contingency plans and risk management (Zsidisin et al., 2005).
Both mitigating the probability of risks and reducing their effects are of great importance for companies, which heavily rely on the quality and timely availability of their supply. But it should also be noted that it is not always possible to obtain reliable estimates of the probability of the occurrence of any particular disruption and accurate measures of the potential impact of each disaster (Dani and Deep, 2010). From this perspective, the BCP for raw materials introduces the approach of identifying the supply risks, which are estimated/expected to have high impact.

1.2. Introduction to SABIC in Europe

This section gives information about SABIC in Europe, where the project will be implemented in the form of a case study. It also provides introductory information about the mother company of SABIC in Europe, namely SABIC, as well as its main strategic procurement activities. The information on SABIC and SABIC in Europe has mainly been gathered from the official website of SABIC in Europe¹.

SABIC

Saudi Basic Industries Corporation (SABIC) is the world’s 6th ranked petrochemical company headquartered in Riyadh (Saudi Arabia) and is the largest non-oil company in the Middle East. It is the world’s largest producer of products like methanol, granular urea, mono-ethylene glycol, MTBE and engineering plastics, 3rd ranked global player in polyethylene and 4th ranked player in polyolefins and polypropylene industries.

SABIC was established in 1976 by royal decree to add value to Saudi Arabia’s natural hydrocarbon resources. The company is 70 percent owned by the Saudi government and 30 percent by GCC-based (Gulf Cooperation Council) shareholders. SABIC’s access to low-cost hydrocarbon resources in Saudi Arabia provides the company with great advantage over its competitors in other regions. Efforts to diversify from base commodity chemicals into specialties, such as polycarbonates and MMA/PMMA, are aimed at creating a more balanced product portfolio.

SABIC extends its geographical coverage and gains access to new technologies and business lines through joint ventures and acquisitions with major global petrochemical producers. Joint ventures with ExxonMobil, Shell and Mitsubishi, and acquisitions including DSM, Huntsman and GE Plastics facilities in West Europe and North America have significantly broadened SABIC’s geographic reach.

SABIC is organized into six strategic business units (SBUs): Chemicals, Polymers, Performance/Specialty Chemicals, SABIC Innovative Plastics, Fertilizers and Metals. Basic Chemicals that is part of the Chemicals SBU, is SABIC’s most important business, accounting for more than 40 percent of the company’s production volume. The production volume per SBU is exhibited below.

In addition to the SBUs, there are three affiliated main global businesses, namely SABIC in Europe, SABIC Asia-Pacific PTE and SABIC Americas. This research is conducted at SABIC in Europe, on which more detailed information is provided in the next section.

**SABIC in Europe**

SABIC in Europe is an affiliate of SABIC, which is a major producer of plastics, chemicals and innovative plastics, and employs approximately 6,000 people. SABIC’s strategic business unit, Innovative Plastics, has its main European office in Bergen Op Zoom, the Netherlands. The main European office for the SBUs Polymers and Chemicals, on the other hand, is based in Sittard, The Netherlands. Sales of the products are managed through local sales offices in Europe. Main manufacturing and research facilities are based at several locations including Geleen and Bergen op Zoom (the Netherlands), Cartagena (Spain), Teesside (UK), Gelsenkirchen (Germany), and 8 smaller sites across Europe (including France, Italy and Austria). The Geleen, Teesside and Gelsenkirchen produce polyethylene, polypropylene, and chemicals and intermediates, whereas the other sites are dedicated to the SBU Innovative Plastics.

The production sites in the UK were included in late 2006, after they have been acquired from Huntsman. The SBU Innovative Plastics, on the other hand, has been established after the acquisition from GE Plastics in 2007.

As to the logistic operations, SABIC in Europe operates strategically located warehouses and storage tanks in key ports in the Netherlands, the United Kingdom, Belgium, Italy, Spain, Sweden, Poland, and Malta. These logistics hubs serve to optimize the supply chain and also secure an uninterrupted flow of products produced in Saudi Arabia and marketed in Europe.

This research covers a case study on the procurement activities of all the three SBUs, namely Innovative Plastics, Chemicals and Polymers.

**Strategic Procurement Activities of SABIC in Europe**

As mentioned above, this research covers the three main business units at which SABIC operates in Europe: SBU Polymers, SBU Chemicals and SBU Innovative Plastics. The direct raw material databases of SBU Polymers and SBU Chemicals are somewhat integrated, resulting in a supply base of around 550 raw materials, whereas SBU Innovative Plastics has a supply base of around 950 raw materials. Along with
the database management systems, the coding of raw materials for SBU Innovative Plastics differs from that of the other two SBUs.

SABIC in Europe works with globally distributed suppliers. Apart from these partners, some of the raw materials are purchased through transactions between SABIC plants inside and outside of Europe. The supply base of SABIC is partially single sourced, meaning that there is only one producer approved for a raw material. Most of the raw materials are used in several product groups, grades and colors.

The direct raw materials of SABIC in Europe are organized under several categories. The main categories are: catalysts, colorants, polymers, polymer additives, process aids, glasses, impact modifiers, comonomers, process chemicals, reinforcements, oils and packaging. All the raw materials are categorized under one of these categories and thus purchased by a related category manager. Category managers are strategic buyers of a portfolio of raw materials. Activities on the operational level, on the other hand, are handled by the Operational Procurement (OP) department. The Technology and Innovation department is also supporting procurement activities by playing an important role on qualifying (approving) suppliers. Under every SBU, there are product groups, which are represented by Value Teams (VT). Value Teams are teams devoted to each product group, where employees from various departments (including Procurement, OP, T&I, Planning, Sales, etc.) are involved in.

### 1.3. Problem Statement and Research Objective

SABIC in Europe is interested in adopting a risk management approach on its entire supply base in order to ensure surety of supply for its production processes. Disruptions on the inbound side directly affect production processes and customers of the company. At this point, it is important to act proactively to have a business continuity plan for raw materials in place, before the risks actually materialize. In that way, surety of supply can be achieved for the production activities.

As SABIC in Europe has a supply base of around 1500 raw materials, it is not possible to apply a business continuity plan for every raw material due to limited resources. Therefore, it is crucial to determine the raw materials that are most critical to SABIC in Europe’s business. For these raw materials, a deeper analysis is required to understand their embedded supply risks and to find ways to mitigate these risks.

Risk management and business continuity planning have been salient subjects in supply management and procurement. However, studies of supply risk management in a considerably large and complex supply base context are lacking, where it is challenging to prioritize critical raw materials for business continuity planning, it is harder to detect vulnerability areas for suppliers, and the global supply base makes inbound operations even more vulnerable to supply risks (Manuj and Mentzer, 2008).

The purpose of this research is thus to develop and implement a business continuity plan for the supply base of SABIC in Europe in order to increase the surety level of supply. As the resources and time that can be dedicated to supply risk management is limited, the BCP should be designed in a way to address raw materials that are critical to the business of SABIC in Europe.

### 1.4. Research Questions

Once the research objective is clear, it is important to identify the questions which will be answered in detail over the course of this paper.
As mentioned earlier, the primary objective of this research is to create a business continuity plan for the procurement activities of SABIC in Europe. This business continuity plan should be applicable to the supply base of SABIC in Europe so that the surety level of supply for critical raw materials is increased. So, the main research question is:

**MRQ: How can a business continuity plan be applied to SABIC in Europe’s supply base in order to increase the surety level of supply for critical raw materials?**

Under this main research question, some sub-questions are formulated in order to better identify the scope of the project. In literature, there are various frameworks regarding supply risk management and business continuity plans. These frameworks, together with discussions within SABIC in Europe commence the development of the sub-questions.

Zsidisin et al. (2005) suggest a 4-step approach for preventing supply discontinuity. These steps are: risk identification, risk assessment, risk treatment, and risk monitoring. The first three steps are supposed to be sequential, whereas the last step is continuous and is considered for the long term. This is a straightforward approach which is in line with the majority of the risk management literature. The individual steps are explained below.

- **Risk identification**: Enumerating the causes and sources of potential supply disruptions.
- **Risk assessment**: Determining the likelihood and impact of the supply risks.
- **Risk treatment**: Developing strategies for reducing the likelihood and/or impact of risks.
- **Risk monitoring**: Monitoring developments in the supply chain that may increase or decrease risks on an on-going basis.

Harland (2003), on the other hand, extends this approach by introducing the aspect of supply network, which includes the involvement of all the actors in the inbound supply chain. The supply network tool of Harland is exhibited below. It should be noted that risk identification, assessment and treatment (management) are present in both of the frameworks, whereas risk monitoring is not shown as a distinctive step in the tool of Harland.
Considering the issue within the context of SABIC in Europe, a missing step is the prioritization of raw materials for the BCP, because it is not feasible to identify, assess and manage risks of every raw material in the supply base of SABIC in Europe due to restricted resources and time. Alberts and Dorofee (2010) suggest that in the preparation phase of risk management, decision making criteria should be set for prioritizing risks during mitigation or deciding when to escalate risks within a program or organization. Therefore, a method is required for selecting critical raw materials prior to risk identification and assessment. As a result, the raw materials business continuity plan of SABIC in Europe should at least include the following steps: prioritization of critical raw materials, risk identification, risk assessment, and risk treatment. Risk monitoring will not be considered as a distinctive step in this aspect as it would contribute to the BCP in the long term and thus remains out of the time scope of the project.

The sub-questions and their explanations, which are generated from the discussions above, are presented next.

A crucial aspect of the research is its necessity: the motivation behind having a business continuity plan in practice has to be clear for SABIC in Europe before going into detail about the BCP itself. This includes an investigation of the nature of inbound disruptions that leaves the buyer company in a rather difficult position.

**RQ1: What is the motivation for SABIC in Europe to have a business continuity plan for its raw materials?**

As far as a relatively large supply base is concerned, it is not possible for SABIC in Europe to run a business continuity plan for its entire supply base, given its limited resources and restricted time. Therefore it is important to rank the raw materials according to their criticality for the business of the company and prioritize part of them for business continuity plan accordingly. For that purpose, certain decision making criteria need to be set.
**RQ2: How can a sub-group of raw materials from the supply base of SABIC in Europe be prioritized for the business continuity plan according to their criticality for business?**

After the critical raw materials are determined, the next step is to investigate where the risks related to the suppliers of these raw materials are present. This requires an analysis of the risk sources of suppliers, as well as their distinctive market characteristics as part of risk identification. As mentioned previously, supplier-related risks of high impact nature will be taken into account for this research, because these risks lead to major disruptions in the inbound supply chain of the company. In order to identify these risks, an extensive risk assessment is required.

**RQ3: What are the supplier-related risk sources of high impact nature addressed by the prioritized raw materials?**

The last part of the research is concerned with treating (managing) risks, namely determining risk reduction methods related to the identified supplier-related risk sources. These risk reduction methods will act as an action list for the company to reduce the probability or impact of the supply risks.

**RQ4: What are the risk reduction methods that can be used for the business continuity plan of the critical raw materials?**

### 1.5. Research Framework

This section explains the research framework in order to give an overview on how the main research question and their sub-questions will be approached. Prior to that, the development process of the research framework will be detailed.

When creating the details of the research framework, every sub-question will be treated as a separate research block and investigated one by one. The main research question will constitute the last research block and will serve to integrate the outcomes of the previous blocks. In total five research blocks are created in accordance with the four sub-questions and one main question:

- Motivation for the BCP at SABIC in Europe (RQ1)
- Prioritization of critical raw materials (RQ2)
- Identification and assessment of supplier risk sources (RQ3)
- Identification of risk reduction methods (RQ4)
- Integration of outcomes: the business continuity plan and its application (MRQ)

**Motivation for the BCP at SABIC in Europe (RQ1)**

In order to understand the motivation behind implementing a BCP for the supply base of SABIC in Europe, one aspect needs to be clear: the characteristics of inbound disruptions that SABIC in Europe comes across. For that purpose, first, the nature of supply disruptions and their impact on the business of a company in general should be investigated based on literature. In addition, the inbound disruptions that have been experienced by SABIC in Europe need to be researched. The outcome of these two steps will create the basis for the motivation for implementing a BCP at SABIC in Europe. Next, a literature survey will be made to elaborate the concept of BCP and its necessity. The result of this survey will be combined with the outcome of the first two steps to explain the motivation behind the implementation of this project.
Prioritization of Critical Raw Materials (RQ2)

The second research block is prioritizing part of the raw materials according to their criticality. In order to be able to rank the supplies according to their criticality, some decision-making criteria must be developed as suggested by Alberts and Dorofee (2010). The development of these criteria will be based on the comparison of two sources: research on how criticality analysis is conducted according to literature, and investigations on how criticality is perceived in SABIC in Europe. It is not expected that these two sources create a perfect match; however, their outcomes will initiate discussions for choosing the right criteria. The selected criteria will be utilized for developing a tool for ranking the raw materials according to their criticality. The development of a tool is necessary for being able to repeat the process on an on-going basis. Concurrently, data will be gathered on the whole supply base of SABIC in Europe in order to create the complete supply map. This supply map should include details on the procurement activities of the raw materials, as well as on their production activities. Once the tool is developed and the supply base of SABIC in Europe is mapped, the raw materials can be ranked in order of decreasing criticality. The ranking of individual raw materials will be followed by categorizing those under two labels, namely high priority and low priority. The rest of the research will only take raw materials with high priority into consideration, since they arouse relatively more urgency for a BCP, as mentioned by many other companies (Zsidisin et al., 2000). Eventually, the results of ranking will be evaluated. The tool is then supposed to be tested by validating the results and evaluation of the ranking process based on the analysis of the high criticality raw materials.

Identification and Assessment of Supplier Risk Sources (RQ3)

The third research block is the identification and assessment of supplier risk sources, namely supplier vulnerability areas, for the prioritized raw materials. Hereby, it is important to create a detailed framework for this research block, because the aim is to take all possible risk sources into account and select those, which are of high impact nature, as indicated in the third research question.

As mentioned by Zsidisin et al. (2005), risk identification is enumerating the causes/sources of potential supply chain disruptions. At this point, it is essential to address a great majority of supplier risks that might cause a disruption. The second step of the risk tool of Harland (2003) suggests that a detailed list can be provided through an extensive literature review. This list can further be enriched with information concerning the type of risk and its location. Any risk sources that are missing in the literature, but are important to SABIC in Europe, should be identified through brainstorming with actors in the supply chain (Harland, 2003).

In order to prepare the identified risk sources for the risk assessment, a risk statement should be created for every risk source, which is described as a succinct and unique description of a risk (Alberts and Dorofee, 2010). This includes the circumstance with the potential to produce loss (i.e., threatening event) and the loss that will occur if that circumstance is realized (i.e., consequence). The consequence is expected to be supply disruption for each risk (with varying impact and probability). Therefore, the focus should be on the risk event when creating the risk statements for the identified risk sources.

The next step is the risk assessment: evaluating the likelihood of occurrence and the impact that a risk event will have on the business for each source of potential disruptions (Zsidisin et al., 2005). The main motivation behind the risk assessment is to only consider risk sources with a significant potential loss to
SABIC in Europe for further research (Harland, 2003). One of the most effective ways of implementing risk assessment is to introduce risk registers (Patterson, 2002). Risk registers are tables that include information on the cause of a risk (i.e. the risk source), the risk event (the outcome of the risk statement), the risk consequence (supply disruption), and the impact and the probability of risk. Risk registers prove to be useful as a risk assessment tool as they provide an overview of all the active risks and their risk rankings. In this context, the probability is defined as a measure of the likelihood that a risk will occur, whereas the consequence is defined as a measure of the severity of a risk’s consequence if the risk were to occur (Alberts and Dorofee, 2010). The risk context is another aspect that should be included into the risk assessment: any relevant background information about the risk, elaborations about the threat and consequence, any aggravating or mitigating conditions, and relationships and dependencies with other risks. The risk assessment will be based on empirical research at SABIC in Europe, because it is not expected that readily available risk assessment results for the identified supply risks will be found and the assessment is likely to be subjective for SABIC in Europe.

Once the risk assessment is completed, the high impact risk sources will be selected for further research. By making use of these high impact risk sources, a risk profile generation procedure will be prepared for every critical raw material, which is defined as a snapshot or summary of all risks relevant to the specific application (in this case: the specific raw material) (Alberts and Dorofee, 2010). The aim of this step is to have a straightforward and repeatable procedure for assessing risks for individual raw materials that are critical to SABIC in Europe’s business.

### Identification of Risk Reduction Methods (RQ4)

The fourth research block is the identification of suitable risk reduction methods for then business continuity plan as part of the risk treatment. Risk treatment is defined as developing strategies for reducing the likelihood and/or mitigating the impact of risks on the business (Zsidisin et al., 2005). In order to identify these strategies, an extensive literature survey is required, as in the case of the identification of supplier risk sources. Once the risk reduction methods are identified in literature, they need to be translated into SABIC in Europe’s context. For that purpose, these methods will be investigated with regard to their advantages and disadvantages through empirical research. By the end of this investigation, some of these risk reduction methods will be selected to contribute to the action lists, which are lists of risk reduction methods specific to individual critical raw materials. It should be noted that action lists will be developed only for part of the critical raw materials due to restricted time frame of the project.

### Integration of Outcomes: the Business Continuity Plan and its Application (MRQ)

The last research block aims to integrate the outcomes of the previous three research blocks in order to create one complete framework for the business continuity plan that will be applied to the entire supply base of SABIC in Europe. In this research block, it will also be indicated which parts are more generic in terms of applicability to other companies and situations, and which parts are strictly specific to SABIC in Europe. It should be noted that the issue of generalizability is also discussed in broader terms in the External Validity section of Section 2.3.
The BCP framework is applied to the supply base of SABIC in Europe. As mentioned earlier, identification of risk reduction methods for individual raw materials will be performed partially due to limited time span of the project. However, it is not feasible to disclose the entire outcome in this report due to size restrictions and confidentiality issues. Therefore, as the final step of the project, the BCP procedure of a few raw materials will be presented, in order to illustrate the BCP framework: The results of prioritization according to criticality will be shown; the risk profile procedure will be applied; and the suitable risk reduction methods will be assigned in the form of action lists.

An overview of the general research approach with the link between the research questions and the individual research steps is exhibited below.

![Figure 1-3: Framework for the Research Approach](image)

The steps in green boxes will be performed through literature review, whereas those in blue will be done based on empirical research. More detailed explanations on the methodology of the literature research and empirical research will be given in Chapter 2.
1.6. Research Deliverables and their Academic and Managerial Relevance

This section gives an overview of the deliverables of the research and elaborates their academic and managerial relevance.

Deliverables of the research

The main deliverable of this research is a set of tools and procedures that will be utilized in order to adopt a business continuity plan for the direct raw materials of SABIC in Europe. It will include:

- a tool to prioritize raw materials according to their criticality for the business
- a procedure for determining high impact supplier-related risk sources of critical raw materials
- a set of procedures to reduce these risks

These components will be integrated to provide a complete framework for adopting a business continuity plan for the raw materials of SABIC in Europe. This framework will be applied to the entire supply base of SABIC in Europe with data from 2010 (currently available). The output of this framework will be:

- A list of critical raw materials for SABIC in Europe’s business (which will not be displayed in this report due to confidentiality)
- Risk profiles of critical raw materials (of which only a few will be exhibited in this report)
- Preliminary action lists for critical raw materials, which are to be confirmed after the project by Value Teams (Preliminary action lists of only a few raw materials will be generated and exhibited in this report)

Academic Relevance

There is a large amount of literature on supply risk management and business continuity plans. This thesis contributes to literature by conducting an extensive literature review on topics like criticality criteria for raw materials, supplier related risk sources, and their risk reduction methods. These literature reviews are followed by empirical research. In this way, the literature reviews are enriched through a case study and the topics are thus elaborated further. Once the framework for the BCP is completed, it is applied to the supply base of SABIC in Europe. In that aspect, the project challenges the literature through application, as the BCP framework is partially based on literature.

Managerial Relevance

This project implements a BCP to the supply base of SABIC in Europe in order to increase its surety level of supply. Therefore, the project is highly relevant for the company. The motivation behind and the importance of the project is further elaborated in section 3.4. The outcome of this project can also partially be utilized by other companies, as it has some generic parts and some parts that are specific to SABIC in Europe. In this context, the thesis is expected to contribute to supply risk management procedures of other companies with a similar supply base structure in terms of size and complexity. The distinction between the generic and specific parts is indicated in Section 7.1.
1.7. Report Structure

The rest of the research is structured in the following way:

- **Chapter 2** Research Strategy and Data Collection Methods
  - Explanation on the research strategy, data collection methods and research’s reliability, and validity

- **Chapter 3** Motivation for the BCP at SABIC in Europe
  - Nature of supply disruptions in literature and at SABIC in Europe, motivation for implementing a business continuity plan in literature, and motivation for this project (RQ1)

- **Chapter 4** Prioritization of Critical Raw Materials
  - Selection of criteria for determining the raw materials that are critical to SABIC in Europe’s business, and evaluation of prioritization results (RQ2)

- **Chapter 5** Identification and Assessment of Supplier Risk Sources
  - Identification supplier related risk sources, their assessment at SABIC in Europe, and procedure for generation of risk profiles for further analyses of critical raw materials (RQ3)

- **Chapter 6** Identification of Risk Reduction Methods
  - Identification of suitable risk reduction methods for managing the risk sources of critical raw materials (RQ4)

- **Chapter 7** Integration of Outcomes: the Business Continuity Plan and its Application
  - Framework of the business continuity plan based on the outcome of the previous 3 chapters and its illustration via examples (MRQ)

- **Chapter 8** Conclusions and Recommendations for Future Research
  - Summary of the research outcomes, limitations of the research and recommendations for future research

![Figure 1-4: Report Structure](image)

1.8. Summary

This chapter has highlighted the importance of a business continuity plan for managing high impact risks on the inbound supply chain of a company. Supply risks might lead to supply disruptions and should therefore be minimized by creating resilient supply chains. The chapter has further presented background information on SABIC, which is a petrochemical company producing basic chemicals, intermediates, polymers, fertilizers, metals and innovative plastics. SABIC in Europe, which is the subject
of the research, is an affiliate of SABIC and a major producer of plastics, chemicals and innovative plastics. For its production activities, SABIC in Europe purchases around 1500 raw materials and works with approximately 375 suppliers globally. The rest of the chapter elaborated the following points:

**Problem statement and research objective:** Disruptions on the inbound side of the supply chain of SABIC in Europe directly affect production processes and customers. The purpose of this research is thus to develop and implement a business continuity plan for the supply base of SABIC in Europe in order to increase the surety level of supply for critical raw materials.

**Research questions:** One main and four sub- research questions are identified.

**MRQ:** How can a business continuity plan be applied to SABIC in Europe’s supply base in order to increase the surety level of supply for critical raw materials?

**RQ1:** What is the motivation for SABIC in Europe to have a business continuity plan for its raw materials?

**RQ2:** How can a sub-group of raw materials from the supply base of SABIC in Europe be prioritized for the business continuity plan according to their criticality for business?

**RQ3:** What are the supplier-related risk sources of high impact nature addressed by the prioritized raw materials?

**RQ4:** What are the risk reduction methods that can be used for the business continuity plan of the critical raw materials?

**Research approach:** The research follows five main blocks in sequential form, each of which corresponds to one research question. These research blocks are:

- Motivation for the BCP at SABIC in Europe (RQ1)
- Prioritization of critical raw materials (RQ2)
- Identification and assessment of supplier risk sources (RQ3)
- Identification of risk reduction methods (RQ4)
- Integration of outcomes: The business continuity plan and its application (MRQ)

**Main research deliverable:** A complete framework for adopting a business continuity plan and the output of its application to SABIC in Europe’s supply base.
2. Research Strategy and Data Collection Methods

This chapter explains the research strategy and reveals the data collection methods. It further judges the research on its reliability and validity.

2.1. Research Strategy

The research employs a combination of qualitative and quantitative research; whereas the focus is on qualitative research due to the exploratory nature of the project. The research will be conducted in the form of a single case study facilitated by the European Procurement Department of SABIC in Europe, backed up by an extensive literature review. Case study has been determined to be the right research strategy as it provides a holistic and in-depth investigation on the procurement activities and the underlying supply risks of SABIC in Europe (Orum et al., 1991). Case study is also favourable in terms of triangulation, which, in this case, is achieved through data source and methodological triangulation (Miles and Huberman, 1994). This issue will be investigated further in Section 2.3.

Yin (2003) lists six types of sources of evidence for data collection in a case study: documentation, archival records, interviews, direct observation, participant observation, and physical artifacts. For this particular case study, three of them are used in order to triangulate the findings: documentation (in the form of desk research), direct observation and interviews. The details on the data collection methods are presented in the following section.

2.2. Data Collection Methods

The main data collection methods utilized in this research are literature review, desk research and interviews (i.e. unstructured, semi-structured and structured). This section gives detailed information on why and how these methods are implemented. As explained in the previous section, every research block corresponding to a research question is initiated with a literature research, which is followed by empirical data collection. The literature review strategy is similar for every section and will therefore be explained on a common basis. Empirical data collection methods, on the other hand, will be presented per research block as they differ substantially from each other.

Literature review

The literature review for this research is systematically conducted. This produces a search process that is repeatable, which increases its reliability (Sekaran, 2003). Data from different journals are acquired by means of search engine queries via three databases: Scopus, Science-Direct and Emerald Insight. The key words that have been entered are the followings and their combinations:

supply risk supplier risk, business continuity plan, inbound disruption, supply disruption, supply chain disruption, risk management, risk mitigation, risk treatment, risk assessment, supply chain resilience, supplier vulnerability, risk reduction, criticality, supplier selection.

In addition to these search queries, Zsidisin (2003) executed a very comprehensive literature review on supply risk sources, which acted as a guide for the further development of the literature review process.

Some issues that were taken into account when evaluating the articles were:
- Variety of journals that the articles are published in (Vanany et al., 2009)
- Variety on year of publication (Armitage and Keeble-Allen, 2008)
- Variety on research strategy (Armitage and Keeble-Allen, 2008)
- Variety on data collection methods (Armitage and Keeble-Allen, 2008)

The articles that were used for the literature research have been gathered from various journals with different focus areas (including logistics, procurement, risk management, business). The year of publication varies from 1983 to 2011. The data collection methods of the articles include both qualitative and quantitative methods; and the research strategies include, but are not limited to, case studies, literature review, grounded theory research and mathematical modelling.

Additional information on the literature review for every research block is given in its relevant chapter.

**Empirical data collection methods**

This section explains the empirical data collection methods used during the case study. These methods include desk research and interviews. Since the details behind these methods vary according to the research block, they will be explained separately.

**Motivation for the BCP at SABIC in Europe (RQ1)**

For the development of this section, unstructured interviews and spontaneous contacts with category managers are utilized. In addition, direct observations on how the procurement activities of SABIC in Europe are affected in case of disruptions and how the Procurement Department responds to them are used as data sources. The reason for preferring unstructured interviews is that the scope varies substantially according to individual disruptions and the particular experiences of the interviewees, which is not allowed by other types of interviews (Lindlof and Taylor, 2002).

**Prioritization of Critical Raw Materials (RQ2)**

For this section, desk research, semi-structured interviews and structured interviews are used. Empirical data collection is conducted at three points: researching criticality criteria at SABIC in Europe, mapping the supply base, and validation of results for high criticality items.

For researching criticality criteria at SABIC in Europe, semi-structured interview and desk research have been performed. The motivation behind choosing semi-structured research is to explore the issue in depth by covering all the relevant aspects that were brought up during the corresponding literature review. The interviews have been done with four regional category managers, as well as some global category managers (although less extensively). These category managers work as part of the Procurement Direct Materials and therefore have in depth knowledge on the procurement activities. The project is aimed at covering the entire direct raw material base that these category managers are purchasing. The pre-determined interview questions on criticality criteria can be found in Appendix A.

The desk research includes presentations and other means of documentation on similar projects or risk management approaches within the company.
For mapping the supply base, extensive desk research has been conducted. Desk research includes consolidation of data from various departments, including Procurement, Supply Chain Planning, Sales and Technology and Innovation. Supplier websites have also been utilized at this stage.

Last, validation of results on the ranking of critical raw materials has been done via structured interviews with global category managers. Global category managers have been consulted on this issue as they were involved in the development of the tool to a smaller extent; however, the items that were prioritized according to their criticality are also under their management. Therefore, they are familiar enough with the raw materials to comment on their criticality. Structured interviews have been preferred as the number of items to be checked was around 100 and the number of interviewees was 10. The interview questions are presented in Appendix A.

**Identification and Assessment of Supplier Risk Sources (RQ3)**

For this section, empirical data collection has been required at two points: For the supplier risk assessment at SABIC in Europe and developing the risk profile generation procedure for prioritized raw materials.

For both parts, desk research and semi-structured interviews have been performed. Interviews have been done with the four regional category managers. As a result of the literature review on the topic, risk registers have been developed. These risk registers have been sent to interviewees prior to the interview in order for them to fill them in and have a first thought on the risk sources and the events mentioned. (A sample risk register is available in Appendix B.) During the interviews, the risk registers are used as a tool for initiating discussions by asking the interviewees for an explanation on why they have rated the probability and impact of individual risk sources the way they did. The risk registers are also utilized for quantifying the risks and visualizing them by reflecting the results in a table. However, it should be noted that the risk registers alone are not a rigour source of information as the number of participants are quite low with respect to quantitative analysis. They are meant to accompany interviews and should thus be interpreted with the remarks brought up during the interviews. The interview questions are exhibited in Appendix A.

The desk research includes presentations and other means of documentation on similar projects or risk management approaches within the company.

**Identification of Risk Reduction Methods (RQ4)**

For this research block, semi-structured interviews and desk research have been used. The risk reduction methods compiled from the literature have been used as an initiator for the risk reduction methods interviews. Interviews were conducted with four regional category managers. The interview questions are exhibited in Appendix A.

Moreover, desk research backed up the procedure through a number of presentations and other means of documentation on similar projects or risk management approaches within the company.

**Integration of outcomes: the business continuity plan and its application (MRQ)**

For this last research block, data collection has been required for creating the risk profiles of critical items and creating the action lists. For gathering data on high criticality raw materials for their supplier
related risk sources, structured interviews and desk research have been conducted. As the number of interviewees and discussion points were relatively high, structured interviews have been preferred.

In addition, documents from the Operational Procurement and Finance departments have been used in order to get details on the logistics of raw materials and on financial status of suppliers.

**2.3. Validity and Reliability of the Research**

This section makes a quality analysis on the research strategy and data collection methods in terms of their reliability, external validity and internal validity.

**Reliability**

Reliability displays the extent to which the findings of a research would be repeated if it were to be conducted with similar or same respondents in different time periods (Sekaran, 2003). This refers to the consistency of the research.

In the long term, it is unavoidable that the perception on supply risks and risk reduction methods will change, because today’s supply chains continue to evolve due to globalization, agility and adaptability trends. Therefore, it is not expected to get similar findings in different time periods of the research; the findings are expected to evolve through time, parallel to the evolvement of the supply chain structures. Therefore, time is not considered as a concern for reliability in the long run. For the short term, reliability is partially ensured through semi-structured interviews, which have a partly fixed framework as described in the previous section. In that way, the interviewees always attribute same or similar meanings to the questions at hand, resulting in similar outcomes for a respondent when the research is repeated. The literature review process is also considered reliable given the detailed description on its procedure in the previous section.

**Internal Validity**

Internal validity is an indication of whether compatibility exists between the constructed realities of the inquiry’s respondents and those that are attributed to them by the researcher (Davis and Cosenza, 1985).

A convenient way to reveal a wide variety of constructions of reality for the context of the study is to implement triangulation by two means: conferring with different sources and making use of different methods (Patton, 2002). This research strategy achieves triangulation through conferring with different sources, as on every topic at least four people are interviewed. However, it should be noted that in most cases the interviewees have similar titles, although they have divergent backgrounds in terms of previous job experience. Making use of different methods is also secured through the parallel use of interviews, desk research and literature review.

Davis and Cosenza (1985) suggest seven threats to internal validity. The table below explains these threats and judges the performance of the research in terms of these factors.
Table 2-1: Internal Validity Analysis

<table>
<thead>
<tr>
<th>Threat</th>
<th>Description</th>
<th>Applicability to this research</th>
</tr>
</thead>
<tbody>
<tr>
<td>History</td>
<td>Events outside of the study/experiment that affect the respondents</td>
<td>Minor threatening event: The Japan earthquake (March, 2011) impacted the inbound supply chain of SABIC in Europe, which might have influenced responses on issues concerning natural disasters.</td>
</tr>
<tr>
<td>Maturation</td>
<td>Changes on respondents during the course of the experiment</td>
<td>No major threat: The interviews were conducted within two months which did not allow room for major changes for the respondents.</td>
</tr>
<tr>
<td>Testing</td>
<td>Biases as a result of testing conditions or repeated testing</td>
<td>Threatening factor: Issues related to confidentiality might have caused the respondents to avoid bringing up certain subjects or facts.</td>
</tr>
<tr>
<td>Instrument change</td>
<td>Changing the research instrument during the research process</td>
<td>No threat: The instrument has not been changed during the data collection process.</td>
</tr>
<tr>
<td>Differential sampling</td>
<td>Improper selection of subjects / Excluding certain subject groups</td>
<td>Threatening factor: The interviews and desk research have mainly been conducted in the Procurement department. Other departments’ participation has been limited.</td>
</tr>
<tr>
<td>Regression to the mean</td>
<td>Existence of outliers in the dataset</td>
<td>No threat: No outlier data have been found.</td>
</tr>
<tr>
<td>Attrition</td>
<td>Attrition of respondents</td>
<td>No threat: No attrition of respondents.</td>
</tr>
</tbody>
</table>

The table above suggests that the main threats come from the side of testing and differential sampling. These issues will further be highlighted in the Conclusions and Recommendations chapter.

**External Validity**

External validity of the research points out to the extent to which the findings can be applied in other contexts or with other respondents. It mainly gives the degree to which the research outcomes can be generalized across other populations and other similar conditions (Davis and Cosenza, 1985).

This research’s objective is to bring a solution to a problem posed by SABIC in Europe as explained in Chapter 1. Therefore, part of the outcomes is case-specific to SABIC in Europe, whereas the rest can be generalized for other industries and companies. External validity of the research is increased by applying thick description when presenting in depth information with sufficient detail, in order to allow the reader to make judgments about the similarities between the current context and future context, where applicable.
Davis and Cosenza (1985) propose three threats to external validity. The table below explains these threats and their impact on the research.

Table 2-2: External Validity Analysis

<table>
<thead>
<tr>
<th>Threat</th>
<th>Description</th>
<th>Applicability to this research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment interaction</td>
<td>Specific effects created through the research methodology</td>
<td>No major threat: The treatment interaction has been minimized by the semi-structured form of interviews.</td>
</tr>
<tr>
<td>Setting specifics</td>
<td>Specific features of the research settings/environment</td>
<td>Threatening factor: The research has been conducted as a single case study at SABIC in Europe, which has its own characteristics as explained in Chapter 2.</td>
</tr>
<tr>
<td>Selection specifics</td>
<td>Specific features of the respondents</td>
<td>Threatening factor: Respondents have mostly been selected among employees from the Procurement department. Employees from other parts of supply chain (sales, supply chain planning, etc.) have not been interviewed.</td>
</tr>
</tbody>
</table>

As observed in the table above, the threats to external validity come primarily from the side of setting specifics and selection specifics. These issues will be discussed further in the Conclusions and Recommendations chapter.

2.4. **Summary**

**Research strategy:** Single case study at SABIC in Europe, backed up by extensive literature review.

**Data collection methods:** Literature research (same procedure for all research blocks), semi-structured, unstructured and structured interviews, desk research (varying according to the research block).

**Reliability and validity:** Reliability is secured for the short term. Internal validity is partially threatened due to confidentiality and lack of differential sampling. External validity is partially threatened due to single case study setting and narrow selection of interviewees.
3. Motivation for the BCP at SABIC in Europe

This chapter investigates the nature and characteristics of supply disruptions in literature. This section is followed by the research on the nature of disruptions that have occurred at SABIC in Europe. Furthermore, the motivation behind implementing a business continuity plan for a purchasing firm is researched in literature. Based on the outcome of these sections, the necessity of this project for the company is clarified.

3.1. Literature Review on Characteristics of Supply Disruptions

By definition, supply chain disruptions are unplanned and unanticipated events that disrupt the normal flow of goods and materials within a supply chain (Manuj and Mentzer, 2008). Disruption on the inbound side thus refers to disruption on supply. All supply chains are considered to be inherently risky because all of them experience unanticipated events that would disrupt normal flow of goods and materials (Craighead et al., 2007). Top executives at Global 1000 firms mention that supply chain disruptions and their associated operational and financial risks are their single most pressing concern (Finch, 2004).

Supply disruptions result in severe costs for purchasing companies if handled poorly. They can cause supply chain delays which, in turn, trigger stock-outs of raw materials and thus inability to meet customer demand and cost increases (Blackhurst et al., 2005). As a consequence, supply disruptions expose firms within the supply chain to operational and financial risks (Foerstl et al., 2010).

Many companies have not been able to quantify the cost of supply disruptions (Blackhurst et al., 2005) because the total cost of a disruption does not only include lost sales, but also communication costs, cost to maintain business interruption, inventory losses, cost of refund/compensation, logistics costs, and fines/lawsuits (Kumar and Schmitz, 2011). Supply disruptions can also result in permanent damage to the product brand and loss of reputation and goodwill with consumers (Blome and Schoenherr, 2011), which are not easily quantifiable in monetary terms. On the other hand, Rice and Caniato (2003) estimate a $50–100 million average cost impact for each day a supply network is disrupted, as the result from a company survey. Radjou (2002) also lists a number of examples of quantifiable supply-chain disruptions including General Motors’ experience of an 18 day labour strike at a brake supplier factory in 1996, which led to disruptions at 26 assembly plants with an estimated reduction in quarterly earnings of $900 million. Similarly, Boeing experienced in 1997 supplier delivery failure of two critical parts with an estimated loss of $2.6 billion to the company. Likewise, the lightning bolt that struck a Philips semiconductor plant in Albuquerque in March 2000 created a 10-minute blaze that contaminated millions of chips and subsequently delayed deliveries to its two largest customers, namely Nokia and Ericsson. As a result of this inbound disruption, a $400 million loss was reported by Ericsson due to late chip deliveries from the Philips plant (Latour, 2001).

Sheffi and Rice (2005) come up with the concept of disruption profile, which demonstrates how the performance level of a company is affected in a disruption. This concept does not only cover inbound disruptions; however, by definition it can also be applied for this field.
Once the disruption occurs, the performance of the company is reduced until the recovery period. In the recovery period, the performance starts increasing, although it might never achieve its initial level due to the long/term impact of the disruption. The total performance loss of the company is indicated by the area between the performance curve and the dotted (initial performance) line.

### 3.2. Characteristics of Supply Disruptions at SABIC in Europe

As with every other company, disruptions also occur in the supply chain operations of SABIC in Europe, including disruptions on the inbound side. The failure of the procurement of a raw material may take many forms, including order delays, quality failures, and quantity problems. In today’s competitive market, SABIC in Europe strives for efficiency and quality, which heavily rely on the timely availability of the raw materials. SABIC in Europe has a huge supply base which is sourced globally. Therefore, events or suppliers all around the world might impact its purchasing activities. The indicators of inbound disruptions can take various forms, including order cancellations from the side of the supplier, not confirmed orders and official force majeure declarations, which all require immediate action by the company.

It has been mentioned that disruptions on the inbound side are caused by several issues, including individual supplier failures or changes and bottlenecks in the market. At this point, it is important to underline that force majeure is a concept that frequently appears behind inbound disruptions. Force majeure is the situation where a supplier is free of liability or obligation when an extraordinary event or circumstance beyond the control of the supplier occurs, such as earthquakes (e.g. recent Japan earthquake, 2011) or strikes. It might also be the case that the suppliers of a supplier might declare force majeure and thus render the supplier incapable of delivering raw materials to SABIC in Europe.

The effects of disruptions on the inbound side of the company might vary according to the disruption event, as well as the associated item. It is noted that a disruption on the inbound side can be resolved on several levels: If the impact of the event is rather minor, the issue can be handled on the procurement
level, e.g. causing procurement to dedicate more time and effort on the particular issue or increasing procurement costs. If the nature of the disruption is more severe, it can affect the production activities, which can be resolved on the level of planning and scheduling, allocation of resources, etc. However, there are also cases where a supply disruption escalates to the customer of a product that the raw material is involved in. These kinds of disruptions are highly unfavourable and therefore need more attention.

### 3.3. Literature Review on BCP

Craighead et al. (2007) suggest that the recovery capability of a supply chain from a disruption should be proactive in nature, which implies that a purchasing company should have strategies to reduce the probability of a risk event or planned actions with several options that are triggered by specific disruptions to reduce their impact. The main questions here are: To what extent should the company be prepared to disruptions and what are the decision criteria for adopting a risk management approach on the inbound side? The answer to these questions indicates the motivation for implementing a BCP.

When judging the utility obtained from a proactive action for mitigating a risk, expected value approach is among the common suggested tools as it calculates and compares the benefits and costs associated with implementing and not implementing that action. However, there are two major limitations to this approach in the BCP environment (Zsidisin et al., 2005). First, the expected value approach assumes awareness of all the relevant events as well as their estimated probabilities and impacts, which is often not the case in a supply chain continuity planning setting. The second limitation of the expected value approach is its linear utility function assumption with respect to the impact of supply disruptions. For relatively minor disruptions, this may be reasonable; however, when major disruptions that could threaten the survival of a business are considered, the linearity assumption is questionable. The focal point of a BCP, on the other hand, covers exactly these two points: high impact risks and uncertainty on the probability and impact of risks.

Due to the above-mentioned reasons, it is very difficult to economically rationalize significant resource investments for striving to eliminate the risk from an expected value perspective. As a consequence, BCP practices are applied when a supply risk is perceived as potentially having a devastating impact on the overall organization and are also considered hard to detect. Awareness of these types of risks is growing and therefore more firms will adopt business continuity planning as a formal risk management technique (Zsidisin et al., 2005). According to the information of 2003, only between 5% and 25% of Fortune 500 companies are prepared to handle crises or disruptions. Chopra and Sodhi (2004), on the other hand, underline that most companies develop practices to protect themselves against recurrent low-impact risks in their supply chains. Many, however, ignore high-impact, low-likelihood risks. These statements illustrate the necessity for adopting a BCP approach for many companies.

### 3.4. Motivation for This Project

Within SABIC in Europe, this project is introduced as “Business Continuity Plan for Raw Materials” by the European Procurement Department Direct Materials Team as part of the risk management practices for the procurement activities of SABIC in Europe. There have been several initiatives within the company which adopted a similar (although less extensive) approach to execute a BCP for the procurement of raw
materials (e.g. STARS project); however they have only focused on specific product categories. This project is of great importance for SABIC in Europe as it will provide the company with an overall view on where the potential risk sources pose a greater threat and how they can be mitigated. The documents and procedures produced by this will be re-used with updated data on an annual basis within the company.

Historically, the company has noted disruptions in its procurement operations due to various reasons explained in the Section 3.2. In these situations, it is important to be prepared to act accordingly. From this aspect, this project is aligned with the company’s approach to be proactive rather than reactive to problems that might arise in any operation. As an example, if a raw material is single-sourced without a contract and has a great impact on the business of the company, the failure of the supplier might be very costly. The implementation of this project will enable those kinds of critical raw materials to be identified and secured by taking measures beforehand or having b-plans at hand. In that aspect, the project contributes to security of supply within the company by providing the avoidance of major business disruptions and losses. At this point, it is important to note that supply risks that have a major impact on the business of SABIC in Europe should be taken into account, which is aligned with the BCP approach.

It is noted by several authors in literature, as well as by SABIC in Europe employees that it is hard to quantify the loss caused by a disruption in monetary terms. However, it is also quite important to quantify the value created by this project with respect to two aspects: First, one should be able to justify the benefits gained from the implementation of the project by presenting value creation figures. Second, presenting expected value to be created through this project is the most convenient way for motivating employees and departments, and set them to action. Therefore, the value gained through this project will be derived from a calculation on the risk exposure of losing a business through a disruption, and the sales generated through that business. This “secured business value” will be set as a KPI to track the improvements made throughout the project. Details on this KPI are presented in Section 6.3.

3.5. **Summary**

Supply disruptions may lead to severe costs for purchasing companies by causing supply chain delays, which result in stock-outs of raw materials and thus inability to meet customer demand and cost increases. As a consequence, supply disruptions expose firms within the supply chain to operational and financial risks, as well as permanent damage to brand name and customer trust. Major disruptions may even threaten the very survival of a business; therefore, adopting a solid risk management approach is crucial. However, it is also essential to justify the benefits that will be gained from adopting a risk management practice clearly. At this point, common approaches like the expected value approach have two major limitations: First, they assume that all relevant risk events and their estimated probabilities and impacts are known, which is usually not the case in supply chain settings. Second, the impact of a supply disruption linearly affects the utility of a company; however, when major disruptions that could threaten the survival of a business are considered, the linearity assumption might be questionable. A business continuity plan, on the other hand, covers exactly these two points: uncertainty on the probability and impact of risks, and high impact risks.

In today’s competitive market, SABIC in Europe strives for efficiency and quality, which heavily relies on the timely availability of the raw materials. Historically, the company has noted disruptions in its
procurement operations due to various reasons including individual supplier failures, bottlenecks in the market, and force majeure conditions. This business continuity plan will enable SABIC in Europe to be proactive rather than reactive to major problems that might arise in its inbound supply chain. For that purpose, supply risks with a major impact on SABIC in Europe’s business will be considered, which is in line with the BCP approach.
4. Prioritization of Critical Raw Materials

A purchasing organization does not need to intercede for every supply chain entity by taking actions with risk management tools given the impact of a harmful supply event is low (Zsidisin et al., 2005). For instance, products categorized as noncritical items (Kraljic, 1983) would not likely be candidates for extensive risk-management efforts. This chapter presents the outcome of the literature survey on how criticality is analyzed and perceived by previous authors in respect to supply or supply chain entities, followed by the analysis on how this issue is evaluated at SABIC in Europe. On the basis of these analyses, a procedure on ranking the raw materials according to their criticality will be introduced and the results of ranking will be discussed at the end of the chapter.

4.1. Literature Review for Developing Criticality Criteria

The literature survey on criticality criteria has been conducted based on procurement related risk management papers. In these papers, authors do not cover the issue of how to determine the criticality of a raw material (or a supply chain entity in general) as a stand-alone topic; they rather include this topic into risk management approaches and consider it as a complementary tool to risk management.

The table below displays an overview of existing literature on the topic, categorized by authors in order of publishing date. It merely serves to highlight some criteria related to criticality analysis mentioned by various authors.

<table>
<thead>
<tr>
<th>Author</th>
<th>Criticality criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kraljic (1983)</td>
<td>Profit impact, availability of supply, number of suppliers</td>
</tr>
<tr>
<td>Elliot-Shircore and Steele (1985)</td>
<td>Value potential (profit), strategic/tactical dimensions</td>
</tr>
<tr>
<td>Blackhurst et al. (2005)</td>
<td>Reachability of disruption</td>
</tr>
<tr>
<td>Choi and Krause (2006)</td>
<td>Supply chain complexity</td>
</tr>
<tr>
<td>Craighead et al. (2007)</td>
<td>Potential supply chain disruption severity, supply chain complexity, node criticality</td>
</tr>
<tr>
<td>Micheli et al. (2008)</td>
<td>Complexity and customization of supply, impact on costs, impact on time, impact on quality</td>
</tr>
<tr>
<td>Foerstl et al. (2010)</td>
<td>Absolute revenue affected, loss of customer credibility, strategic status of supplier, purchasing volume</td>
</tr>
</tbody>
</table>
The literature on criteria for criticality of raw materials (and for supply chain entities in general) can be summarized under the points presented below. These points are mentioned in order of frequency of appearance in key publications that have been scanned in the literature survey.

**Impacted Profit/Sales**

In literature, criticality of a raw material is frequently related to its revenue impact or profit impact. Zsidisin (2003) emphasizes that even relatively inexpensive items, namely commodities, can have detrimental effects on profit in case of a disruption, regardless of their price. In line with Zsidisin’s approach, Kraljic (1983) performed an initial classification on purchased materials prior to their risk assessment in terms of their profit impact. Similarly, Gelderman and Van Weele (2005) set out a procurement positioning overview, in which supply risk is accompanied by value potential determination, whereas value potential refers to profit. Zsidisin et al. (2000) illustrate in a case study, how a company performs risk assessments on items that are identified as critical to profitability.

Foerstl et al. (2010), on the other hand, look into the revenue impact of an item in order to determine its criticality. Micheli et al. (2008) expand this approach by including impact on costs, impact on time and impact on quality. In summary, an item is perceived more severe if it has more financially devastating impact (Craighead et al., 2007).

**Purchase Volume/Spend**

Purchasing volume of an item is considered a criticality criterion by several authors (Foerstl et al., 2010; Zsidisin et al., 2000). Zsidisin emphasizes that risk assessments are mainly performed on certain items that are purchased in abnormally large quantities or that require a significant cash outlay.

**Supply Chain Complexity**

The criticality of a supply chain entity is strictly related to how severe a disruption on that particular entity would be, which is connected to the number of entities within a supply chain, whose ability to ship and/or receive goods is affected (Craighead et al., 2007). Choi and Krause (2006) define the complexity of a supply chain as “the sum of the total number of nodes and the total number of material flows within these nodes, counting forward and backward flows separately. For instance, a more complex supply chain would contain a larger number of nodes and flows than one that is relatively less complex. Since the complexity of a supply chain indicates the number of nodes and the interdependencies among these nodes, a more complex supply chain is affected by a disruption more severely: A disruption at any node can potentially propagate, with the effects of the initial disruption being passed from one node to another connected node and so on (Craighead et al., 2007). A similar approach is utilized for the reachability analysis, which is a modelling methodology used for understanding how far reaching the effects of a disruption would be on a supply chain (Blackhurst et al., 2005).

**Number of Suppliers**

Number of suppliers for a raw material is considered as a criterion for the criticality of a supply (Kraljic, 1983). In a case study, Zsidisin et al. (2000) demonstrate how some of the companies develop contingency plans only for their single sourced items; multi sourced supplies are not formally considered for supply risk management.
Similarly, Craighead et al. (2007) consider node criticality as a criterion for the criticality of a supply chain entity, whereas node criticality is defined as importance of a node within a supply chain. Although the concept of node criticality is broadly defined, an example from his case study illustrates its meaning in a more clear way: A company considers sole supplier situations (i.e., the sole supplier would be a critical node) to be more risky than multi source cases. It sole sourced a particular component from a supplier, who had sole sourced a component part to a second-tier supplier. When distribution from the second-tier supplier was disrupted, the first-tier supplier was unable to deliver the component to the company. The company eventually went out of business.

**Supply Characteristics**

Several authors underline the importance of supply characteristics when prioritizing raw materials. Zsidisin (2003) claims that the use of a supply for a new product application is perceived as having greater risk than using it in an existing product, because there is a lack of historical data from which accurate assessments of potential risks can be made. Kraljic (1983) point out to how available a supply is when determining its criticality. The significance of a material is also determined by its strategic/tactical dimension: strategic items are considered relatively more critical (Gelderman and Van Weele, 2005). Other criteria related to the characteristics of a supply are its complexity and customization (Micheli et al., 2008).

**Impacted Reputation**

Items, for which a disruption in their supply chain would impact corporate reputation, cause negative media exposure and loss of customer credibility, are considered to be relatively more critical (Foerstl et al., 2010).

### 4.2. Criticality Criteria at SABIC in Europe

This section deals with how the criticality of raw materials are perceived in SABIC in Europe, what kind of criteria are taken into account and how their perception differs from the literature.

Within SABIC in Europe, the judgement on the criticality of raw materials followed by their prioritization is mainly in line with the literature, although it deviates at certain points from what the previous authors stated on that topic. The points that have been found out as to criticality criteria during the research, which adopted interviews and desk research as data collection methods, are summarized under the headlines below in order of decreasing importance according to the company. The following table gives an overview of these points in comparison with the literature.
**Table 4-2: Comparison of criticality criteria in Literature and SABIC in Europe**

<table>
<thead>
<tr>
<th>Criterion in Literature</th>
<th>Utilized at SABIC in Europe?</th>
<th>Equivalent/implicit criterion at SABIC in Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impacted profit/sales</td>
<td>X</td>
<td>-</td>
</tr>
<tr>
<td>Purchase volume/spend</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Supply chain complexity</td>
<td>X</td>
<td>Product/grade count</td>
</tr>
<tr>
<td>Number of suppliers</td>
<td>X</td>
<td>-</td>
</tr>
<tr>
<td>Supply characteristics</td>
<td>X</td>
<td>Multiple criteria</td>
</tr>
<tr>
<td>Impacted reputation</td>
<td>X</td>
<td>Impacted customers</td>
</tr>
</tbody>
</table>

**Impacted sales**

The impacted sales that are connected to a raw material are stated to be a direct indication for the criticality of that raw material for the business of the firm. Therefore they are the most important criterion for determining the criticality of raw materials; this criterion is also agreed upon in literature. The generally suggested methodology hereby is to make use of production recipes in order to find out about the products in which a certain raw material is used. The summation of the annual sales of these products indicates the sales impact of a certain raw material. Preference on impacted sales over impacted profit is mainly explained by the relative ease of consolidating sales data as compared to profitability data, which also requires the availability of cost related information. Another point to take into consideration is to update the sales impact information on raw materials on an annual basis. An aspect that should be added to the impacted sales approach is the contracts with customers, which are also deterministic for the business impact. If SABIC is bound with heavy contracts to a customer for a certain product, than having a disruption on the inbound side of that product would not just cost SABIC the sales impact, but also the contract terms.

**Number of Suppliers**

When labelling the raw materials according to their urgency for a business continuity plan, procurement and supply chain experts give higher priority to single sourced raw materials, as also emphasized by previous authors. It is important to note at this stage that SABIC in Europe clearly distinguishes between the concepts “single source” and “sole source”; this distinction is not always clear in literature. Sole source is formally defined as the existence of only one supplier producing a certain raw material. Single source, on the other hand, refers to having only one approved supplier producing a raw material. The request by an internal customer to obtain materials or services from a single source must be accompanied by appropriate justification and be internally approved on a higher level.²

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² Global Procurement Policy, SABIC in Europe, 2011
Another point that was emphasized by the experts, however was not mentioned in literature, is the distinction between producer and distributor identity of a supplier. Determining the number of suppliers for a raw material refers to the count of approved producers of that raw material. If the raw material is purchased from a distributor, the producer(s) behind that distributor is (are) investigated. It is noted that in some cases the distributor delivers a raw material from an approved producer; a problem with that producer would also affect the distributor. Therefore, the distributor alone is not considered a source for the raw material.

Single sourced raw materials are given priority for risk management, because a failure of their producers for delivering the supply might result in an immediate disruption in production of related products. Therefore, the efforts for a business continuity plan are focused on those raw materials, whether they are perceived to be easily second sourced or they are sole sourced. The only exception is made for internal purchases: If SABIC acts as a producer for an internally bought raw material, SABIC is hold accountable for that raw material and therefore the perceived risk is low, even if the raw material is single sourced. On the other hand, if a raw material is purchased by a SABIC plant from an external producer and then internally sold to another plant, SABIC is considered a distributor and thus not a source.

**Product/Grade Count**

Another criterion that the experts attach importance to is the count of product grades that a raw material is involved in, regardless of their production volumes. The count of product grades for a raw material is considered to be an important criterion as it indicates the number of production lines that will be affected in case of a disruption of a raw material. The greater the number of product grades, the harder it is to communicate a disruption on the inbound side into individual production lines and to handle the arising problems on a production line basis.

An alternative approach on product grade count is that it also adds complexity to a raw material from the aspect of solving a problem associated with that raw material. So, from the perspective of implementing a business continuity plan, it is easier to attack items with less complexity.

This criterion can partially be translated into “supply chain complexity” concept in literature, which indicates “the sum of the total number of nodes and the total number of material flows within these nodes for a supply chain”.

**Impacted Customers**

The impacted customers of to the end products connected to a raw material are considered to be important for its criticality. At that point, the judgment is on whether major customers are involved in that business or not. The involvement of major customers (e.g. top 10 customers of SABIC in Europe) increases the criticality of a raw material. Whether a customer is a major customer or not depends on the revenue generated through that customer. The motivation behind this criterion is that a disruption does not only affect the particular business line it is directly involved in, but also future business with that customer.
This criterion is mentioned in literature as “impacted reputation”; however, impacted reputation does not only include loss of customer credibility, but also negative media exposure and negative corporate reputation.

**Other Criteria**

Some other criteria that were brought up by the experts or seen during the desk research include the following:

- When for some raw materials data is not readily available, an initial screening enables the labelling of items, which are considered commodities, as non-critical. The motivation behind this is that commodities are mostly easy to purchase on the market and therefore recovery from a disruption is relatively easy. This point is in line with Kraljic’s criterion on availability of supply.

- Another proposed criterion is whether a raw material differentiates the end product of SABIC significantly. If they do, they are considered more critical than items that provide less differentiation.

- Besides the number of suppliers, another mentioned criterion is the number of active suppliers, defined as suppliers that SABIC has made business with during the previous year. It is emphasized that although a supplier is approved for a raw material, it might not be active in that business anymore or might be fully engaged in business with other customers. Therefore, it is important to keep track of the active suppliers.

- Number of purchasing plants is another criterion that adds complexity to the supply chain, just like the number of products/grades. However, as for the number of grades, the general perception is that the more the number of purchasing plants, the harder it is to take actions against supply risks (e.g. second sourcing takes more time and effort for multiple sites).

**Remarks on Purchasing Volume/Spend**

The general perception of purchasing volume/spend as a criticality criterion is negative. This is the most major point where the view of SABIC employees deviates from the majority of authors. However, Zsidisin (2003) also emphasized that the unavailability of an item from a supplier can have detrimental effects on profit, regardless of its price; this statement is in line with SABIC’s approach.

The motivation behind eliminating this criterion is that it does not reflect the true risk impact associated with an item. There are materials, which have relatively minor spends; however, they are used in the production of a high number of products and/or the products they are used in have high sales impact. This situation has been experienced by the company in some cases, including the following example:

**4.3. Development of the Tool for Ranking the Raw Materials**

This section explains the procedure on how the raw materials were ranked by going into detail about which criteria have been used directly and which other information have been included in the overview of raw materials.

Taking the outcomes of the literature review, interviews and desk research into account and further discussing the availability and accessibility of data within SABIC in Europe, the direct criterion for ranking has been decided to be the sales impact of raw materials based on the end products they are used in,
which is obtained through production recipes. After the raw materials were ranked according to their sales impact, an initial filtering has been implemented on single sourced ones in order to give priority; although multi sourced items have not been eliminated completely from the list. It is also important to note at this step that raw materials, which are considered direct materials, but are not directly used in production (e.g. water treatment agents etc.), are left out of the scope of the project. In total, around 1500 raw materials have been included in the analysis.

Information other than raw material code, raw material description, sales impact and single/multi source status, which have been included in the overview of raw materials and the reasoning behind them are presented below. These information have been included for further analysis of individual items and act complementary to ranking criteria.

- Product grades list and counts: Although not used as a direct ranking criterion, the number of grades that a raw material is used in gives a good overview of the supply chain structure associated with that raw material. The list of grades also proves useful for communicating any disruption of a raw material into necessary production lines, and if required, customers.

- Purchasing sites: This information indicates how many and which sites are affected in case of a disruption.

- Purchasing volume and spend: This data shows the size of the business associated with the raw material and whether the raw material is active (purchased in the previous year) or not. High spend does not imply high criticality; it merely serves to make a comparison between business impact and buy.

- Approved producers, distributors and their counts: This data reveals both the single/multi source status of a raw material, and the particular producer/distributor name that may cause a disruption related to that supply.

- Active suppliers and its count: This information shows which suppliers SABIC has done business with in the previous year regarding a certain item, suggesting that other approved suppliers might not offer that item anymore. Special attention is required for the inactive suppliers.

- Category manager name: Category manager is the direct contact person for the procurement activities related to a raw material.

- Technology item owner: Technical issues such as recipe information or second source approvals are under the responsibility of the technology item owners.

- Other remarks: Other remarks include information on specific supply characteristics (if any), such as special packaging, potential of becoming obsolete, involvement in internal sales, etc.

Including impacted customers have also been considered; however, since most of the raw materials are linked to a relatively large number of product grades and these grades are purchased by a large number of customers, this criterion has eventually been omitted in order to limit the data collection process.

The next step here is to set the sales impact limit, above which a raw material is considered “critical”. This decision is heavily dependent on the number of raw materials that can be taken into the scope of the BCP, taking the restricted resources into account. Discussions with the Regional Category Managers
have revealed that around 100 raw materials can be evaluated within the BCP in one year. Therefore, single sourced raw materials with a sales impact over €10 M have been marked as critical. In addition, raw materials that have a sales impact over €100 M have also been marked as critical, regardless of their single sourced status. The reason for that is justified as follows: Raw materials with such major sales impact need to be further analyzed with respect to their risk sources in order to make sure that their surety is truly secured.

Below, the decision chart for prioritizing the raw materials is exhibited.

![Decision Chart](image)

Figure 4-1: Decision chart for prioritizing raw materials

### 4.4. Evaluation and Validation of Results for High Criticality Items

This section presents the outcome of ranking the raw materials and evaluates the outcome. It further displays the validation of the outcome.

**Evaluation of Prioritization Results**

The evaluation of ranking is based on the analysis of the data regarding the prioritized raw materials and discussions with the category managers for validating the results. Due to confidentiality, the complete outcome of the ranking will not be displayed; however, some issues will be discussed without revealing sensitive data.

As exhibited in the decision chart above, the single sourced raw materials among those are given priority as they are considered more critical, unless they have a business impact higher than €100M.
The most interesting point on the ranking results is the comparison between the spend on raw materials and their sales impact. The figure below displays spend vs. sales impact for the prioritized raw materials. The numbers that the axes represent have been removed due to confidentiality issues.

As it can be observed from the figure above, the spend of a raw material is not indicative of its business impact. If that would be the case, the data points would all lie around a trend line; in the figure there are some items with very little buy and very high sales impact and some with much higher buy and relatively lower sales impact. If the purchasing spend data was to be taken into account for determining criticality, those with small but very high sales impact would not have appeared in the overview of prioritized raw materials.

**Validation of Prioritization Results**

The prioritization results of critical items have been validated through discussions with global category managers of their portfolio. The global category managers have not been directly involved in the development of the prioritization procedure; therefore an explanation has been made on that prior to discussions. They have been asked whether they agree on the criticality of the particular raw material and what their motivation for the answer is. In most of the cases, the category managers agreed on the criticality levels of their items, given the procedure behind it. Only in a few cases, they disagreed with the criticality levels due to recent updates on the item (e.g. the item has recently been dual sourced) or due to possible future trends (e.g. the item is likely to disappear from the portfolio in the long). The name of
the category managers that were part of the validation process, and their categories are given in Appendix A.

4.5. Summary

This chapter’s objective was to develop a tool that identifies the critical raw materials of SABIC in Europe in order to prioritize them for the business continuity plan. The tool is based on literature review, as well as desk research and interviews.

The table below displays the overview of criteria for criticality based on literature and SABIC in Europe.

<table>
<thead>
<tr>
<th>Criterion in Literature</th>
<th>Equivalent criterion at SABIC in Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impacted profit/sales</td>
<td>Impacted sales</td>
</tr>
<tr>
<td>Purchase volume/spend</td>
<td>Not used</td>
</tr>
<tr>
<td>Supply chain complexity</td>
<td>Product grade count, number of purchasing plants</td>
</tr>
<tr>
<td>Number of suppliers</td>
<td>Number of suppliers (single sourced vs. multi sourced)</td>
</tr>
<tr>
<td>Supply characteristics</td>
<td>Commodity/non-commodity</td>
</tr>
<tr>
<td>Impacted reputation</td>
<td>Impacted customers</td>
</tr>
</tbody>
</table>

For the sake of simplicity, the prioritization of raw materials according to their criticality is based on their sales impact and number of suppliers, such that raw materials with

- sales impact > €10M & single sourced,
- sales impact > €100M,

are prioritized for the business continuity plan.

Additional interpretation on the criticality of items is enabled by gathering data on:

- grade count linked to the raw material
- number of purchasing sites
- number of active suppliers
- other remarks

The list of raw materials above €10M business impact includes 210 items. It is essential to note that there is not a proportional relationship between the spend and the business impact of an item.
5. Identification and Assessment of Supplier Risk Sources

Closely interconnected with the concept of risk is the notion of supply chain vulnerability, defined as the “existence of random disturbances that lead to deviations in the supply chain from normal, expected or planned activities, all of which cause negative effects or consequences” (Svensson, 2000). The importance of identifying the supplier vulnerability areas is to find out the potential risk sources that might cause a disruption within the inbound supply chain for any of the raw materials on the supply base (Zsidisin, 2003). Getting a better understanding of the supply risk sources can guide supply management professionals in determining how those risks can influence supply strategies and corresponding risk reduction methods. For example, if risk is caused by a supplier firm due to quality problems, the buying firm can take actions such as investing in supplier development in order to eliminate those quality issues and in that way reducing the risk caused by that supplier (Jüttner, 2005).

In literature, there are various sources dealing with supply risk sources. However, this research specifically focuses on risk sources that are directly posed by individual suppliers or by the supply market, which will be sorted out of other types of supply risks (e.g. product related risk sources or operational risks sourcing from the purchasing firm) and be discussed in detail during the course of this chapter.

This chapter identifies the supplier risk sources in literature and assesses them according to their context and their probability and impact levels at SABIC in Europe. The outcome of this risk assessment enables the selection of high impact risk sources, since these risk sources cause major supply disruptions. At the end of this chapter, a procedure is proposed for generating risk profiles of high criticality items with respect to high impact risk sources.

5.1. Supplier Risk Identification Based on Literature

The literature review on supplier risk sources is based on publications that particularly deal with risks on the inbound side of companies. The authors of these publications are mostly focused on supplier selection, procurement risks, supplier vulnerabilities, as well as supply risk mitigation approaches. An overview of literature on supplier risk sources is presented in the table below, categorized and ranked according to authors and publication dates, respectively.

<table>
<thead>
<tr>
<th>Author</th>
<th>Supplier Risk Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kraljik (1983)</td>
<td>Supply monopoly or oligopoly conditions, entry barriers, technological advancement</td>
</tr>
<tr>
<td>Baird and Thomas (1990)</td>
<td>Disasters</td>
</tr>
<tr>
<td>Noordewier (1990)</td>
<td>Quality issues</td>
</tr>
<tr>
<td>Wagenaar (1992)</td>
<td>Natural disasters</td>
</tr>
<tr>
<td>Author</td>
<td>Supplier Risk Sources</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Min (1994)</td>
<td>Global sourcing</td>
</tr>
<tr>
<td>Steele and Court (1996)</td>
<td>Shipping method, shipping distance, price trends</td>
</tr>
<tr>
<td>Lee et al. (1997)</td>
<td>Information system sophistication, capacity</td>
</tr>
<tr>
<td>Krause and Handfield (1999)</td>
<td>Management vision, information system compatibility, inventory management</td>
</tr>
<tr>
<td>Zsidisin (2000, 2003)</td>
<td>Financial health, capacity constraints, inflexibility, quality, variable cycle times, IT backwardness, earthquakes, currency fluctuations, political stability, geographic concentration, market capacity, supplier patents and contracts</td>
</tr>
<tr>
<td>Kelle and Miller (2001)</td>
<td>Global sourcing</td>
</tr>
<tr>
<td>Finch (2004)</td>
<td>Technological capabilities</td>
</tr>
<tr>
<td>Chan and Kumar (2005)</td>
<td>Terrorism</td>
</tr>
<tr>
<td>Craighead et al. (2007)</td>
<td>Geographical density of suppliers</td>
</tr>
<tr>
<td>Lyles et al. (2008)</td>
<td>Multi-tier sourcing, supply chain visibility</td>
</tr>
<tr>
<td>Micheli et al. (2008)</td>
<td>Financial instability, price increases, safety stocks, delivery delays, IT incompatibility, market saturation, qualified supplier number, supplier obligations</td>
</tr>
<tr>
<td>Blos (2009)</td>
<td>Debt &amp; credit rating, existence of a mother company, logistics route or mode disruptions, currency and exchange rate fluctuations, financial market instability, economic recessions</td>
</tr>
<tr>
<td>Kumar and Schmitz (2010)</td>
<td>Product recalls</td>
</tr>
<tr>
<td>Tse and Tan (2010)</td>
<td>Location, sub-tier suppliers</td>
</tr>
<tr>
<td>Sawik (2011)</td>
<td>Technological inadequacy</td>
</tr>
</tbody>
</table>

Before the supplier related risk sources mentioned by the authors will be summarized under several headlines, a categorization of these risk sources will be introduced in order to facilitate the analysis. As mentioned earlier, this research takes into account risk sources posed by individual suppliers and by the supply market. Therefore, there will be a distinction between these two categories. Individual supplier risk sources will further be divided into sub-categories according to SWOT-analysis, which distinguishes between internal and external factors when examining an entity (Houben, 1999). In this context, internal supplier risk sources refer to factors, which are under the direct influence radius of the supplier; whereas
external ones refer to risk sources existing outside of the supplier, which are not under the direct control of the supplier in the short-term. When internal supplier risk sources are examined, they can further be classified into business related and operational risk sources. An overview of the important risk sources according to the proposed categorization is exhibited below.

Table 5-2: Categorization of Risk Sources

<table>
<thead>
<tr>
<th>Supplier Risk Sources</th>
<th>Internal Supplier Risk Sources</th>
<th>External Supplier Risk Sources</th>
<th>Market Risk Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Business Related Risk Sources</strong></td>
<td><strong>Operational Risk Sources</strong></td>
<td><strong>Natural disasters</strong></td>
<td><strong>Market constraints</strong></td>
</tr>
<tr>
<td>Poor financial health</td>
<td>Capacity constraints</td>
<td>Currency and exchange rate fluctuations/economic stability of the region</td>
<td>Low number of qualified suppliers</td>
</tr>
<tr>
<td>Poor management vision</td>
<td>Flexibility constraints</td>
<td>Political stability of the region/terrorism</td>
<td>Multi-tier sourcing</td>
</tr>
<tr>
<td>High price variability</td>
<td>Quality problems</td>
<td></td>
<td>Geographical density of suppliers</td>
</tr>
<tr>
<td>Supplier obligations to other customers</td>
<td>Poor inventory management</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High cycle time variability</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Technological backwardness</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inadequate information systems sophistication</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shipping and distribution distance and methods</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Insufficient safety measures/man-made accidents</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Business Related Supplier Risk Sources**

Business related risk sources refer to a supplier’s organizational, managerial and financial characteristics, which might cause the supplier to become enable to temporarily or permanently deliver products to its customer. All of these risk sources are under the direct influence sphere of the company. There are four such risk sources identified in the literature: poor financial health of suppliers, poor management vision, high price variability, and supplier’s obligations to other customers.
**Poor financial health**

Various sources indicate financial instability of a supplier as a crucial risk source (Micheli et al., 2008; Zsidisin, 2000). Financial issues might result in temporary disruptions due to liquidity problems; however, financial failure can also cause much severer consequences if it forces the supplier to bankrupt or to go out of a specific business. It can also result in an acquisition which might require a reorganization of the supplier on a managerial level. In order to measure the financial health of a supplier, some indicators can be utilized: profitability trends in cash flow, liquidity, existence of financial guarantees, debt & credit rating, existence of a mother company, etc. (Zsidisin, 2003; Blos et al., 2009).

**Poor management vision**

Management vision of the supplier is defined as its management attitude and ability to foresee market and industry changes accurately and on time (Krause et al., 1998). A poor management vision might cause a supplier to remain incapable of adjusting its capacity according to market trends or acquiring new technologies in order to meet novel market needs.

**High price variability**

Sudden increases in price of a raw material might place the purchasing firm in a rather difficult position, especially if the quantity of the material purchased is relatively high. These price increases can be related to supply market conditions or to individual supplier behavior. In any case, if the price increase is not expected by the purchasing firm and thus created budgetary issues, it might cause a disruption of raw materials (Micheli et al., 2008).

**Supplier obligations to other customers**

A supplier’s obligation to other customers is perceived as a supplier risk source, because in case of bottlenecks the supplier might need to allocate its products among many customers, resulting in disruptions for some of the purchasing firms (Zsidisin, 2003). The impact of this risk source is increased, if the supplier is contractually linked to other customers, meaning that those customers will be prioritized in terms of order approval and product delivery (Micheli et al., 2008).

**Operational Supplier Risk Sources**

Operational activities cover those that are related to production, supply chain management, logistics, information technologies, etc. Risks that are caused by these operations are called operational risk sources and they are also under direct control of the supplier. There are mainly nine operational risk sources related to suppliers: capacity constraints, flexibility constraints, quality problems, poor inventory management, cycle time variability, technological backwardness, inadequate information systems sophistication, shipping and distribution distance and methods and insufficient safety measures/man-made accidents.

**Capacity constraints**

Capacity constraint is defined as the inability of a system to produce an output quantity in a particular time period (Lee et al., 1997). It is noted that supplier capacity constraints are a significant risk to the purchasing organization because they detrimentally affect firm competitiveness by causing disruptions on the inbound side of the firm (Zsidisin, 2003). Therefore, as the production level of a product is
increased, the purchasing firm should make sure that its suppliers have the capacity to supply the raw materials for that product, in order to ensure the continuity of that particular business.

**Flexibility constraints**

Flexibility refers to the ability of a supplier to adjust itself to sudden increases in demand or sudden problems within production in terms of planning and scheduling; in other words, being responsive to such events. For a company, a sudden increase in demand for a product is reflected as an increase in the purchased quantities of raw materials for that product. The inability of a supplier to adapt itself to these kinds of variability in raw material demand might result in supply disruptions for the buying organization (Zsidisin, 2003). In the same manner, if a production line of a supplier is impacted, the supplier is considered flexible if it manages to shift the production to another site, plant, etc.

**Quality problems**

Noordewier et al. (1990) define quality with respect to procurement as “the ability of a supplier to conform to specifications”. In line with Noordewier’s findings, quality is considered a significant supplier risk and therefore supplier quality is mandatory (Zsidisin, 2003). If suppliers are unable to ensure quality in their products, product recalls might become frequent, causing disruptions on the inbound side and consequentially production stoppages (Kumar and Schmitz, 2011).

**Poor inventory management**

Supplier’s inventory management is its ability to manage raw materials, work-in-process and finished goods and inventories (Krause and Handfield, 1999). Poor inventory management is considered to be a supplier vulnerability area, because it might result in inadequate quantities or safety stock of finished goods on supplier’s side, making the buying firm inflexible for its procurement activities (Micheli et al., 2008).

**High cycle time variability**

Professionals of organizations perceive the cycle time from a supplier order to its receipt as a significant risk. At this point, the primary driver of this risk is the bullwhip effect. Cycle time variability increases forecast errors and due to the bullwhip effect it is amplified at each level of the supply chain. The consequence is uncertain and erratic order cycle times (Zsidisin, 2003). Delivery delays caused by cycle time variability are one of the main causes of supply disruptions for purchasing organizations (Micheli et al., 2008).

**Technological backwardness**

Some sources in literature consider technological backwardness as a supplier related risk source (Finch, 2004; Sawik, 2011). Technological inadequacy of a supplier can cause disruptions on the inbound side of a company due to the inability of the supplier to quickly implement technological changes and to quickly respond to product changes demanded by the purchasing company. This is especially the case for fast-changing and high-tech product markets (Micheli et al., 2008).

**Inadequate information systems sophistication**

Information system sophistication is referred to as the information system compatibility of suppliers to transfer timely, accurate and relevant information to buyers (Krause and Handfield, 1999; Lee et al.,
1997). According to literature, information technology backwardness and incompatibility are perceived as a significant supplier related risk source because it can eventually lead to supply interruptions (Micheli et al., 2008; Zsidisin, 2003).

Issues related to information systems are created internally at a supplier or at the supplier – buying organization interface, when there is disconnection of information at any point from order entry to product delivery. Some supplier organizations, especially smaller firms, find it difficult to effectively communicate internal information with all of their business units, leading to inbound supply disruptions of their customers (Zsidisin, 2003).

**Shipping and distribution distance and methods**

Harland (2003) considers shipping and distribution distance and methods of a supplier as a risk source that can have severe effects on the purchasing company. This risk is related to the number of transitions in transportation, which strictly depends on the location of suppliers. The time of transitions is likely to be greater from off-shore suppliers, in comparison to domestic suppliers (Tse and Tan, 2011). Min (1994) and Kelle and Miller (2001) also note additional perceived supply risk from global sourcing. Logistics route or mode disruptions are mentioned as supply risks in the same context (Blos et al., 2009).

**Insufficient safety measures/man-made accidents**

Man-made accidents such as fire, explosion, etc. are claimed to be caused by the interaction between technology and organizational failings. Organizational accidents usually stem from latent errors and events which might be culturally taken for granted (Pidgeon and O'Leary, 2000). A supplier’s tendency not to take safety measured and education seriously might result in major accidents and lead to supply disruptions.

**External Supplier Risk Sources**

Some risk sources are outside the control sphere of the suppliers. These risk sources are caused by the conditions associated with the location of the suppliers. Mitchell (1995) perceives the country of origin of a supplier as a direct risk source; especially due to increased global sourcing strategies. In literature, the following risk sources are presented as to external risk sources: natural disasters, currency and exchange rate fluctuations/economic stability of the region and political stability of the region/terrorism.

**Natural disasters**

According to risk literature, disaster is defined as any occurrence that causes great harm or calamity to individuals or organizations (Iwan et al., 1999). Some of the most critical natural disasters that affect organizations are earthquakes, storms, floods and tsunami. Zsidisin (2003) underlines the risk associated with suppliers in Far Eastern countries located in earthquake-prone regions. He provides examples of how the 1999 earthquake in Taiwan had a detrimental effect on some organizations.

**Currency and exchange rate fluctuations/economic stability of the region**

Blos (2009) considers currency and exchange rate fluctuations, financial market instability and economic recessions in the origin of country of a supplier as a risk source. For instance, Cell stated that a supply risk it faces is currency fluctuation, which has a significant effect on Earnings Before Interest and Taxes (EBIT) (Zsidisin, 2000).
Political stability of the region/terrorism

Zsidisin (2000) considers part of supplier risk management as assessing and choosing suppliers manufacturing in politically stable areas. Political stability and terrorism are also considered as risk sources which might lead to supply chain disruptions on the inbound side of purchasing firms (Chan and Kumar, 2007).

Market Risk Sources

Market related risk sources are related to the market conditions of a particular supplier or an item, that are either determined by the supplier’s behaviour or by the characteristics of an item that the supplier delivers. The following risk sources are covered by this category: market constraints, small number of qualified suppliers, multi-tier sourcing and geographical density of suppliers.

Market constraints

Market constraints for a raw material can pose a risk when there are only a few supply sources available in the market and there is a high degree of market saturation (Micheli et al., 2008). An illustration of market capacity risk presented by Zsidisin (2003), which notes that in 1999, a fire occurred with a manufacturer of beryllium oxide. The purchasing company of this raw material discovered that only two suppliers in the world were manufacturing this chemical used in producing computer chips. When the facility in Germany was destroyed due to the fire, the global production capacity for this chemical was immediately reduced by 40 percent.

The extreme level of market constraint is supply monopoly conditions, meaning that there is only one supplier producing a particular raw material (Kraljik, 1983). In that case, this supplier is called a sole source. Sole source conditions can be present due to highly customized nature of a product, or due to supplier having a patent for that particular item (Zsidisin, 2003).

Low number of qualified suppliers

Although there might be a large number of suppliers providing a raw material, the number of approved suppliers for that raw material is also as important in term of supply risks (Micheli et al., 2008). Zsidisin (2003) illustrates this with an example: A company producing semiconductors stated that there are many suppliers capable of manufacturing resins in the market. However, if that supplier is not certified by the purchasing organization in advance, there is greater perceived risk due to the lack of knowledge of its production processes, testing, and interaction with the final product. This is especially important in industries where it is difficult to qualify some supplier processes. Having qualified, approved and certified suppliers is critical for implementing a successful supply strategy.

Multi-tier sourcing

Multi-tier sourcing is considered in literature as a risk source in the sense that higher tier suppliers outsource to sub-tier suppliers and this causes the supply chain to become a ‘long’ supply chain. The longer the supply chain, the harder for the focal firm to keep track of their quality control processes, production levels, etc. along the supply chain, which results in lack of supply chain visibility and traceability (Lyles et al., 2008). It is highly unlikely that a supplier would provide all the information it receives from its sub-tier suppliers to the purchasing firm, as some of the suppliers may try to withhold
their quality assessment information or other similar issues and not be willing to reveal their vulnerabilities to their customers (Tse and Tan, 2010).

**Geographical density of suppliers**

Geographic concentration of suppliers is considered as a risk source by several authors (Zsidisin, 2003). Supplier density is revealed to be a contributing factor to how severe a supply disruption can be. It connotes the geographical spacing of suppliers, with supplier density being inversely related to geographical spacing. The severity of a supply disruption appears to be positively related to supplier density. The reason for that is that for a supply chain that has a low supplier density level, the probability of a disruptive event affecting many suppliers is likely to be lower than in the case of a dense supplier network. For example, a tornado impacting a location with many suppliers would cause a much severer disruption for an organization as compared to one impacting a location with one supplier (Craighead et al., 2007).

5.2. **Supplier Risks Assessment at SABIC in Europe**

The risk assessment at SABIC in Europe related to supplier risk sources includes the judgement on the probability and the impact of the corresponding risk events and the risk context (additional remarks on risk sources). For this purpose, risk registers are introduced. Risk registers prove to be useful as a risk assessment tool as they provide an overview of all the active risks and their risk rankings (Patterson, 2002). The sample version of the risk register can be found in Appendix B.

When assessing the subjective probability of a risk event, the company’s own experience is utilized. Some risk sources might be of higher probability, whereas others might be perceived as low probability. The potential consequences should also be assessed from the viewpoint of the enterprise. The impact of the risk events should not only consider monetary impact, but also immaterial consequences such as reputation loss, degradation of knowledge, etc. (Harland et al., 2001). Both probability and impact of events are evaluated on a 5-point scale. Details on the scale are shown in the table below.

<table>
<thead>
<tr>
<th>Rating</th>
<th>Probability</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Not perceived as a risk</td>
<td>Not perceived as a risk</td>
</tr>
<tr>
<td>1</td>
<td>Less than every three years</td>
<td>No considerable impact</td>
</tr>
<tr>
<td>2</td>
<td>Every three years</td>
<td>Procurement activities lightly affected</td>
</tr>
<tr>
<td>3</td>
<td>Every year</td>
<td>Procurement activities heavily affected</td>
</tr>
<tr>
<td>4</td>
<td>Every quarter</td>
<td>Production activities directly affected/ minor delays of customer orders</td>
</tr>
<tr>
<td>5</td>
<td>Every month</td>
<td>Customer heavily affected</td>
</tr>
</tbody>
</table>

After the identified risks have been assessed, it is practical and useful in visual terms to present them in a table. This table gives an overall view upon all risks, and makes the high impact risks requiring the most
attention visible. Furthermore, it indicates whether these risks can be reduced by decreasing their probability or their impact (Hallikas, 2004). This table is exhibited below. Those, over which a consensus has been reached for their high impact nature, have been marked in the “high impact” column. It is assumed that those with an average over 4.0 are high impact, as they cause customers to be heavily affected.

Table 5-4: Risk Register Outcomes

<table>
<thead>
<tr>
<th>Risk Category</th>
<th>Risk Name</th>
<th>Average Probability</th>
<th>Average Impact</th>
<th>High Impact?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business</td>
<td>Poor financial health</td>
<td>2.0</td>
<td>4.7</td>
<td>X</td>
</tr>
<tr>
<td>Business</td>
<td>Poor management vision</td>
<td>2.3</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>Business</td>
<td>High price variability</td>
<td>3.7</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>Business</td>
<td>Supplier obligations to other customers</td>
<td>2.0</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>Operational</td>
<td>Capacity constraints</td>
<td>3.3</td>
<td>4.0</td>
<td>X</td>
</tr>
<tr>
<td>Operational</td>
<td>Flexibility constraints</td>
<td>3.3</td>
<td>4.0</td>
<td>X</td>
</tr>
<tr>
<td>Operational</td>
<td>Quality problems</td>
<td>2.3</td>
<td>4.0</td>
<td>X</td>
</tr>
<tr>
<td>Operational</td>
<td>Poor inventory management</td>
<td>2.7</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>Operational</td>
<td>High lead time variability</td>
<td>2.7</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>Operational</td>
<td>Technological backwardness</td>
<td>2.7</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>Operational</td>
<td>Inadequate information system sophistication</td>
<td>2.3</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>Operational</td>
<td>Shipping and distribution distance and methods</td>
<td>2.0</td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td>Operational</td>
<td>Insufficient safety measures/man-made disasters</td>
<td>1.7</td>
<td>4.0</td>
<td>X</td>
</tr>
<tr>
<td>External</td>
<td>Natural disasters</td>
<td>1.7</td>
<td>4.3</td>
<td>X</td>
</tr>
<tr>
<td>External</td>
<td>Currency and exchange rate fluctuations / economic stability</td>
<td>1.3</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>External</td>
<td>Political stability of the region / terrorism</td>
<td>1.0</td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td>Market</td>
<td>Market constraints</td>
<td>3.0</td>
<td>4.7</td>
<td>X</td>
</tr>
<tr>
<td>Market</td>
<td>Low number of qualified suppliers</td>
<td>3.3</td>
<td>4.0</td>
<td>X</td>
</tr>
</tbody>
</table>
These results merely serve to give a rough overview on the probability and impact analysis of the risk events; the risk registers are designed to accompany the interviews on supplier risk sources and should therefore be interpreted in combination with the results of the interviews. Important issues and remarks brought up during the interviews build up the risk contexts and they are explained next in the table below.

### Table 5-5: Interview Outcomes for Identified Risk Sources

<table>
<thead>
<tr>
<th>Risk Source</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor financial health</td>
<td>Poor financial health of a supplier which might result in its bankruptcy was found to be a very high impact risk by the interviewees (production stoppage on the supplier side in some cases), although the probability is quite low. Especially in the chemical industry, it is quite rare and you hopefully get a warning beforehand. The bankruptcy of a supplier does not necessarily lead to an immediate disruption; it might also result in acquisition. The business model of the supplier might change after a merger or an acquisition. These kinds of supply issues place sales revenue at risk.</td>
</tr>
<tr>
<td>Poor management vision</td>
<td>Not being able to foresee market changes might result in capacity problems for the supplier; however, the probability of such an event is also dependent on the purchasing: accuracy and frequency of sharing forecast, demanding delivery confirmation, contracts etc. The impact of such an event depends mostly on the supplier: how fast it can rearrange its capacity. However, there is usually no sudden major disruption.</td>
</tr>
<tr>
<td>High price variability</td>
<td>Sharp price increases might happen due to market changes, in which case the alternatives sources of that supply would usually follow the increase. However, it might also happen due to opportunistic behaviour of the supplier. In that case, the impact on business is high in financial terms, but the impact on the availability of supply is relatively lower. Increase in the procurement costs is usually reflected as an increase on the price of the end product for the customer. Supply disruption occurs if a sudden price increase is introduced which is not acceptable by the purchasing firm.</td>
</tr>
<tr>
<td>Supplier obligations to other customers</td>
<td>No major importance is attached to this risk source as it is very common that a supplier is contracted by other consumers, however, a disruption rarely occurs due to that issue. The only big concern is that when there is a joint product development, the supplier should not share it with the competitors. This risk can also be related to poor inventory management of the supplier.</td>
</tr>
<tr>
<td>Risk Source</td>
<td>Remarks</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Capacity constraints</td>
<td>Purchasing firms usually get information on the capacity of a supplier upfront (during vendor qualification); therefore the probability is not very high. In case it happens, most of the time there is some raw material available, but not enough. Hence, it usually leads to delivery delays rather than major production stoppages. In any case, the customer can be affected according to the severity of the situation. Capacity constraints can also be caused due to market dynamics. In case of a crisis, the supply for an item is reduced due to demand decrease. When the demand increases again, there is usually a major capacity constraint. This risk source is interrelated with flexibility constraints (e.g. number of plants) and inventory management of the supplier.</td>
</tr>
<tr>
<td>Flexibility constraint</td>
<td>Flexibility constraint of a supplier is considered to be somewhat related to capacity constraint. The most important indicator of the risk source is the number of plants that a particular raw material is produced in. In case of single plant, the supplier might fail to supply raw materials due to a problem in that plant and the impact can be major. The number of plants producing a particular item should therefore be checked with the supplier. However, this risk source adds additional risk only if a disruption occurs due to a problem in one of the supplier’s plants.</td>
</tr>
<tr>
<td>Quality problems</td>
<td>The pre-selection of suppliers and working with certified suppliers minimizes the probability of risk related to quality issues. When they do, the lead time of the raw material and the readily available safety stocks are important: When can the next order arrive? Another important aspect is whether the whole batch is faulty; if that’s the case, the impact is big.</td>
</tr>
<tr>
<td>Poor inventory management</td>
<td>In many cases, SABIC in Europe asks its suppliers to hold safety stocks for their end-products. The probability of a risk associated with poor inventory management can be reduced by providing the suppliers with accurate forecast or fixing lead times via contracts. In that aspect, inventory management is interrelated with capacity constraints and lead time of the item. Poor inventory management of the supplier usually causes inbound delays rather than production stoppages.</td>
</tr>
<tr>
<td>Risk Source</td>
<td>Remarks</td>
</tr>
<tr>
<td>-------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>High lead time and lead time variability</td>
<td>In addition to lead time variability, high lead time itself is also considered a risk source. If there is a disruption, there is the issue of when the next orders will arrive. Lead time includes shipping distance implicitly; however, it is not always proportional to shipping distance. It is also dependent on other variables such as order size compared to truck load, safety stocks on the supplier side, and capacity of the supplier. In general, high lead time is considered as a high impact risk source as it can heavily affect customer orders linked to a raw material. High lead time variability might also heavily affect procurement activities. The probability of an event associated with high lead time variability can be reduced by sending forecasts in advance and through contracts.</td>
</tr>
<tr>
<td>Technological backwardness</td>
<td>If there is a requirement for a particular technology or a major technological change, usually there is a whole process behind it; the supplier is supposed to have that technology beforehand. However, sometimes SABIC in Europe wants to change the spec of a raw material for urgent orders. Only in that case, if the supplier fails to implement it fast, it can have some impact on production activities.</td>
</tr>
<tr>
<td>Inadequate information system sophistication</td>
<td>IT incompatibility only causes minor issues. It can sometimes cause the supplier not to send confirmation order (on time). If there is an issue caused by that, it costs procurement more time, but does not really lead to major disruptions.</td>
</tr>
<tr>
<td>Distribution distance and methods</td>
<td>Off-shore suppliers are perceived more risky due the increase in high lead time. Therefore, this risk source is implicit in high lead time. However, there are other variables influencing lead time other than distribution distance and methods.</td>
</tr>
<tr>
<td>Insufficient safety measures/man-made accidents</td>
<td>Man-made accidents such as fire heavily affect the production or distribution activities of the supplier and therefore have a major impact on SABIC in Europe’s inbound supply chain. However, they are quite rare and during vendor qualification, safety standards are thoroughly checked.</td>
</tr>
<tr>
<td>Natural disasters</td>
<td>Natural disasters are the mostly the reason behind Force Majeure, such as earthquakes (e.g. Japan), hurricanes (e.g. in the southern part of USA). They can result in heavy impacts on the supplier’s production line or lead to capacity reduction. Hurricanes usually lead to disruptions in transportation of supply, rather than in its production. The probability of disruptions due to natural disasters depends on the location of the supplier; however, they are very hard to judge without expert view.</td>
</tr>
<tr>
<td>Risk Source</td>
<td>Remarks</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Currency and exchange rate fluctuations / economic stability</td>
<td>Just like high price variability, currency and exchange rate fluctuations impact procurement in financial terms, rather than with respect to supply availability. Sometimes the exchange rate can be fixed through contracts. Only if a severe crisis happens in a country, then its currency might collapse. This would result in a major impact; the business in that country might heavily be affected.</td>
</tr>
<tr>
<td>Political instability of the region/terrorism</td>
<td>Although the impact of political instability can be relatively high on a supplier, the probability of such a risk event can be decreased by avoiding countries that are in the “black list”.</td>
</tr>
<tr>
<td>Market constraints and low number of qualified suppliers</td>
<td>In case of a single source, it is crucial to have a B-plan, such as contract. If there is only one producer in the market for a certain item, single source is unavoidable. This situation can be due to the characteristics of the item being highly customized, as well as due to a patent. In any case, the failure of a single source leads to major impact.</td>
</tr>
<tr>
<td>Multi-tier sourcing</td>
<td>SABIC in Europe strives to work with producers directly, but if the purchasing volume is low, the supplier might have an exclusive contract with a distributor. Multi-tier sourcing might be a bigger problem for smaller companies, because they can only approach relatively small distributors which source from larger distributors. Therefore their supply chain can be relatively longer, decreasing visibility.</td>
</tr>
<tr>
<td>Geographical density of suppliers</td>
<td>Geographical density of suppliers is not a stand-alone risk, but certainly increases the risk associated with other risk sources in a great manner.</td>
</tr>
<tr>
<td>Supplier being under no legal liability</td>
<td>A risk source that has been introduced by the interviewees is the supplier’s lack of legal liability, which occurs when there is no legally binding agreement between the supplier and the buyer form, namely a contract. Having a contract is considered a risk reduction method in literature, therefore its absence is perceived as a risk source, which might have a major impact on the buying firm. However, it is noted that in case of force majeure, this risk source does not introduce an additional impact.</td>
</tr>
</tbody>
</table>

5.3. Selection of High Impact Risk Sources

As a result of this investigation, the high impact risk sources, which will contribute to the generation of risk profiles for critical items, are chosen to be the following:

1. Poor financial health of the supplier (business related)
2. Flexibility constraints (operational)
3. Market constraints (market)
4. Low number of qualified suppliers (market)
5. High lead time (operational)

6. Supplier being under no legal liability (business related)

7. Geographical density of suppliers (market)

Risk sources that will be left out of the rest of the research despite their high perceived impact are given next. These will be left out for the sake of keeping the procedure simple and due to some additional motivations, which are explained below.

- Capacity constraints (operational), because this risk source is somewhat included in flexibility constraint, and is also interrelated with lead time. It should also be noted that increasing the number of qualified suppliers also increases the capacity; therefore low number of qualified suppliers is also related to capacity constraints as a risk source.

- Quality problems (operational), because this is usually not an issue for SABIC since it works with certified suppliers and extensive examination takes place during vendor qualification.

- Natural disasters (external), because they are very hard to judge without having the expertise on this topic.

- Insufficient safety measures/man-made disasters (operational), because extensive examination takes place during vendor qualification with regard to safety issues.

5.4. Risk Profile Generation Procedure for Prioritized Raw Materials

This section aims to develop a procedure for creating individual risk profiles for critical items. A risk profile gives a snapshot of risks for a critical raw material. In order to measure these risks, metrics need to be developed to find out whether a particular risk exists for a certain raw material. For this analysis, only high impact risk sources that have been identified in the previous section are taken into account.

For every risk source, a risk metric is developed as a result of the desk research and interviews at SABIC in Europe. These metrics are strive to be easy to measure and easy to evaluate. The ratings associated with the metrics provide a rough score on the risk exposure for the corresponding supplier/item. Herewith, the risk exposure is defined as a measure of the magnitude of a risk based on current values of probability and impact (Alberts and Dorofee, 2010), regardless of the sales impact of the associated raw material. Below, the parameters and scales for the individual risk sources are explained:

Low number of qualified suppliers/Market constraints: As these two risk sources are not mutually exclusive, they are evaluated together. The number of suppliers is the primary metric for low number of qualified suppliers. This metric has been simplified to single sourced/multi sourced, as the incremental risk of having one less supplier is much greater for switching from 2 suppliers to 1 supplier as compared to any other change (e.g. 3 to 2). An intermediate step between single source and multi source is the 2nd source being in process, meaning that a second supplier is currently under evaluation. An extreme version of single source, on the other hand, is that there are no alternative suppliers in the market producing the same raw material. As explained previously, this can be due to the raw material being patented or highly customized, which poses the greatest risk for the particular raw material.
Financial instability of the supplier: There are various ways of measuring the financial stability of a supplier, including the annual operating revenue of the supplier, its profits before tax, as well as its years of experience in business. However, there are also readily available ratings, which are generated by professional companies such as Dun & Bradstreet (D&B). For this analysis, the D&B rating on financial stress score will be used, which is designed to help predict a business’ potential for failure over a scale of 5. This score is also used during vendor qualification of SABIC in Europe. For this analysis, it is simplified into a two-scale score.

Supplier being under no legal liability: A supplier’s legal liability can be provided through contracts or other means of agreements. For this particular analysis, this risk source will be measured according to the existence of a contract between suppliers and SABIC in Europe. No distinction will be made between quarterly or yearly contracts, and non-official agreements will be considered as “no contract”. An intermediate step will be introduced for the situations where a contract is in draft version.

Flexibility constraints: Flexibility constraints can be measured via the number of plants or product lines producing an item. They can also be associated with the ability of a firm to shift production to another product line or back-up company in case of emergency. For the sake of simplicity, only the number of plants producing an item will be taken into account. Just like the number of suppliers, number of plants will also be organized into two categories: single plant and multiple plants.

High lead time: The obvious measure for this risk source is the lead time of an item for a particular plant, which is defined as the time slot between the order placement and the arrival of the order. The lead time for an item might vary between a few days and several months. Lead time is categorized into three: less than 1 week, between 1 and four weeks, and more than 4 weeks. For items which are purchased by several plants, an average of all the lead times is taken.

The weights associated with the risk sources are given according to their importance. These weights are the result of structured interviews and hereby it should be noted that managers tend to focus more on the magnitude of the loss associated with a risk event, rather than on the probability that it will be realized (Miller and Leiblein, 1996). Due to confidentiality issues, these weights and their reasoning will not be revealed.

The table below displays the high impact risk sources, their corresponding parameters, and their scale (over 1.0).

---

Since the prioritized raw materials are mostly single sourced, geographical density of suppliers does not apply to all cases as a risk source. In case of multi sources, this criterion should also be introduced as a high impact risk source and be evaluated separately.

When evaluating an item according to these metrics, the given ratings for individual risk sources will be multiplied by their weights and add up to a percentage, which will be an indication of the risk exposure linked to that item, independent from its business impact.

Among the prioritized raw materials, a secondary ranking will be applied according to “value at risk”, which is calculated in the following way:

\[
Value \text{ at Risk} = Risk \text{ Exposure Rating} \times Business \text{ Impact}
\]

This ranking will enable a more detailed view on where the highest risks are, so that they can be challenged with top priority. The value at risk will further be considered a KPI for tracking how much business has been secured through an action or in a certain period of time:

\[
KPI: \text{Secured Business Value} = \Delta \text{Risk Exposure Rating} \times \text{Business Impact}
\]

It should be noted that the KPI calculated above is merely aimed at obtaining a relative indication on the size of business secured, rather than giving an absolute measure on the money secured through the action.

The long term target set for all the prioritized items is to reduce the risk exposure level to 40%. This target has been set through discussions with category managers. The motivation behind setting the target to 40% is to reduce the risk as much as possible, but also to take into account the limited amount of resources and time to be spent on one item’s BCP. As a result, the following labelling for risk exposure level is introduced:

---

### Table 5-6: Risk Profile Framework

<table>
<thead>
<tr>
<th>Risk Source</th>
<th>Risk Metric</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low number of qualified suppliers/Market constraints</td>
<td>Single sourced? (In case of distributor, single producer behind?)/Only producer in the market? (e.g. patented)</td>
<td>Multi sourced 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2nd source in process 0,5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Single sourced 0,75</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Single sourced &amp; no alternative in the market 1</td>
</tr>
<tr>
<td>Financial instability of the supplier</td>
<td>D&amp;B rating (Financial stress score)</td>
<td>1-3 0</td>
</tr>
<tr>
<td>Supplier under no legal liability</td>
<td>Contract</td>
<td>Yes 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Draft/in process 0,5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No 1</td>
</tr>
<tr>
<td>Capacity/Flexibility Constraints</td>
<td>Single production plant for the item?</td>
<td>Multiple Plants 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Single plant 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LT &lt; 1 week</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 week &lt; LT &lt; 4 weeks 0,5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LT &gt; 4 weeks 1</td>
</tr>
</tbody>
</table>
An exception for the 40% target is the case, where an item is single sourced and there are no alternative suppliers in the market due to market constraints. In that case, the target is set to 60% as it is not possible to second source the item.

The concepts explained in this section will be illustrated in detail via examples in Section 7.2.

5.5. **Summary**

This chapter’s target was to find a method to analyze the high impact supplier risk sources of prioritized raw materials and come up with a procedure to generate the risk profile of individual items in order to quantify and track their risk exposures.

In literature, 20 risk sources have been identified, which have been organized into four categories: business related risk sources, operational risk sources (these two make up the internal supplier risk sources), external supplier risk sources, and market risk sources. These risk sources have been evaluated at SABIC in Europe with regard to their probabilities and impacts; hereby, two risk sources have been added to the previous 20. As a result of this investigation, the following risk sources have been determined to have a high impact, and have therefore been subject to the rest of the research:

1. Poor financial health of the supplier
2. Flexibility constraints
3. Market constraints
4. Low number of qualified suppliers
5. High lead time
6. Supplier under no legal liability
7. Geographical density of suppliers

Next, a procedure for generating risk profiles for prioritized items has been developed by making use of the high impact risk sources. For this purpose, metrics have been developed to measure these risk sources. A rating scheme (over 1.0) has been developed for these risk sources, in order to evaluate a raw material’s risk exposure rating. The weights associated with individual risk sources have been attached according to their impact and probability, where low number of qualified suppliers and market constraints received the highest weight. Every prioritized raw material is given a label according to its risk exposure percentage: low, medium or high. Moreover, a KPI has been developed to quantify and track the improvement that is achieved when a risk is reduced, which calculated in the following way:
**KPI: Secured Business Value = Δ Risk Exposure Rating x Business Impact**

The main target is to reduce the risk exposure rating to a minimum of 40% for every critical item, given the limited time and resources that can be dedicated to risk management for raw materials.
6. Identification of Risk Reduction Methods

Understanding supply risks through assessments can permit purchasing organizations to take actions in response to those risks. This section discusses the methods in literature for reducing the risks that were presented in the previous chapter.

The term “risk reduction” is interpreted differently by different authors. Khemani (2007) suggests seven ways of taking action for risk management: avoid, respond, minimize, accept, transfer, mitigate and monitor. DeLoach (2000) on the other hand, proposes five ways, which are overlapping with Khemani’s definitions: avoid, exploit, reduce, retain and transfer. For this research, risk reduction refers to any kind of action that is aimed at reducing the probability and/or impact of a risk. Therefore, it covers all of the above mentioned terms except for accept/retain.

This chapter first introduces the risk reduction methods that are found in literature. Then, it goes into detail about the downsides, advantages and other features of risk reduction methods with regard to how they are perceived in SABIC in Europe. Finally, the most suitable risk reduction methods for SABIC in Europe will be identified with respect to their effectiveness and applicability. Responsible departments will be identified for these actions.

6.1. Risk Reduction Methods in Literature

In literature, there are various risk reduction methods introduced by several authors as part of supply risk treatment (management) approaches and business continuity plans. An overview of the methods per author is displayed in the table below. The papers that are utilized to create this overview have different focus points; only few of them focus on risk reduction methods of supply risks in general, whereas the majority focuses on specific supply risks such as quality constraints/recalls, transportation issues, risks related to location.

<table>
<thead>
<tr>
<th>Author</th>
<th>Risk Reduction Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grandori and Soda (1995)</td>
<td>Incentive systems</td>
</tr>
<tr>
<td>Fawcett et al. (1996)</td>
<td>Flexibility</td>
</tr>
<tr>
<td>Hartley and Choi (1996)</td>
<td>Developing suppliers</td>
</tr>
<tr>
<td>Smeltzer and Siferd (1998)</td>
<td>Forming strategic alliances</td>
</tr>
<tr>
<td>Krause (1999)</td>
<td>Developing suppliers</td>
</tr>
<tr>
<td>Chopra and Van Mieghem (2000)</td>
<td>Implementing and using information systems</td>
</tr>
<tr>
<td>Ritchie et al. (2000)</td>
<td>Supply chain partnerships, long-term financial security arrangements</td>
</tr>
</tbody>
</table>
Risk reduction methods are categorized in literature in a variety of ways. According to Svensson's (2000) categorization, risk reduction methods can be analyzed in three categories: knowledge increasing methods, risk probability reduction methods and risk consequence mitigation methods. Another approach for presenting risk reduction methods which is more suitable for this research is: operational buffers, mitigation plans and contingency plans (Colicchia et al., 2010).

Operational buffers are strategies to build up reserves in order to reduce the impact of a disruption. They are measures that are taken before a disruption occurs. Mitigation plans, on the other hand, aim at reducing the probability of the materialization of the risk. Last, contingency plans are procedures that are conducted once a disruption actually materializes. Just like operational buffers, they have the goal of

<table>
<thead>
<tr>
<th>Author</th>
<th>Risk Reduction Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zsidisin (2000, 2005)</td>
<td>Process improvement, buffer strategies, inventories, alternative sources of supply, contracts with back-up suppliers, forming alliance relationships, having suppliers responsible to develop risk mitigation plans, early supplier involvement, timely information sharing</td>
</tr>
<tr>
<td>Zheng et al. (2001)</td>
<td>Designing and using a system of incentives, risk sharing practices and rewards for suppliers</td>
</tr>
<tr>
<td>Handfield and Bechtel (2002)</td>
<td>Supplier integration</td>
</tr>
<tr>
<td>Giunipero and Eltantawy (2004)</td>
<td>Coordination with suppliers, creation of a flexible supply base</td>
</tr>
<tr>
<td>Chopra and Sodhi (2004)</td>
<td>Excess inventory or productive capacity, backup sourcing, multiple sourcing</td>
</tr>
<tr>
<td>Hallikas et al. (2004)</td>
<td>Closer supplier co-ordination, individual supplier development, producing in-house</td>
</tr>
<tr>
<td>Norrman and Jansson (2004)</td>
<td>Response plans, recovery plans, restoration plans</td>
</tr>
<tr>
<td>Blackhurst et al. (2005)</td>
<td>Real-time sharing of correct information</td>
</tr>
<tr>
<td>Tomlin (2006)</td>
<td>Multiple sourcing, excessive inventory, contingent rerouting</td>
</tr>
<tr>
<td>Craighead et al. (2007)</td>
<td>Recovery capability, warning capability</td>
</tr>
<tr>
<td>Manuj and Mentzer (2008)</td>
<td>Supplier development</td>
</tr>
<tr>
<td>Ellegaard (2008)</td>
<td>Holding reserves, multi sourcing, flexibility, relationship management, contracts, local sourcing, financial reserves</td>
</tr>
<tr>
<td>Sanchez-Rodrigues et al. (2009)</td>
<td>Demand forecasting, quality management</td>
</tr>
</tbody>
</table>
reducing the impact of the disruption by being prepared for the risk (Chopra and Sodhi, 2004). An effective risk management strategy is supposed to consider all the three approaches as part of business continuity planning (Colicchia et al., 2010). Next, the risk reduction methods in literature will be gathered under these three categories and be explained in detail, in order to provide a better understanding of these methods.

An overview of all the risk reduction methods is provided in the table below.

<table>
<thead>
<tr>
<th>Operational Buffers</th>
<th>Mitigation Plans</th>
<th>Contingency Plans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety stocks</td>
<td>Supplier process improvement</td>
<td>Alternative sources of supply</td>
</tr>
<tr>
<td>Multi-sourcing</td>
<td>Increased coordination with supplier</td>
<td>Increased supply and production flexibility</td>
</tr>
<tr>
<td>Financial reserves</td>
<td>Contracts</td>
<td>Loss sharing with suppliers</td>
</tr>
<tr>
<td></td>
<td>Integrating risk mitigation plans with supplier</td>
<td>Contingent rerouting</td>
</tr>
<tr>
<td></td>
<td>Local sourcing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Incentive systems</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accurate demand forecasting</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quality management</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Early supplier involvement</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Producing in-house</td>
<td></td>
</tr>
</tbody>
</table>

**Operational buffers**

As mentioned before, operational buffers aim at reducing the impact of disruptions. However, these traditional buffering strategies might decrease operational performance of companies and also negatively impact their competitive advantage (Giunipero and Eltantawy, 2004). Operational buffer strategies in literature include safety stocks, multi sourcing and financial reserves.

**Safety stocks**

According to several authors, the most traditional way of creating buffers in order to shield negative impacts of disruptions is building up safety stocks (Ellegaard, 2008; Zsidisin, 2000; Tomlin, 2006). Inventories are required for most purchasing organizations to reduce the impact of any disruption on the
inbound side (Zsidisin, 2000). Chopra and Sodhi (2004) further suggest purchasing companies to enforce their impact reduction by having both excess inventories, and excess productive capacity.

**Multi sourcing**

Multi sourcing is another buffer strategy that is mentioned by various authors (Chopra and Sodhi 2004; Ellegaard, 2008; Tomlin, 2006) and it refers to sourcing an item from more than one producer. Zsidisin (2000) emphasizes the importance of developing multiple sources especially for strategic items. However, there is also a negative effect associated to multi-sourcing: When a firm switches from sole sourcing to multi sourcing a particular item, its supply chain complexity increases for that item, which, in turn, directly increases the coordination costs embedded in it. The reason for that is that more nodes and accompanying flows require greater effort for coordination. Managing one supplier is thus relatively lower in coordination costs than managing multiple suppliers for an item (Craighead et al., 2007).

**Financial reserves**

Ellegaard (2008) suggests that keeping financial reserves allocated for inbound disruptions may reduce the impact of a disruption.

**Mitigation plans**

Mitigation plans are strategies that are carried out before a risk materializes, in order to reduce the probability of the risk. Mitigation plans that are found in literature are supplier process improvement, supplier relationship development, contracting suppliers, early supplier involvement in product developments, local sourcing, incentive systems, demand forecasting, quality management and producing in-house.

**Supplier process improvement**

Attempts to develop and improve suppliers’ operational processes are mentioned by several sources as an important mitigation method (Choi and Hartley, 1996; Manuj and Mentzer, 2008). Krause (1999) mentions that process improvement strategies can greatly reduce the risks embedded with suppliers. Some Japanese companies implement individual supplier development by cross-exchanging staff between buyers and suppliers (Hallikas et al., 2004).

One downside of supplier process improvement mentioned in the literature is that in order to improve the processes of a supplier, the purchasing company is supposed to make partner specific investments in technology, processes and skills. This would render the purchasing company more dependent on that supplier, resulting in an asymmetry in the relationship. This kind of asymmetry is likely to cause a decrease in the negotiation power of the purchasing company, and might even facilitate opportunistic behaviour for the supplier (Hallikas et al., 2004).

**Increased coordination with supplier**

Many authors, including Ritchie and Brindley (2000), and Giunipero and Eltantawy (2004) argue that risk management strategies may involve supply chain partnerships such as increased coordination with suppliers. Activities like forming strategic alliances might serve to increase the communication level between the purchasing organization and its suppliers (Smeltzer and Siferd, 1998) and increasing supply chain visibility (Pettit, 2008). Initiatives aimed at increasing the communication level with and knowledge
about suppliers include real-time sharing of correct information (Blackhurst et al., 2005), sharing future demand forecast information immediately with suppliers to improve the planning process (Zsidisin, 2005), as well as frequent supplier visits and personal interaction with suppliers (Ellegaard, 2008).

Similarly, Craighead et al. (2007) bring up the concept of warning capability, which is defined as “the interactions and coordination of supply chain resources to detect a pending or realized disruption and to subsequently disseminate pertinent information about the disruption to relevant entities within the supply chain”. Carr (1997) states that purchasing should be used as a strategic weapon to create collaborative relationships for a firm’s advantage. Other authors have also highlighted some concepts related to strategic purchasing, including proactive, long-term and strategically managed supplier relationships (Reck and Long, 1988; Carter and Narasimhan, 1993; Carr, 1997). Another related concept is supply chain socialisation, which refers to the level of interaction and communication between supply chain actors, based on personal familiarity, improved communication, and problem solving. Socialisation mechanisms increase when each party acquires knowledge of the other enterprise’s social values and norms (Lawson et al., 2009).

Other methods of increasing communication level and visibility are establishing compatible IT-infrastructures, Radio Frequency Identification (RFID), e-mails, phone calls, etc. (Pettit, 2008).

**Contracts**

Contracting suppliers is another mitigation method mentioned in literature, as a supplier tends to prioritize contracted customers as compared to non-contracted ones due to mutually signed obligations. In that aspect, contracts are considered a behavior based technique for risk reduction (Ellegaard, 2008).

**Integrating risk mitigation plans with suppliers**

Zsidisin (2000) introduces integrating risk mitigation plans with suppliers as a crucial mitigation plan. There are two primary ways of implementing this strategy: First, the buying firm can form alliance relationships with its suppliers in order to work with the suppliers on mitigating risks. Second, the buying firm can hold the suppliers responsible for having developed risk mitigation plans.

**Local sourcing**

Local sourcing is considered as a strategy to reduce supply risks related to global sourcing and its implicit risks related to shipping mode and distance (Ellegaard , 2008).

**Incentive systems**

Designing and utilizing a system of incentives and rewards for suppliers is mentioned as a mitigation tool by various sources (Snow et al., 1992; Harland et al., 2002). This is especially made possible in joint ventures and strategic alliances, where a mutual benefit exists between opposite parties through joint ownership (Johnsen et al., 2004), as well as formal agreements such as profit sharing schemes and property rights sharing (Grandori and Soda, 1995).

**Accurate demand forecasting**

If communicated timely, accurate demand forecasting is a supply risk mitigation tool as it enables the right amount of order to be placed on the customer side, reducing the probability of a disruption on the inbound side of the buying firm (Sanchez-Rodrigues et al., 2010).
Quality management

Extensive quality management on raw materials is utilized for mitigating supply risks by reducing the number of product recalls from the supplier side (Sanchez-Rodrigues et al., 2010). Similarly, establishing industry standards with the suppliers (Zsidisin, 2000) and certifying suppliers (Larson and Kulchitsky, 1998) are used for reducing the probability of supply disruptions.

Early supplier involvement

Early supplier involvement is a useful tool for managing supply risks, especially in new product development phases. This strategy aims at reducing the likelihood of supply risk occurrence from issues such as design flaws, extended development times and cost overruns. The main motivation behind this strategy is that there is a higher degree of perceived risk for new product designs (Zsidisin, 2005). By involving the supplier into the process in the early phases of product development or improvement, the risk is partially shifted to the supplier through requirements of initial investments of time, money and other resources by the supplier (Eisenhardt, 1989; Shapira, 1995; Logan, 2000). Early supplier involvement also implicitly allows the buying firm to better monitor the supplier (Kannan and Tan, 2002; Baiman, Fischer and Rajan, 2000).

Producing in-house

It is suggested that on the basis of procurement related literature review, it can be concluded that strategic make or outsource decisions should include the strategic assessment of what is a firm’s core competency, as well as what is the risk associated with outsourcing. In-house production is an alternative to buying certain items from suppliers and can be used for eliminating supplier sourced risks (Hallikas et al., 2004).

Contingency plans

Contingency plans are defined as “plans and actions which provide alternative modes of operation for those activities or business processes which, if interrupted, might bring a damaging or loss to the supply chain” (Norrman and Jansson, 2004). According to (Zolkos, 2003) successful companies are those that can identify and develop contingency plans for the various sources of risk that exist internally and externally. However literature suggests that contingency plans are generally considered in context with catastrophic risks, rather than for managing minor impact risks (Colicchia et al., 2010). Contingency plans that are mentioned in literature are identifying alternative sources of supply, increasing flexibility, loss sharing with suppliers and contingent rerouting.

Alternative sources of supply

Even though a raw material is single sourced, it is important to identify potential suppliers as alternative sources of supply as most of the organizations do (Zsidisin, 2000), which can also be referred to as back-up sourcing (Chopra and Sodhi, 2004), or substitute sourcing (Craighead et al., 2007). In case problems arise with single source suppliers, namely the primary supplier is unable to deliver the necessary materials, the backup suppliers are utilized. However, when contingency suppliers are utilized, total procurement costs might substantially rise (Zsidisin, 2000).
Increased supply and production flexibility

Several authors consider flexibility as an impact reducing strategy once a disruption on the inbound side of a firm occurs (Ellegaard, 2008; Barnes, 2001). Giunipero and Eltantawy (2004) propose creation of a flexible supply base as a practice for managing risk. Flexible supply base refers to having the capability of utilizing different raw materials by changing the recipes of products. Similarly, (Sheffi and Rice, 2005) mention conversion flexibility as an impact reducing characteristic, which reflects the organisation’s ability to respond to a disruption in one of its own manufacturing facilities. For example, this could involve capability to shift production from one plant to another. A prerequisite for this is the use of standardised processes.

Several studies, including Fawcett et al. (1996), Goldsby and Stank (2000), Fredericks (2005), and Swafford et al. (2006) confirm that organizations associated with higher levels of flexibility are capable of responding to unexpected events such as disruptions in a more successful manner when compared to their non-flexible competitors. According to (Rice and Caniato, 2003), contingency planning means developing a plan to be prepared to respond to and restore operations after an unexpected disruption. Barnes (2001) also agrees that through the integration of such formalized procedures and resource information, organizations can recover from a disaster that causes a disruption to business operations.

Loss sharing with suppliers

Loss sharing practices which are usually secured by contracts are utilized for reducing the impact of disruptions in financial terms (Snow et al., 1992). Harland et al. (2001) also underline the importance of designing and using risk sharing practices with suppliers with formal agreements such as contracting (Grandori and Soda, 1995). For example, much of Toyota’s success in their Japanese supply networks was attributed to the long term contracts they formed with suppliers that provided commitment to sharing losses (Womack et al., 1990). In that context, contracts, which promote loss sharing, also reduce the probability of disruptions as explained in the Contracts sub-section.

Contingent rerouting

Several authors refer to contingent rerouting (also mentioned as restoration plans) as a strategy that should be readily available for a firm or its individual business units (Norrman and Jansson, 2004; Tomlin, 2006). If there is a major disruption on the inbound side of a purchasing company, the company might need to shift its business or start up the whole organization from scratch.

6.2. Perception of Risk Reduction Methods at SABIC in Europe

This section explains how and to what extent risk reduction methods are utilized as part of risk management practices and what the motivation behind them is. It further goes into detail about the advantages and downsides of the particular risk sources. These are evaluated as a result of the interviews and desk research at SABIC in Europe.

The table below provides the important points of the outcome of the empirical research. They are gathered under three columns: general remarks, advantages and downsides.
<table>
<thead>
<tr>
<th>Operational Buffers</th>
<th>Remarks</th>
<th>Advantages</th>
<th>Drawbacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety stocks</td>
<td>Safety stocks can either be kept on SABIC in Europe’s site or in producer’s/distributor’s inventory. When checking safety stocks on a SABIC plant, stocks at other plants should also be checked for internal raw material transfers. Making the supplier keep safety stocks can be fixed through contracts.</td>
<td>Reduces lead time in a great manner.</td>
<td>Increases costs, especially if safety stocks are kept on SABIC in Europe’s sites.</td>
</tr>
<tr>
<td>Multi-sourcing</td>
<td>This is the mostly used strategy to reduce risks related to supply disruptions. Time on dual sourcing depends on complexity of the item (type) and criticality of the raw material to quality.</td>
<td>Reduces supply risk associated with a single source.</td>
<td>Higher number of purchasing plants for an item adds complexity to 2nd sourcing that item.</td>
</tr>
<tr>
<td>Financial reserves</td>
<td></td>
<td>Buffer for sharp price increases on raw materials.</td>
<td>Does not reduce the risk related to supply disruptions.</td>
</tr>
<tr>
<td>Mitigation Plans</td>
<td>Remarks</td>
<td>Advantages</td>
<td>Drawbacks</td>
</tr>
<tr>
<td>------------------</td>
<td>---------</td>
<td>------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Supplier process improvement</td>
<td>Supplier process improvements can mostly be applied in strategic suppliers.</td>
<td>By improving a supplier’s processes, you can customize the supplier according to your needs and also develop stronger relationships. The supplier, on the other hand, grows thanks to you.</td>
<td>Process improvement investments costs money and other resources.</td>
</tr>
<tr>
<td>Increased coordination with supplier</td>
<td>Increased coordination can be in the form of sending orders in advance, sharing demand and consumption information on a frequent basis, utilizing more advanced order exception procedures and asking for safety stocks on their sides.</td>
<td>Strategic supplier relationships provide better surety and value than transactional relationships. Increased supply chain visibility on: You may get warning in advance before a supply disruption occurs.</td>
<td>Costs too much time and effort if you implement it with every supplier.</td>
</tr>
<tr>
<td>Contracts</td>
<td>-</td>
<td>Increases communication. If you don’t have a contract, you’re not considered a regular customer. Offers better pricing. Makes the supplier legally liable and offers warranty. Lead time can be fixed via contracts.</td>
<td>It costs time and effort. Contracts do not work for force majeure conditions. Some suppliers do not want contracts. They can be too expensive for small buy suppliers. If the market changes, you might be stuck with the contract.</td>
</tr>
<tr>
<td>Mitigation Plans</td>
<td>Remarks</td>
<td>Advantages</td>
<td>Drawbacks</td>
</tr>
<tr>
<td>------------------</td>
<td>---------</td>
<td>------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Integrating risk mitigation plans with supplier</td>
<td>This method is somewhat inclusive increased communication with the supplier. It is sometimes checked for operational disruptions (e.g. like safety issues) In some cases, SABIC discusses with the supplier to make it keep safety stocks or reduce lead time. In case of distributors, it is checked whether the distributor is multi sourcing the particular item. In addition, sometimes a supplier makes agreement with other suppliers to produce for him, in case he cannot fulfil customer demand.</td>
<td>Dive into the root of the problem. Especially helpful for the operational problems of the supplier.</td>
<td>The supplier might not always be open to it. Costs time and effort.</td>
</tr>
<tr>
<td>Local sourcing</td>
<td>Having local stocks is much more important than local sourcing. Embedded costs (e.g. transportation) should also be taken into account when taking the decision of local or off-shore sourcing.</td>
<td>Shorter lead times. Less risk associated with logistics disruptions and lead times.</td>
<td>Might be more costly as compared to low cost countries.</td>
</tr>
<tr>
<td>Incentive systems</td>
<td>Incentive systems might be useful for long term relationships in the sense of discounts depending on the quantity of raw material purchased.</td>
<td>-</td>
<td>Complicates transactions.</td>
</tr>
<tr>
<td>Mitigation Plans</td>
<td>Remarks</td>
<td>Advantages</td>
<td>Drawbacks</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
<td>-------------------------------------------------</td>
<td>----------------------------------------------------------------</td>
</tr>
<tr>
<td>Accurate demand forecasting</td>
<td>This method is considered as part of the increased coordination with suppliers. From the sales forecast, you can go back in the supply chain down to raw materials and send the forecast for raw material demand as accurately as possible.</td>
<td>Reduces lead time.</td>
<td>Accurate forecasting requires time and effort.</td>
</tr>
<tr>
<td>Quality management</td>
<td>Quality management is usually part of vendor management: vendors should be selected according to clear criteria (compliance with standards etc.)</td>
<td>Prevents last moment product recalls.</td>
<td>-</td>
</tr>
<tr>
<td>Early supplier involvement</td>
<td>-</td>
<td>Provides information on which types of raw materials SABIC in Europe should consider (for new products), as well as information on market, competitors and novel technologies.</td>
<td>By early involvement, you promise the suppliers a certain profit/sales figure for the raw material. If your production is not as expected (due to low demand), then you have a problem.</td>
</tr>
<tr>
<td>Producing in-house</td>
<td>Producing in-house can also be in the form of joint ventures or acquisitions.</td>
<td>Allows to manage your supply yourself, thus risk is eliminated.</td>
<td>This is not really related to surety of supply; however, it is important for innovation. If you don’t have the production system in place, it requires major investments and is thus very costly. Capacity allocation problems within your own production.</td>
</tr>
<tr>
<td>Contingency Plans</td>
<td>Remarks</td>
<td>Advantages</td>
<td>Drawbacks</td>
</tr>
<tr>
<td>--------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Alternative sources of supply</td>
<td></td>
<td>It would be very useful in the sense of skipping the first step in vendor qualification: the searching part.</td>
<td></td>
</tr>
<tr>
<td>Increased supply and production flexibility (Standardization)</td>
<td>In addition to determining alternative raw materials beforehand as a back-up, standardization is done in the form of moving to more standardized raw materials. In that case, it is considered a mitigation plan rather than a contingency plan.</td>
<td>Approaching standard raw materials and procedures, which are more easily available in the market.</td>
<td>Not always possible depending on the nature of the item.</td>
</tr>
<tr>
<td>Loss sharing with suppliers</td>
<td>In some cases, a supplier can be held liable through contracts for the costs incurred (e.g. production stoppages).</td>
<td>Motivates the supplier to prevent disruptions.</td>
<td>Can be too complicated; therefore not favorable for the supplier.</td>
</tr>
<tr>
<td>Contingent rerouting</td>
<td></td>
<td></td>
<td>This method is meant for the whole business; it does not really concern procurement. It’s out of scope for this research.</td>
</tr>
</tbody>
</table>

Additional

<table>
<thead>
<tr>
<th>Remarks</th>
<th>Advantages</th>
<th>Drawbacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changing transportation mode</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In urgent cases, it is wise to consider changing the transportation mode; for example to airplane. The decision usually depends on the customer linked to the raw material. This method is considered a contingency plan.</td>
<td>Reduces lead time.</td>
<td>Increases transportation costs.</td>
</tr>
<tr>
<td>Simplification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>It favorable to divert poor business of end-products with single sourced raw materials into profitable business with limited or inexistent number of supply risks. This is done as a risk mitigation or elimination method.</td>
<td>Reduces the business impact linked to a raw material.</td>
<td>Concerns products rather than raw materials. Therefore, the decision needs to be taken with the business.</td>
</tr>
</tbody>
</table>
6.3. Selection of Suitable Risk Reduction Methods

As a result of this assessment, the risk reduction methods in the following table have been determined to be primarily suitable for SABIC in Europe. These methods have been chosen based on their effectiveness (in terms of advantages and downsides) and their applicability (as some methods turned out to be incompatible with/unfavorable for SABIC in Europe’s strategy). They will be actively considered when creating the action lists for the critical raw materials. However, it should be noted that the risk reduction methods, which have been excluded from the list below, can also be alternatively considered according to the specifics of the situation at hand. The table below also indicates the responsible departments for the actions.

<table>
<thead>
<tr>
<th>Risk Reduction Methods</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi sourcing</td>
<td>Operational buffer</td>
</tr>
<tr>
<td>Alternative sources of supply</td>
<td>Contingency plan</td>
</tr>
<tr>
<td>Safety stocks</td>
<td>Operational buffer</td>
</tr>
<tr>
<td>Accurate demand forecasting</td>
<td>Mitigation plan</td>
</tr>
<tr>
<td>Increased coordination with supplier</td>
<td>Mitigation plan</td>
</tr>
<tr>
<td>Contracting</td>
<td>Mitigation plan</td>
</tr>
<tr>
<td>Standardization</td>
<td>Contingency/Mitigation plan</td>
</tr>
<tr>
<td>Simplification</td>
<td>Mitigation plan</td>
</tr>
</tbody>
</table>

6.4. Summary

This chapter aimed to identify the methods that can be used to reduce the risks which have been identified in Chapter 6. The analysis has been based on literature review, as well as desk research and interviews at SABIC in Europe.

In literature, 17 risk reduction methods have been identified, which have been classified into three categories: operational buffers, mitigation plans and contingency plans. These risk reduction methods
have been assessed with respect to their advantages, disadvantages and other particular features. Two methods, which were not identified in the literature review, have been added to the list.

The analysis on these risk sources resulted in the selection of the following risk reduction methods, as they are found to be more suitable in terms effectiveness and applicability:

- Multi sourcing
- Alternative sources of supply
- Safety stocks
- Accurate demand forecasting
- Increased coordination with supplier
- Contracting
- Standardization
- Simplification
7. Integration of Outcomes: the Business Continuity Plan and its Application

This chapter is aimed at integrating the outcomes of the previous three chapters in order to build the framework for applying the business continuity plan for the raw materials of SABIC in Europe. While the framework is explained, the generic and SABIC-specific parts will be distinguished. This framework will then be applied to the supply base of SABIC in Europe. Due to size limitations and confidentiality issues, application will be illustrated for five raw materials.

7.1. Business Continuity Plan Framework

This section builds the framework for the complete business continuity plan by integrating the outcomes of Chapters 4, 5 and 6. It aims to give the complete overview of the process. The framework consists of three main steps and follows the same sequence as these three chapters: first, prioritization of critical raw materials; then, risk profile generation for prioritized raw materials; last, preparation of action lists for prioritized raw materials, as given in the figure below. At the end of every step, its applicability to other companies will be discussed.

Prioritization of critical raw materials

The first step of the business continuity plan is to identify the critical raw materials for the business of SABIC in Europe, in order to prioritize them for the BCP. The main motivation behind this step is to allocate limited resources and time wisely, such that the surety level of supply for critical raw materials is increased. For that purpose, the following data are gathered for the whole supply base of SABIC in Europe.

- Impacted sales and impacted volume by the raw material
- Producers and distributors of the raw material
- Active suppliers of the raw material
- Number of grades linked to the raw material
- Plants that purchase the raw material
- Purchased volume and spend of the raw material
- Other remarks

The critical raw materials among the entire supply base of SABIC in Europe are identified according to the following decision chart, as exhibited in Chapter 4:
The criticality of these raw materials is validated by category managers and these raw materials are prioritized for further analysis for the business continuity plan.

Companies, which have a similar size and complexity of supply base, might also have the necessity to identify their critical raw materials. For that purpose, they can use a similar procedure (same criticality criteria); however, the sales impact limit for critical raw materials (in SABIC in Europe’s case: € 10M) will have to be varied according to supply-product links and production sales.

**Risk profile generation for prioritized raw materials**

The prioritized raw materials need to be further analyzed with respect to their high impact risk sources. This is required in order to see where the risks of individual items are existent and how severe the risks are. It is conducted by filling in the following risk profile table:
After this table is filled in, the risk exposure rates are calculated by the multiplication of scale factors by the weights; and the total risk exposure percentage is calculated by the addition of the individual risk exposure rates. Again, the weights are not revealed due to confidentiality.

The long term target set for all the prioritized items is to reduce the risk exposure level to 40%. This level has been determined considering the limited time and resources that can be dedicated to the BCP. Risk exposures below 40% are thus tolerated. As a result, the following labelling for risk exposure level is introduced.

Only in case an item is single sourced and there are no alternative suppliers in the market due to market constraints, the target is set to 60%.

Value at risk is an indication of urgency that the raw material should be treated with. It is calculated in the following way:

\[ Value \text{ at Risk} = Risk \text{ Exposure Rating} \times Business \text{ Impact} \]

The general procedure for risk profile generation can be utilized by other companies; however, some details need to be thought through in advance. The selection of high impact risk sources, which constitute the risk profiles, is not only based on literature, but it is also based on risk assessment at
SABIC in Europe. Therefore, different companies can perceive different risk source as high impact risks. The risk metrics are strived to be easy to measure and straightforward, therefore they are generic in nature. The weights attached to risk sources, as well as the 40% risk toleration limit are also based on the risk assessment at SABIC in Europe, that's why they also need to be re-evaluated before implementation. The calculation of value at risk, on the other hand, is not company-specific.

**Preparation of action lists for prioritized raw materials**

The utilization of risk reduction methods is quite case-dependent. Therefore, a one-to-one mapping of risk sources and risk reduction methods is not feasible. The risk reduction methods that should primarily be considered are given in the table below. The departments that should be involved in these actions are provided in the second column.

The utilization of risk reduction methods is quite case-dependent. Therefore, a one-to-one mapping of risk sources and risk reduction methods is not feasible. The risk reduction methods that should primarily be considered are given below.

- Multi sourcing
- Alternative sources of supply
- Safety stocks
- Accurate demand forecasting
- Increased coordination with supplier
- Contracting
- Standardization
- Simplification

For every item, an action list consisting of risk reduction methods is prepared. According to the outcome of the actions, the secured business value is calculated. If the pre-set target is reached with regard to the risk exposure percentage, the business continuity plan is successfully completed. In case it is not reached, a re-evaluation is made in terms of risk exposure and risk reduction methods.

The value at risk initiates the calculation of secured business value, which is a KPI for tracking how much business has been secured through an action or in a certain period of time:

\[
KPI: \text{Secured Business Value} = \Delta \text{Risk Exposure Rating} \times \text{Business Impact}
\]

This KPI is meant for obtaining a relative indication on the size of business secured and does not give an absolute measure on the money secured through the action.

The selection of suitable risk reduction methods is based on both literature and empirical research at SABIC in Europe. Therefore, they need to be evaluated again before being used by other companies: Some risk reduction methods might be more favourable or prove more useful as compared to SABIC in Europe, or vice versa. However, the outcome of this step can build the basis for other companies’
evaluations. Once the suitable action list is implemented for an item, the calculation of the KPI, namely the secured business value, is not company specific.

### 7.2. Illustration of the BCP via Examples

The framework explained in the previous section is applied to the entire supply base of SABIC in Europe. This section illustrates this business continuity plan via examples. This will be conducted on an example basis, where several prioritized raw materials will be presented with their unique characteristics. These raw materials will further be analyzed with respect to their supplier vulnerability areas and mitigation methods will be developed for these raw materials with regard to the risk reduction methods. Due to confidentiality reasons, the raw material names and types will not be revealed when explaining the examples. Some further details on the raw materials are also not disclosed and the numbers are rounded for the same reason.

**Example I**

This raw material is considered critical to SABIC in Europe’s business according to the criticality analysis as it is single sourced and has a sales impact of € 132.738.700. Below, some further information that has been collected during the criticality analysis is presented.

<table>
<thead>
<tr>
<th>Table 7-3: Example I - Criticality Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single sourced status</strong></td>
</tr>
<tr>
<td><strong>Impacted sales € (2010)</strong></td>
</tr>
<tr>
<td><strong>Number of grades using the item</strong></td>
</tr>
<tr>
<td><strong>Number of purchasing plants</strong></td>
</tr>
<tr>
<td><strong>Spend € (2010)</strong></td>
</tr>
</tbody>
</table>

There is only one plant purchasing this raw material; this implies that in case of a multi sourcing action, only one plant needs to qualify the item for a second producer, which would cost relatively less effort and time. The raw material goes into 10 grades which are produced in high volumes. Therefore, the sales impact of the item is quite high as well.

In order to figure out, what kind of inbound risks are associated with this raw material and how they can be reduced, the high impact supplier vulnerability areas will be investigated. The following table exhibits the results of the analysis:
This investigation revealed that a dual sourcing process has been continuing: Technology & Innovation Department has been working on a co-spec with another producer. Until the dual sourcing process is completed, SABIC in Europe will rely on the fact that the current producer is contracted and has multiple sites to produce the particular item. As the risk exposure rating is below 40%, resources and efforts on reducing the risk further will be saved and they will be allocated to other items.

If the dual sourcing is completed successfully, the risk exposure rating will further reduce to 10%, resulting in a secured business value of:

\[
\text{Secured Business Value} = 25\% \times €132,738,700 = €33,184,675
\]

**Example II**

This raw material has been prioritized for BCP as it has a sales impact of €26,662,300 and is single sourced. The following data have been collected for this item during the criticality analysis:
Table 7-5: Example II - Criticality Analysis

<table>
<thead>
<tr>
<th>Single sourced status</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impacted sales € (2010)</td>
<td>26,662,300</td>
</tr>
<tr>
<td>Number of grades using the item</td>
<td>6</td>
</tr>
<tr>
<td>Number of purchasing plants</td>
<td>3</td>
</tr>
<tr>
<td>Spend € (2010)</td>
<td>3,350,000</td>
</tr>
</tbody>
</table>

The number of grades linked to this item are relatively low; however, those grades are produced in large volume and therefore the sales impact of the item turns out to be above the €10,000,000 limit.

This item is purchased through a distributor and there is only one producer in the market which supplies the item; so there is no alternative producer available in the market. The item is purchased from Asia.

The high impact supplier vulnerability areas analysis results in the following table:

Table 7-6: Example II - High Impact Vulnerability Areas Analysis

<table>
<thead>
<tr>
<th>Risk Source</th>
<th>Risk Metric</th>
<th>Scale</th>
<th>Weight</th>
<th>Risk Exposure Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low number of qualified suppliers/Market constraints</td>
<td>Single sourced?/Only producer in the market?</td>
<td>Multi sourced</td>
<td>0</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2nd source in process</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Single sourced</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Single sourced &amp; no alternative in the market</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Financial instability of the supplier</td>
<td>D&amp;B rating (e.g., Financial stress score)</td>
<td>1-3</td>
<td>0</td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4-5</td>
<td>1</td>
<td>0%</td>
</tr>
<tr>
<td>Supplier under no legal liability</td>
<td>Contract</td>
<td>Yes</td>
<td>0</td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Draft/in process</td>
<td>0.5</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Capacity/Flexibility Constraints</td>
<td>Single production plant for the item?</td>
<td>Multiple Plants</td>
<td>0</td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Single plant</td>
<td>1</td>
<td>10%</td>
</tr>
<tr>
<td>High lead time</td>
<td>Lead time</td>
<td>LT &lt; 1 week</td>
<td>0</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 week &lt; LT &lt; 4 weeks</td>
<td>0.5</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LT &gt; 4 weeks</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Total Risk Exposure</td>
<td></td>
<td></td>
<td></td>
<td>80%</td>
</tr>
<tr>
<td>Business Impact</td>
<td></td>
<td></td>
<td></td>
<td>€26,662,300</td>
</tr>
<tr>
<td>Value at Risk</td>
<td></td>
<td></td>
<td></td>
<td>€21,329,840</td>
</tr>
</tbody>
</table>

As seen in the table above, the risk exposure percentage turns out to be 80%, and the value at risk is calculated as €21,329,840. The risk exposure percentage is at “high” level according to the scale introduced in Chapter 5. At this point, it is important to note that the main driver behind the risk exposure rating is the fact that the item is single sourced and the producer is a monopole in the market. Therefore, the target is to reduce the risk exposure rating to 60%.
This action will secure a business value of:

\[
\text{Secured Business Value} = 20\% \times €26,662,300 = €5,332,460
\]

In order to reduce the risk from 80% to 60%, to risk reduction methods are evaluated. As an alternative producer is not available in the market, multi sourcing is not an option. Keeping this remark in mind, it is also highly challenging to manipulate the number of plants producing the item. Therefore, the right risk source to attack is the lead time of the raw material. For that purpose, the following actions are planned to be undertaken.

- **Increasing safety stock levels**: This risk reduction method will both shorten the lead time, and it will act as a buffer in case of disruptions to reduce the impact of the unavailability of the raw material. At this point, it is important to decide whether safety stocks should be kept on the supplier’s side or on SABIC in Europe’s side. The decision criterion here is the purchased volume of the raw material. Low volume supplies are more feasible for being kept in SABIC in Europe’s inventory. However, as the volume of this item is relatively high, supplier inventories should be preferred.

- **Sending accurate forecasts**: Accurate forecasts should be shared with the supplier in advance in order to reduce the lead time of the raw material.

- **Contract modification**: The existing contract with the supplier should be modified to include the updated lead time.

- **Increased coordination with the supplier**: This is required to increase the warning capability of SABIC in Europe with regard to possible disruptions of the raw material.

**Example III**

This raw material has been prioritized for BCP as it has a sales impact of €66,188,700 and is single sourced. Some details on the item are displayed below:
Table 7-7: Example III - Criticality Analysis

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Single sourced status</td>
<td>Yes</td>
</tr>
<tr>
<td>Impacted sales € (2010)</td>
<td>66.188.700</td>
</tr>
<tr>
<td>Number of grades using the item</td>
<td>239</td>
</tr>
<tr>
<td>Number of purchasing plants</td>
<td>4</td>
</tr>
<tr>
<td>Spend € (2010)</td>
<td>19.000</td>
</tr>
</tbody>
</table>

The number of grades linked to this item and the number of plants purchasing the raw material are relatively high. The raw material thus has a relatively complex supply chain and its disruption would cause severe communication issues.

This item is purchased through a distributor based in Europe, and there is only one producer behind.

The outcome of the high impact supplier vulnerability areas analysis is as follows:

Table 7-8: Example III - High Impact Vulnerability Areas Analysis

<table>
<thead>
<tr>
<th>Risk Source</th>
<th>Risk Metric</th>
<th>Scale</th>
<th>Weight</th>
<th>Risk Exposure Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low number of qualified suppliers/Market constraints</td>
<td>Single sourced?/Only producer in the market?</td>
<td>Multi sourced</td>
<td>0.0</td>
<td>37.5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2nd source in process</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Single sourced &amp; no alternative in the market</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td>Financial instability of the supplier</td>
<td>D&amp;B rating (e.g. Financial stress score)</td>
<td>1-3</td>
<td>0</td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4-5</td>
<td>1</td>
<td>0%</td>
</tr>
<tr>
<td>Supplier under no legal liability</td>
<td>Contract</td>
<td>Yes</td>
<td>0</td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Draft/in process</td>
<td>0.5</td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No</td>
<td>1</td>
<td>10%</td>
</tr>
<tr>
<td>Capacity/Flexibility Constraints</td>
<td>Single production plant for the item?</td>
<td>Multiple Plants</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Single plant</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>High lead time</td>
<td>Lead time</td>
<td>LT &lt; 1 week</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 week &lt; LT &lt; 4 weeks</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>LT &gt; 4 weeks</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Total Risk Exposure</td>
<td></td>
<td>67.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business Impact</td>
<td></td>
<td>€ 66.188.700</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value at Risk</td>
<td></td>
<td>€ 44.677.400</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

There is no effort on dual sourcing yet, but the raw material is in queue for evaluation. The distributor is not contracted and there is one plant where the item is produced. The total risk exposure is 67.5% and the resulting value at risk is €44.677.400. As multi sourcing might take a relatively long time, the initial step will be to reduce the risk exposure associated with legal liability to 0% and subsequently work on dual sourcing. These actions will reduce the risk exposure rating to 20%. The figure below shows the current and target risk exposure ratings.
This action will secure a business value of:

\[
\text{Secured Business Value} = 47.5\% \times €66,188,700 = €31,439,600
\]

The actions for reducing the inbound risks are detailed below.

- **Ensuring safety stocks**: Until the multi sourcing process is successfully completed, it is important to make sure that the availability of supply is secured. For that purpose, the safety stock levels need to be revised to provide a solid buffer for a potential disruption. As the volume of the raw material is relatively low, it is favourable to keep the safety stocks on SABIC in Europe’s sites; this would grant SABIC in Europe more control over the inbound supply chain and in return the inventory costs would be on a reasonable level. In case of a disruption for a particular plant, it is also important to check safety stocks in other plants.

- **Contracting**: As mentioned above, there is no contract with the current supplier, which is mainly due to the relatively low spend on the item. In order to reduce the possibility of a disruption with SABIC in Europe, contracting the supplier is essential and thus should be forced. This might require a better relationship basis with the supplier. Contracting will also cover part of the risk exposure in a quick way, until the multi sourcing option is evaluated and the process is successfully completed.

- **Multi sourcing**: As there is no monopoly condition regarding the particular raw material, multi sourcing is the most effective way of reducing the risk exposure in a great manner. For that purpose, the search and qualification process of an alternative supplier will be prioritized and accelerated. Hereby it should be noted that qualifying the item for four purchasing plants might require relatively more time and effort.

**Example IV**

This raw material has been prioritized for BCP as it has a sales impact of €1,332,600,000 and is single sourced. The following data have been collected for this raw material during the criticality analysis phase:
It is important to note that this raw material is a particularly expensive one and has a very high business impact.

The high impact supplier vulnerability areas analysis for this raw material has the following outcome:

The risk at value for this item is among the highest ones. For this raw material, there is no particular effort on dual sourcing yet; however, there are two alternative suppliers identified. These suppliers do not provide the same raw material; however, their items (which also differ from each other) can be used for the same purpose as the original one. One of the suppliers is SABIC, whereas the other one is an external party. The current supplier is contracted and the item is purchased from outside Europe.

Looking at the complete picture, the risk source that should be tackled with high priority is the low number of qualified suppliers. This will alter the risk exposure percentage in the following manner:
The secured business through this action is calculated as follows:

\[
\text{Secured Business Value} = 37.5\% \times €1.332.600.000 = €499.725.000
\]

The actions for this item will be built around the qualification of the alternative item provided by SABIC.

- **Qualifying the SABIC item:** This action is not a regular multi sourcing process, as an alternative item is involved in the qualification process. In this aspect, this action somehow includes standardization as well. Qualifying the SABIC item should be the first step to be taken as it also enables in-house production, which reduces the inbound risk in a great manner. If the SABIC item is indeed qualified, it may remain as an alternative supply which replaces the current item in case of disruptions or capacity problems. This one step approach is straightforward and effective. On the other hand, if the SABIC item fails the qualification process, the raw material sourced from the external supplier should be tested.

### 7.3. Summary

This chapter presented the complete framework for the business continuity plan, which includes the following steps:

The criticality analysis is applied to the supply base of SABIC in Europe, in order to prioritize critical raw materials for the business continuity plan. Next, high impact vulnerability areas of these raw materials are investigated in order to generate a risk profile. Last, an action list consisting of suitable risk reduction methods is prepared per prioritized items for managing their supply risks. The framework is illustrated via five examples which reveal different aspects of the business continuity plan.
8. Conclusions and Recommendations for Future Research

This final chapter draws conclusions about the research with respect to the research questions as stated in Chapter 1. It further looks into the limitations of the research and draws avenues for future research.

8.1. Conclusions

This research has served to answer one main research question and four sub-research questions, all of which will be given in summary throughout the course of this section. The first sub-question was:

*RQ1: What is the motivation for SABIC in Europe to have a business continuity plan for its raw materials?*

Both by SABIC in Europe and by other companies, it has been experienced that supply disruptions may lead to severe costs for purchasing companies by causing stock-outs of raw materials and thus inability of the purchasing firm to meet customer demand. Major disruptions may even threaten the very survival of a business.

In today’s competitive market, SABIC in Europe strives for efficiency and quality, which heavily relies on the timely availability of raw materials for production activities. Historically, the company has noted disruptions in its procurement operations due to various reasons including individual supplier failures, bottlenecks in the market, and force majeure conditions. Therefore, a business continuity plan is needed. This business continuity plan will enable SABIC in Europe to be proactive rather than reactive to major problems that might arise in the inbound supply chain.

This project is of great importance for SABIC as it will identify the critical raw materials for SABIC in Europe, and provide the company with an overall view on where the potential risk sources pose a greater threat and how they can be mitigated. The documents and procedures produced by this research are planned to be re-used with updated data on an annual basis within the company.

The second research question was:

*RQ2: How can a sub-group of raw materials from the supply base of SABIC in Europe be prioritized for the business continuity plan according to criticality for business?*

The main two criteria for judging the criticality of a raw material are chosen to be its sales impact and its number of suppliers. Taking into consideration the limited time and resources that can be put into the business continuity plan, items with

- sales impact > €10M & single sourced, or
- sales impact > €100M,

are prioritized for the business continuity plan.

Additional interpretation on the criticality of items is enabled by gathering data on:

- grade count linked to the raw material
- number of purchasing sites
- number of active suppliers
- other remarks

It is essential to note that the spend of a raw material has not been chosen as a criticality criterion.

The third sub-question was:

**RQ3: What are the supplier-related risk sources of high impact nature addressed by the prioritized raw materials?**

In total, 22 vulnerability areas have been identified, which have been organized into four categories: business related vulnerability areas, operational vulnerability areas, external supplier vulnerability areas, and market vulnerability areas. As a result of the probability-impact assessment, the following risk sources have been determined to have a high impact, and have therefore been subject to the rest of the research:

1. Poor financial health of the supplier (business related)
2. Flexibility constraints (operational)
3. Market constraints (market)
4. Low number of qualified suppliers (market)
5. High lead time (operational)
6. Supplier under no legal liability (business related)
7. Geographical density of suppliers (market)

These vulnerability areas are measured according to the following scales for the calculation of the risk exposure rating per item:

<table>
<thead>
<tr>
<th>Risk Source</th>
<th>Risk Metric</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low number of qualified suppliers</td>
<td>Single sourced? (In case of distributor, single producer behind?)</td>
<td>Multi sourced 0</td>
</tr>
<tr>
<td></td>
<td>2nd source in process</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Single sourced</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>Single sourced &amp; no alternative in the market</td>
<td>1</td>
</tr>
<tr>
<td>Financial instability of the supplier</td>
<td>D&amp;B rating (Financial stress score)</td>
<td>1-3 0</td>
</tr>
<tr>
<td></td>
<td>4-5</td>
<td>1</td>
</tr>
<tr>
<td>Supplier under no legal liability</td>
<td>Contract</td>
<td>Yes 0</td>
</tr>
<tr>
<td></td>
<td>Draft/in process</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>Capacity/Flexibility Constraints</td>
<td>Single production plant for the item?</td>
<td>Multiple Plants 0</td>
</tr>
<tr>
<td></td>
<td>Single plant</td>
<td>1</td>
</tr>
<tr>
<td>High lead time</td>
<td>Lead time</td>
<td>LT &lt; 1 week 0</td>
</tr>
<tr>
<td></td>
<td>1 week &lt; LT &lt; 4 weeks</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>LT &gt; 4 weeks</td>
<td>1</td>
</tr>
</tbody>
</table>
Every prioritized raw material is given a label according to its risk exposure percentage: low, medium or high. Moreover, a KPI has been developed to quantify and track the improvement that is achieved when a risk is reduced, which calculated in the following way:

\[
KPI: \text{Secured Business Value} = \Delta \text{Risk Exposure Rating} \times \text{Business Impact}
\]

The main target is to reduce the risk exposure rating to a minimum of 40% for every critical item.

The fourth research question was:

**Q4: What are the risk reduction methods that can be used for the business continuity plan of the critical raw materials?**

In total, 19 risk reduction methods have been identified, which have been classified into three categories: operational buffers, mitigation plans and contingency plans. These risk reduction methods have been assessed with respect to their advantages, disadvantages and other particular features. The analysis on these risk sources resulted in the selection of the following risk reduction methods, as they are found to be more suitable in terms effectiveness and applicability within SABIC in Europe:

- Multi sourcing (operational buffer)
- Alternative sources of supply (contingency plan)
- Safety stocks (operational buffer)
- Accurate demand forecasting (mitigation plan)
- Increased coordination with supplier (mitigation plan)
- Contracting (mitigation plan)
- Standardization (contingency/mitigation plan)
- Simplification (mitigation plan)

The main research question was:

**MRQ: How can a business continuity plan be applied to SABIC in Europe’s supply base in order to increase the surety level of supply for critical raw materials?**

The business continuity plan can be applied by following the three step approach as given below:

- Prioritization of critical raw materials
- Risk profile generation for prioritized raw materials (risk identification and assessment)
- Preparation of action lists for prioritized raw materials (risk treatment)

**8.2. Limitations of the Research**

As with every other research, this research has also some limitations which should be carefully studied in order to understand the boundaries of the report. The disclosure of limitations will also help the reader to generate recommendations for further research.

As mentioned in Section 2.3, the main limitation of this research is that its research strategy is a single case study at the European Procurement department of SABIC in Europe. On one hand, this is a given
fact considering the problem statement; this research has been conducted bring a solution to a problem raised by SABIC in Europe. On the other hand, it somewhat hampers the internal validity of the research in terms of lack of differential sampling; but more importantly, it greatly limits its external validity. At this point, the question is: How generalizable is the outcome of this research? The research has been conducted on SABIC in Europe’s specifics; however, the main outcome (the business continuity plan framework) can be adapted in a way to allow other firms to use it, provided that they have a similar supply base in terms of size, complexity, being global, etc. The framework’s design also allows flexibility on a case basis; but some parts of the business continuity plan might as well not fit other companies. For instance, other companies might disagree with the weights attached to high impact risk sources when calculating the risk exposure rate, as they experience other types of disruptions more often. Another example is the limits set to prioritization of critical raw materials; this research defines criticality as having a sales impact greater than €10M and being single sourced, whereas this figure can be very high for a smaller business. These kinds of variables/issues should be thought thoroughly before implementing the BCP to another company.

The internal validity is further limited due to the fact that the empirical research has mainly been conducted in the Procurement department, whereas other departments’ view on the issue has been neglected in most cases. The business continuity plan primarily concerns the Procurement department as it brings a risk management approach from the aspect of Strategic Procurement. However, especially the risk reduction methods require the involvement of other departments, which might also have contributed to the process of developing the framework for the BCP.

Confidentiality is another issue that introduces limitations to the research in two ways: First, the interviewees might have given deficient or misleading information under the pressure of being quoted for confidentiality issues. Second, some parts of the outcome have not been revealed in the report due to confidentiality issues; although they have been documented during the research.

As to the content of the report, it covers a very broad topic in terms of analyzing all supplier risk sources (with a secondary filtering on high impact ones) and all risk reduction methods. This broad coverage of topics, however, compromises the depth of analysis. The analysis on risk sources takes into account the interrelationship between the individual risk sources only to a limited extent. There is also a lack of quantitative analysis on how the probability or impact of a risk event would change if a related variable would be changed (e.g. how would the risk change in case the number of suppliers is increased from 2 to 3 for a raw material). This limitation is partly due to limited time of the research, and partly for the sake of simplicity, because this BCP will be used repeatedly and possibly also in other regions.

Another limitation of the research is the lack of a quantitative data collection method such as a questionnaire. The availability of such a data collection method backing up the interviews would enable a more rigor analysis, especially for the probability-impact assessment of risk sources. However, this would require expanding the scope of data collection outside of the company.

There have also been two main practical limitations on the research. First, raw materials which are considered direct raw materials, but which do not show up in recipes (such as cleaning agents), have not been included into the scope of the research. This is mainly due to practical reasons and time limitations. Second, maintaining the whole procedure on an annual basis is challenging as the consolidation of data
for the entire supply base (for the criticality analysis) is quite time-consuming and requires manual work as well. This limitation can be overcome by introducing a fixed IT business partner for the consolidation of data.

8.3. Recommendations for Future Research

This section will make the closure of the report by identifying ways for improvement on the research limitations, as well as by pointing out to opportunities for future research.

This research is conducted as a single case study. The implementation of this research through multi case studies in different companies covering other industries would reveal their differences with respect to their approaches toward supply risk management and BCP in general. Including other departments linked to supply chain management more intensively into the data collection process, such as supply chain planning, sales and operational procurement, would make the research more interesting in terms of including their perspective as well.

In order to make the probability-impact analysis more reliable, a quantitative data collection method can be included in future research. This can be done by sending out questionnaires to employees of other companies. The research can further adopt a more in-depth approach for risk sources by implementing a more quantitative analysis method for this section. For instance, individual risk sources can be analyzed by including theories like reliability theory into the research. The risk reduction methods can also be researched in a more quantitative way by calculating their associated costs and benchmarking them against the secured business value for every action taken.

Future researchers might also consider integrating several concepts into the research approach, which are considered “hot topics” in the supply chain management world. The impact of risk reduction methods on supply chain adaptability and agility, novel inventory management approaches vs. safety stocks, and outsourcing trends in developing countries are among the topics that can be integrated into future research.
References


Appendix A. Interview Questions

Criticality criteria at SABIC in Europe
- How would you define “criticality” for a raw material?
- Do you have methodologies in place to label raw materials according to their criticality?
- What kind of criteria do you use/suggest to prioritize raw materials according to their criticality?

Validation of results for high criticality items
- Can you confirm that these items single sourced? (Yes/No)
- Do you agree on the criticality of these raw materials? (Yes/No, Why?)
- Have you already been discussing with Technology on the status of these raw materials? What is the latest update?

Supplier risk assessment at SABIC in Europe
- What is the motivation behind the score on the impact and probability of the individual risk sources?
- Are there any additional risk sources that are not in the register, or risk sources that you don't agree with?
- Are there any specific comments on particular risk sources?
- If any, are there certain methods/parameters to track these risks?

Perception of risk reduction methods at SABIC in Europe
- What are the advantages of the particular risk reduction method?
- What are the downsides of the particular risk reduction method?
- Is this risk reduction method used in SABIC Europe? Why/why not?
- Are there any special/additional remarks on the particular risk reduction method?
- Is there any risk reduction method that you would like to add?
Appendix B. Risk Register

The risk register below contains supplier-related risk sources, which might cause a disruption on the inbound side of the company. Please kindly fill in the probability (how often does/would the risk event happen?) and impact (how severe is/would the supply disruption be?) columns for the risk events on a scale from 0 to 5, based on your own perception and experience at SABIC in Europe.

<table>
<thead>
<tr>
<th>Rating</th>
<th>Probability</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Not perceived as a risk</td>
<td>Not perceived as a risk</td>
</tr>
<tr>
<td>1</td>
<td>Less than every three years</td>
<td>No considerable impact</td>
</tr>
<tr>
<td>2</td>
<td>Every three years</td>
<td>Procurement activities lightly affected</td>
</tr>
<tr>
<td>3</td>
<td>Every year</td>
<td>Procurement activities heavily affected</td>
</tr>
<tr>
<td>4</td>
<td>Every quarter</td>
<td>Production activities directly affected/minor delays of customer orders</td>
</tr>
<tr>
<td>5</td>
<td>Every month</td>
<td>Customer heavily affected</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Risk category</th>
<th>Risk source</th>
<th>Risk event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business</td>
<td>Poor financial health</td>
<td>The supplier bankrupts or stops production due to financial issues.</td>
</tr>
<tr>
<td>Business</td>
<td>Poor management vision</td>
<td>The supplier is unable to foresee market changes (e.g. increase in demand for a product) and thus fails to adjust its capacity accordingly.</td>
</tr>
<tr>
<td>Business</td>
<td>High price variability</td>
<td>The supplier introduces a sudden increase in the price of a raw material.</td>
</tr>
<tr>
<td>Business</td>
<td>Supplier obligations to other customers</td>
<td>The supplier fails to supply a product because it is contracted by a competitor and thus chooses to allocate most of its production capacity for the competitor.</td>
</tr>
<tr>
<td>Operational</td>
<td>Capacity constraints</td>
<td>The supplier is unable to increase production level due to limited capacity, consequential to the demand increase of a product.</td>
</tr>
<tr>
<td>Risk category</td>
<td>Risk source</td>
<td>Risk event</td>
</tr>
<tr>
<td>-----------------------</td>
<td>------------------------------</td>
<td>----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Operational</td>
<td>Flexibility constraints</td>
<td>The supplier is unable to shift production of a product to another site/plant/production line, when there is a problem with the current production line or there is a sudden increase in demand for that supply.</td>
</tr>
<tr>
<td>Operational</td>
<td>Quality problems</td>
<td>The raw materials are recalled due to quality problems.</td>
</tr>
<tr>
<td>Operational</td>
<td>Poor inventory management</td>
<td>The supplier fails to meet customer demand as it keeps insufficient stocks of finished product.</td>
</tr>
<tr>
<td>Operational</td>
<td>High lead time variability</td>
<td>Highly variable lead times by the supplier result in erratic forecasts and delivery delays.</td>
</tr>
<tr>
<td>Operational</td>
<td>Technological backwardness</td>
<td>The supplier fails to quickly implement technological changes and to quickly respond to product changes demanded buy the purchasing company.</td>
</tr>
<tr>
<td>Operational</td>
<td>Inadequate information system sophistication</td>
<td>Disconnection or false transmission of information on the supplier side occurs at any point from order entry to product delivery, due to poorly performing information system.</td>
</tr>
<tr>
<td>Operational</td>
<td>Shipping and distribution distance and methods</td>
<td>The global supplier is temporarily unable to supply raw materials from off-shore/far locations due to logistics route or mode disruptions.</td>
</tr>
<tr>
<td>Operational</td>
<td>Insufficient safety measures/man-made disasters</td>
<td>The supplier is impacted by a man-made disaster (e.g. fire) and is unable to proceed with production or shipping activities</td>
</tr>
<tr>
<td>Risk category</td>
<td>Risk source</td>
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</tr>
<tr>
<td>---------------</td>
<td>-------------</td>
<td>------------</td>
</tr>
<tr>
<td>External</td>
<td>Natural disasters</td>
<td>The supplier is impacted by a natural disaster (e.g. earthquake) and is unable to proceed with production or shipping activities.</td>
</tr>
<tr>
<td>External</td>
<td>Currency and exchange rate fluctuations / economic stability of the region</td>
<td>The supplier fails to supply its products due to economic instability.</td>
</tr>
<tr>
<td>External</td>
<td>Political stability of the region / terrorism</td>
<td>The supplier fails to supply its products due to political unrest or terrorist threats.</td>
</tr>
<tr>
<td>Market</td>
<td>Market capacity constraints</td>
<td>A raw material is sole sourced (only produced by one supplier) and its supplier fails to supply the raw material.</td>
</tr>
<tr>
<td>Market</td>
<td>Low number of qualified suppliers</td>
<td>A raw material is single sourced (one approved producer for that raw material) and its supplier fails to supply the raw material.</td>
</tr>
<tr>
<td>Market</td>
<td>Multi-tier sourcing</td>
<td>Higher tier suppliers outsource to sub-tier suppliers and the supply chain becomes a long supply chain, greatly decreasing supply chain visibility and traceability. (e.g. in case of distributors)</td>
</tr>
<tr>
<td>Market</td>
<td>Geographical density of suppliers</td>
<td>The suppliers are located in the same region and are thus impacted by the same event (e.g. earthquake, political unrest, etc.)</td>
</tr>
</tbody>
</table>