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Master Thesis

Risk management in product channels: how much does the distributional structure of flour mills' products influence the risk associated with contaminated products?

April 2008

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Preface

This master thesis marks the end of my study in Wageningen as well as in Bonn. The report is the result of six months of work and the last requirement to graduate for both, my MSc in Management and Economics and for my diploma in Agricultural Economics.

Hereby I would especially like to express my gratitude to Prof. Gerhard Schiefer, from Bonn University, and to Dr. Jacques Trienekens, from Wageningen University for their supervision and their critical advices. Furthermore I would like to thank Mr. Oliver Poignée from Bonn University, who is an expert in the crop business. Finally I would like to mention all interview partners, who spend their time to give me an insight in their business. Without the cooperation of the interview partners the outcome of this research would not be achieved.

Henrik Krapp
Bonn, April 2008

Executive summary

To manage risk in food safety, typically the focus is on risks on failure in enterprise production processes. By contrast, the focus of the risk management approach of this research is on the magnitude of consequences if a safety deficiency is not detected by a flour mill. The objective of this thesis is to investigate the impact of the distribution channel's structure on the flour mill's risk associated with contaminated products by analysing the movement of a problem along the distribution channel.

The background of the research is based on literature review. Industry information about the flour mill business in Germany presents an insight in the production processes, the market situation and the business organisation. It is shown that the flour mill industry is characterised by an ongoing consolidation process with an involved specialisation process as well as that the market is dominated by VK Mühlen AG and Werhahn Mühlen GmbH & Co. KG with a total market share of almost 50%. Literature review on supply chain management concentrates on the supply chain structure and supply chain management components. Theories of risk management deliver the main components of risk analysis and the Failure Mode and Effects Analysis (FMEA), which is a tool to estimate risk. The literature review concludes with a framework to estimate risk in food supply chains.

Following a case study is designed. First interviews with the German flour mill association, the association of the German craft bakeries and the association of producers of bakery improver are done. Then an in-depth interview with the director of the Plange Flour Mill is carried out, which delivers the most important information to work on the research objective. The main result is that marketing flour to craft bakeries comprises the lowest risk, followed by industrial bakeries, food retail and other food industries. Furthermore as to the probability of occurrence of contaminated flour it is to say that the flour mills are in general very insusceptible for product contaminations. Nevertheless the contaminations can be ranked according to their risk as follows: (1) biological, (2) physical, and (3) chemical contaminations.

It is to conclude that the research is too short to comprise all details of the very heterogeneous supply chain network structure, but the results present tendencies and starting points for further research. It is to recommend focusing on one marketing channel to compass the heterogeneity of the flour mill's customers. Furthermore the concentration of the flour on the final product as well as the proportion on the value chain should be considered.

Key words: flour mill, supply chain network structure, contaminated products, risk

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Abbreviations

BRC	British Retail Consortium
CCP	Critical Control Points
ECR	Efficient Consumer Response
EDI	Electronic Data Interchange
EPoS	Electronic Point of Sale
Eurep	European Retailer Working Group
FMEA	Failure Mode and Effects Analysis
GAP	Good Agricultural Practice
GHP	Good Hygienic Practice
GMP	Good Manufacturing Practice
GTP	Good Trade Practice
HACCP	Hazard Analysis of Critical Control Points
ICT	Information and Communication Technology
ISO	International Standard Organization
IT	Information Technology
RPN	Risk Priority Number
RQ	Research Question
SC	Supply Chain
SCM	Supply Chain Management
SQF	Safe Quality Food
UK	United Kingdom

INTRODUCTION

1 Problem definition

1.1 Introduction and problem statement

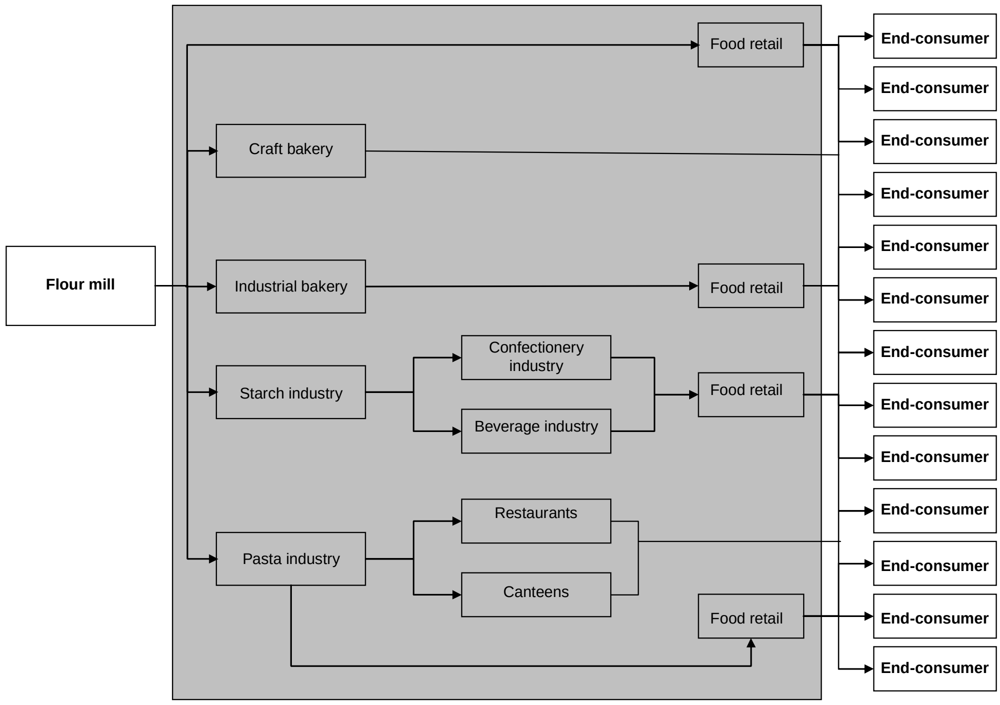
Food safety is a very important aspect in discussions about risk management in food industry. To manage risk in food safety, typically the focus is on risks on failures in enterprise production processes. There are different management systems, e.g. HACCP and ISO, which should help to achieve the desired quality. This risk management approach only considers the probability of failure. What is missing is an idea of the magnitude of consequences if a safety deficiency is detected too late in dependency on the distributional effects; i.e. how many organisations and customers might have to face risks associated with contaminated products.

During the last years food safety became more and more important. The consequences of failure can be enormous for both, the end-consumers and the company where the loss occurs. The reasons for the product failure can be quite different: bacterial, chemical or physical contaminations. Depending on the quality defect of the product the consumer can incur serious injuries and diseases. Also the company has to assume the risk of a serious damage. Recalls, liability suits and damage to its image can burden a company very heavily. Independently from the character of the product failure, the effects, if a safety deficiency is detected too late, depend on the product distribution; i.e. the number of tiers, the organisations in each tier and its dealings. As a consequence and with regard to good risk management the selection of marketing channels with controllable distributional effects should keep clearly in mind. To measure the risk associated with the distribution channel a preferably detailed picture of the whole product chain should be available.

The term ‘risk’ will be used and brought together with the term ‘distributional structure’ quite often in the following sections. For better understanding, a short explanation is given: Above it is said that contaminated products can occur and might have consequences for the flour mill, so accordingly there is risk for the flour mill. It is to assume that the magnitude of the consequences is influenced by the distributional structure of the products; e.g. the more organisations and end-consumers are affected by contaminated products, the higher is the magnitude of consequences for the flour mill. Thus, the distributional structure influences the flour mill's risk.

This problem applies to a lot of food products. The following research investigates this risk aspect with focus on the flour mill industry and its main products for human food. The business of flour mills is characterised by purchasing wheat and rye, milling these crops and selling different granulations of flour and its by-products to the food- and non-food industry. Flour is useful for a lot of products, so even in the food industry flour mills' customers are not all in the same kind of business. Following, a small list of organisations which can be all members of the distribution channel should clarify the complexity: craft bakeries, industrial bakeries, starch industry, confectionery industry, pasta industry, restaurants, canteens, food retail and end-consumers. See also figure 1.1-1 for an illustration.

Figure 1.1-1 Flour mill product channel



Source: Own illustration

This thesis investigates the distributional effects in the marketing channels of flour; from the flour mill to the end-consumer. The aim is to generate a detailed picture of all participants and their dealings. This is a precondition to measure the correlation between the distributional effects and the flour mill's risk.

1.2 Research objective

Objective in relation to the problem
Verify the influence of a product's distribution channel on the flour mill's risk, under the supposition that a contaminated product will leave the flour mill and will be detected at another stage.

Objective in relation to the research project
The objective of this thesis is:

To investigate the impact of the distribution channel's structure on the flour mill's risk associated with contaminated products by analysing the movement of a problem along the distribution channel.

The precondition is an in-depth mapping and analysis of the distribution channel from the flour mill to the end-consumer; i.e. the number of tiers and the organisations in each tier until the product reaches the end-consumer are to identify. Thereupon the movement of a problem along the distribution channel should be unveiled. At last a statement on the flour mill's risk should be provided. There the main marketing channels with their single effects on the magnitude of the consequences and accordingly their single effects on the risk will be compared.

1.3 Research questions

The general research question is:
Granted that a safety deficiency is detected too late, how does a product failure affect the flour mill's risk?

Research question 1:

How does the distribution channel from a flour mill to the end-consumer look like?

1.1 What are the different tiers from a flour mill to the end-consumer?

1.2 How many participants might be affected by contaminated flour on each tier?

1.3 What does the time horizon look like from one product stage to the other?

1.4 What does the regional distribution of flour from one tier to the next tier look like?

Research question 2:

How to assess the risk aligned with the main marketing channels?

2.1 What is the probability of occurrence of a safety deficiency in a flour mill?

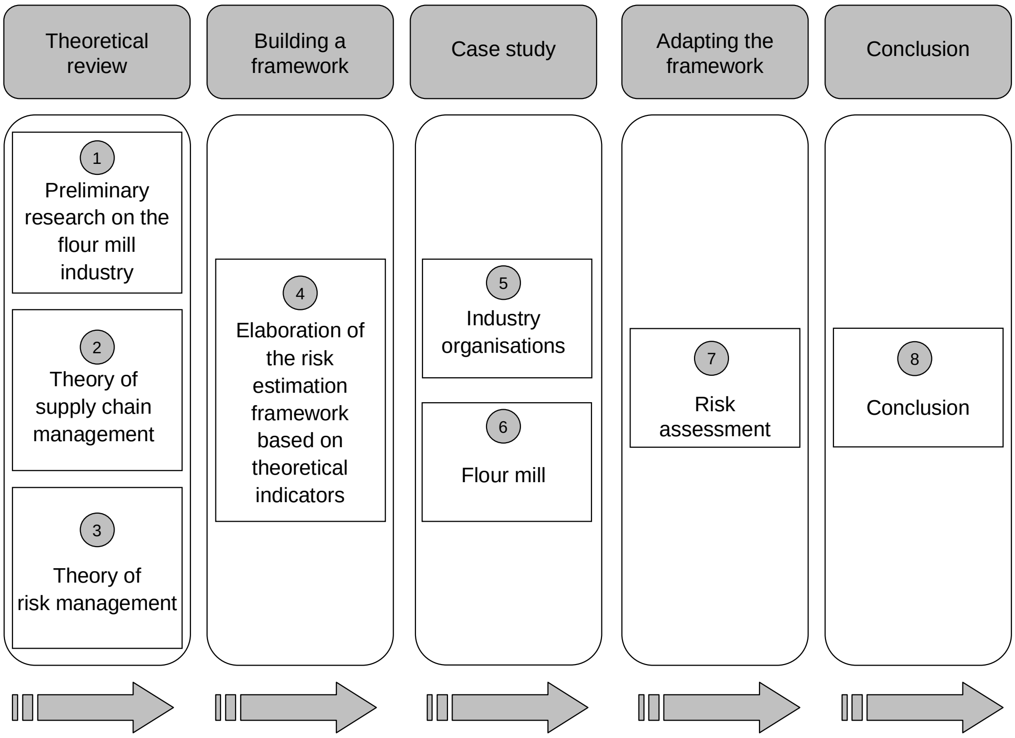
2.2 How is the magnitude of the effects of a safety deficiency to assess in the main marketing channels?

1.4 Research methodology

The methodology of this research is visualised in the figure 1.4-1 to get an overview of the single steps, which are arranged on each other.

Before starting to collect and review necessary theories step 1 is to acquire an insight in the flour mill industry. Therefore, first theoretical background on the flour mill business including the trends during the last years and the activity of the production processes are of interest. To be consistent, the following theoretical parts are structured based on the two research questions. The objective is to gather information on the supply chain network structure, and on analysing and measuring risk. Step 2 is the theoretical review on supply chain management. According to the title of the thesis the supply chain network structure is along supply chain management components in the main focus of the study on supply chain management (SCM). Due to the special features of food the theory of SCM has to comprise food supply chain specifics. Combining the given information of the flour mill

Figure 1.4-1 Research methodology



Source: Own illustration

business and the supply chain theory the flour mill can be positioned in its supply chain network structure. The third step is to gather theoretical background on risk management and on methods of measuring risk. Theories on risk management deliver a structured procedure to analyse the risk this thesis concentrates on. Furthermore from the review of risk management the FMEA results as a useful tool to estimate risk. To keep up the given structure the FMEA is arranged in the risk analysing process.

Concluding the theoretical part step 4 enhances the previous information and provides a theoretical framework. Taking the studied concepts of SCM and risk management into account a framework to estimate risk associated with contaminated products in food supply chains is presented. Main components of the framework are the indicators ‘occurrence’, ‘severity’ and ‘detection’. This framework considers the structure of the two research questions as well as the structure of the risk analysing processes.

After the theoretical framework the empirical study follows. The case study consists of two different types of interviews with the same kind of questions. First (step 5) the German flour mill association, the association of the German craft bakeries and the association of producers of bakery improver are interviewed to get information about the flour mill and its main customers based on a macro perspective. This enables to get brought and general applicable information, which should also qualify for objectivity. The results should serve as a control and completion to the interview with the flour mill. Furthermore the questions are readapted after every interview to build up the most effective questionnaire for the interview with the flour mill. This last interview with the PLANGE FLOUR MILL (step 6) should deliver a real business insight on the micro perspective, and it should deliver the necessary information to fill in the risk estimation framework. As to the interview protocol, it is arranged based on the components of the elaborated risk estimation framework. A pre-interview document should guarantee that the interviewee is well prepared.

The next step presents the results of the interviews. The structure is again based on the risk analysing structure and the risk estimation framework, so that the methodology is consistent all along the report.

Finally step 8 concludes the research.

1.5 Research material

Risk management of marketing channels is not for a long time on spotlight, so that there is no scientific literature dealing with exactly this problem. Therefore, detailed interviews with flour mills and if possible with other participants are very important information sources. Furthermore industry reports and literature about distributional theory, supply chain theory and risk measurement analysis are of particular importance.

Following the main research material is listed:

- Scientific literature (library, digital sources)
- Industry reports
- Interviews
- Documents
- The media

1.6 Research strategy

The research has a mainly qualitative approach. First the research starts with **desk research**, also known as secondary research. This research is characterised by gathering data that already exist; to gain theoretical background and to get a general idea of what is already known. There is already general literature about supply chain management, risk management and analysis for measuring risk. Furthermore there are reports and literature with information about the flour mill industry. Based on this research method the theoretical framework is developed. But information about the reality of the research objective is still missing.

To valid the results of the desk research and to fill up the lacking information a **case study** follows. A case study method involves an in-depth examination of a single instance or event; i.e. a systematic data collection and information analysis. With regard to the research objective the `case´ of this case study is the distribution of flour mills' products. The data collection is done through a small number of selected in-depth interviews. The research units are a flour mill and associations of the different tiers; e.g. WERHAHN MÜHLEN GMBH & CO. KG, the German flour mill organisation. Further research units will be identified by the analysis of the distribution structure itself. Thus the case study strategy is essential to valid the theoretical information gathered during the desk research and get detailed real business information.

1.7 Outline

This master thesis consists of an introduction (chapter 1), a part with industry information (chapter 2), a theoretical framework (chapter 3, 4 and 5), an empirical research (chapter 6 and 7), and an evaluation (chapter 8).

Chapter 1 explains the research problem and the conceptual as well as the technical research design.

In the following, chapter 2 delivers general information about the flour mill industry. To get an idea of the business of a flour mill the way flour is produced is shown, as well as an overview of the flour market and the business organisation is given.

Chapter 3 focuses on the supply chain management theories. Thereby the supply chain management framework and the focused components are discussed. Furthermore, with regard to food supply chains quality management schemes are introduced. Finally the flour mill is arranged in the generally known network structure. Chapter 4 presents the theoretical background on risk management. The main steps of risk management including a risk estimation tool are introduced. Chapter 5 finalises the theoretical framework with a generally applicable risk estimation framework for food supply chains. The chapter is based on the theoretical information of chapter 3 and 4.

The empirical part starts with chapter 6, which introduces the interview partners and summarises the interview questions. Furthermore the interview procedure is explained. Chapter 7 presents the results of the interviews and the outcome of the risk estimation.

The evaluation is presented in chapter 8 where the final conclusion and recommendations for further research are given.

INDUSTRY INFORMATION

2 The flour mill industry

2.1 Introduction

Core business of the mill industry is the processing of crop to produce different kinds of flour and other nutriments. In Germany in the financial year 2005/06 in total 8,112,000 tons of crop were grinded, which is mainly composed by 6,832,000 tons of wheat and 902,000 tons of rye. The remaining amount is durum (378,000 tons), which is grinded in special durum mills. (BMELV, 2006) Wheat and rye are grinded in flour mills, which following will be specified in more detail. Possible sales to the feeding industry will not be accounted for.

The data in this research includes only notifiable mills; i.e. mills with a yearly grinding of at least 500 tons.

2.2 Processing technology

The principal activity of a flour mill is to grain wheat and rye to flour in different granulations. This process can be divided into three sections: cleaning, preparation and milling.

Cleaning

First of all the crop has to be cleaned and separated from foreign matters. Because of hygienic and economical reasons this is done in a dry process via differences in design, size and density, magnetic properties and mechanical behaviour. In the pre-cleaning phase the crop will be separated from external elements; e.g. husks, stones, metal and damaged grain. This takes about 1% to 2.5% of uncleaned crop. The main cleaning process takes away the dust and other small contaminations from the grain's face. (KLINGLER, 1995)

Preparation

The aim of the preparation process is to achieve a differentiated breaking performance of the grain's dish and the endosperm. Therefore the crop is first moistened and than dried until it has a relative humidity of 16% to 18%. (KLINGLER, 1995)

Milling

In the milling process the crop will be broken up by compressive force and cutting actions. During every crushing different pieces of grain occur, which have to be separated into grain's dish and endosperm as well as sorted into the same range. This is done by mechanical systems for pieces bigger than 100 µm and by pneumatic systems for smaller pieces. During this break up process primarily grit and dunst occur. Grit and dunst can either be brought to market or can be processed to mill. The milling process itself is the step from dunst to mill. (BOLLOING, 1991; KLINGLER, 1995; BELITZ und GROSCH, 1992)

The classification of the different milling products is done by the size of the particle: grist (> 1000 µm), gross grit (600 – 1000 µm), fine grit (300 – 600 µm), dunst (80 – 300 µm) and flour (< 180 µm). (KLINGLER, 1995)

Co products of the milling process are different types of bran, flour for non-food and germs. The amount of the co-products is about 20% to 21% of the used crop. (JEROCH ET AL., 1993)

2.3 Crop milling

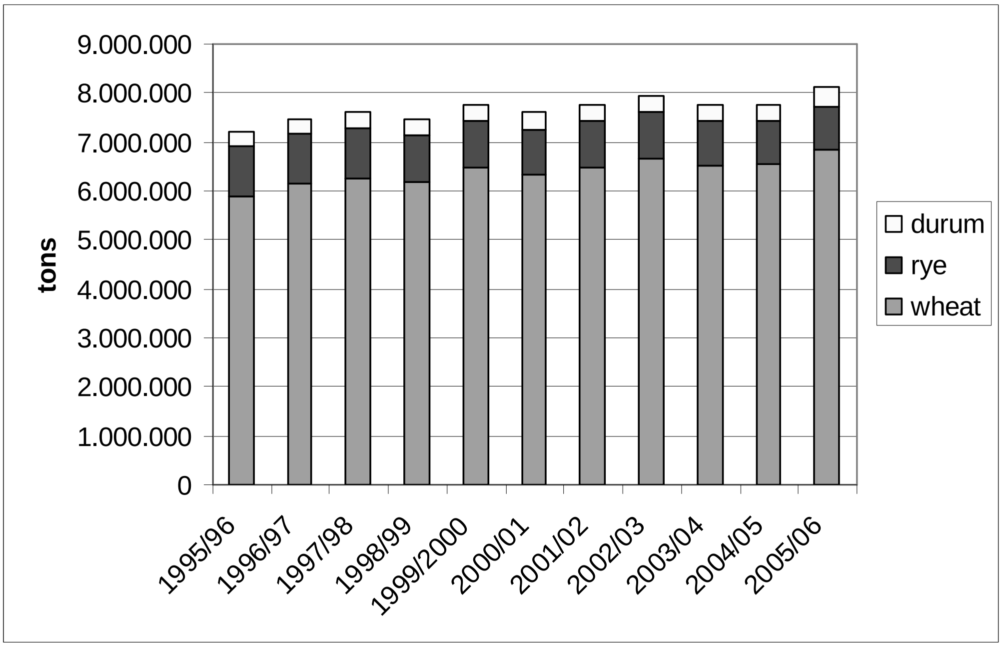
In the financial year 2005/06 6.83 Mio tons of wheat and 0.9 Mio tons of rye were milled. This corresponds to an increase in milled wheat of 294,000 tons (plus 4.5%) and an increase in milled rye of 7,500 tons (plus 0.8%). The proportion of wheat to rye is about 88.3% wheat and 11.7% rye; in comparison to the year before it changed a little bit in favour of wheat. The production yield of the milling process is for wheat about 79.3% and for rye about 87.2%.

Milling of imported wheat from the EU increased by 125,000 tons; to 356,000 tons. Thus the rate of imported wheat from the EU is about 5.2%. From third countries the imported amount of wheat is about 18,000 tons, this are 7,000 tons less than one year before. The total rate of domestic wheat decreased from 96.1% in the year 2004/05 to 94.5% in the year 2005/06.

The rate of exported mill products was about 717,000 tons or 9.3%. This is an increase of 183,000 tons in comparison with the year before and consists of 699,000 tons milled wheat and 18,000 tons milled rye. Most important for export are the federal states Niedersachsen/Bremen which exported an amount of 383,000 tons and Nordrhein-Westfalen which exported an amount of 186,000 tons. Milling for export increased in the northwest of Germany by 158,000 tons, in Bavaria by 17,000 tons and in Sachsen-Anhalt by 12,000 tons. In the other federal states the export of flour is not of that importance.
(BMELV, 2006)

Figure 2.3-1 illustrates the development of the amount of milled crop during the last decade. The sum of milled crop increased continually from 7.215 Mio tons in 1995/96 to 8.112 Mio tons in 2005/06. This is mainly caused by the high increase in milled wheat, from 5.881 Mio tons in 1995/96 to 6.832 Mio tons in 2005/06. The positive change in milled durum and the negative change in milled rye are relatively small.
(BMELV, 2006)

Figure 2.3-1 Amount of milled crop from 1995/96 to 2005/06



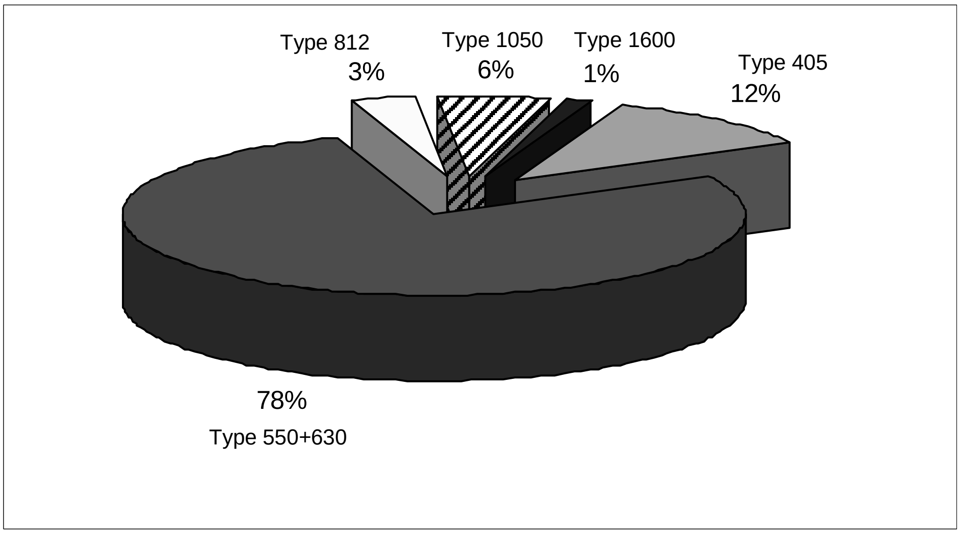
Source: BMELV (2006)

2.4 Flour production

In the year 2005/06 the flour production increased by 191,000 tons (plus 3.2%) to the amount of 6.2 Mio tons. This is mainly caused by the increasing importance of milled wheat, shown in figure 2.3-1, which follows the persistent trend of an increasing consumption of food based on flour.

The amount of produced flour was about 5.4 Mio tons, which is an increase of 203,000 tons (plus 3.9%). Whereas the production of rye flour decreased by 12,000 tons (minus 1.5%) to the amount of 787,000 tons. A differentiated picture occurs looking at the flour types. The amount of flour type 550+630, which is the typical bakery flour, increased by 4.2% to the amount of almost 3.8 Mio tons; also the flour type 812 could reach the amount of 156,000 tons. On the other hand the typical household flour type 405 decreased by 5.1% to the amount of 573,000 tons. Figure 2.4-1 points out the importance of flour type 550+630. As mentioned above the production of rye flour in total decreased. The only rye flour type with a positive growth was type 1800, which increased by 2.1% to the amount of 76,000 tons. The most important rye flour, type 1150 decreased by 1.1% to the amount of 336,000 tons. All other rye flour types had a negative growth, too: type 815 minus 8.8% to the amount of 25,000 tons, type 1740 minus 10.9% to the amount of 12.000 tons, type 997 minus 2.2% to the amount of 167,000 tons and type 1370 minus 0.4% to the amount of 65,000 tons. (BMELV, 2006)

Figure 2.4-1 Rate of flour types in 2005/06



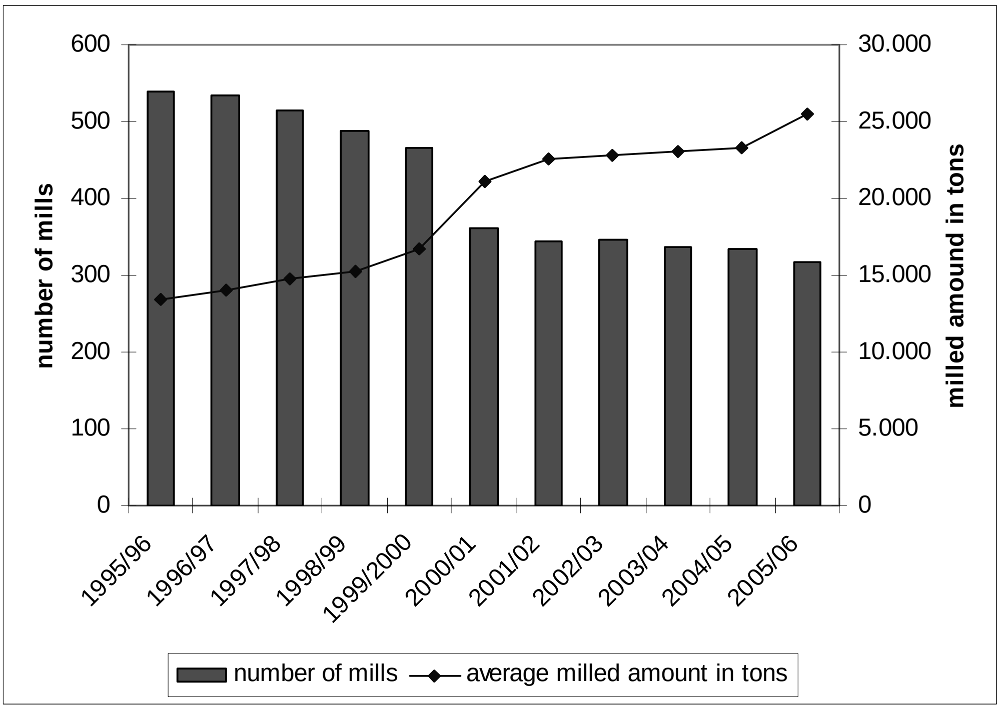
Source: BMELV (2006)

The production of some flour types shows regional concentrations. Almost 59% of the produced flour type 405 comes from Baden-Württemberg, Bavaria and Niedersachsen/Bremen. Flour type 550+630 is mainly produced in Nordrhein-Westfalen (962,000 tons), Niedersachsen/ Bremen (706,000 tons) and Bavaria (533,000 tons). The production of rye flour is regionally distributed as follows: type 815 is mainly produced in Rheinlandpfalz/Saarland, Bavaria and Hessen; one third of type 997 is produced in Bavaria; and more than one fourth of type 1150 is produced in Nordrhein-Westfalen. (BMELV, 2006)

2.5 Business organisation

The flour mill business is characterised by a persistent consolidation process, which is clarified below. From 2004/05 to 2005/06 the number of notifiable mills decreased by 15 factories to the amount of 318. The last 30 years show explicitly the consolidation process: the number of flour mills decreased from 3,462 by 3,144 mills. Figure 2.5-1 illustrates the changes in the last decade. Most flour mills are located in Bavaria (85), followed by Baden-Würtemberg (79) and Nortrhein-Westphalen (30). (BMELV, 2006)

Figure 2.5-1 Changes in flour mills and average amount of milled crop



Source: BMELV (2006)

The increased amount of milled crop and the coeval reduction of flour mills lead in 2005/06 to a broad gain in average milled crop per year and flour mill (see figure 2.4-1). The average amount of milled crop is about 25,510 tons per flour mill, which is a rise of 9.3%. Nevertheless there are enormous differences across the country. In Sachsen-Anhalt the average amount of milled crop per flour mill is about 101,000 tons, in Niedersachsen/Bremen it is about 87,630 tons, and in Nordrhein-Westphalen it is about 57,970 tons. The lowest average amount of milled crop is in Sachsen (10,680 tons), followed by Baden-Würtemberg (10,920 tons) and Bavaria (13,580 tons). (BMELV, 2006)

Table 2.5-1 shows explicitly the concentration process in the German flour mill industry. The market is dominated by flour mills with an annual output of more than 100,000 tons. This group presents only 8% of the flour mills, but process more than 60% of the milled crop and the trend is positively. The size range of flour mills which produce between 500 and 5,000 tons contains the highest number of flour mills (195 mills or 61%), but has a market share of only 4%.

Table 2.5-1 Flour mills sorted by size range

year		500 to < 5,000 tons	5,000 to < 25,000 tons	25,000 to < 50,000 tons	50,000 to < 100,000 tons	100,000 to < 200,000 tons	200,000 tons and more	in total
2004/05	number	204	68	22	14	18	7	333
	percent	61%	20%	7%	4%	5%	2%	100%
	crop milled (1,000 t)	338	781	774	933	2,624	1,983	7,773
	market share	4%	10%	10%	12%	34%	26%	100%
2005/06	number	195	62	24	12	17	8	318
	percent	61%	19%	8%	4%	5%	3%	100%
	crop milled (1,000 t)	338	713	859	842	2,598	2,383	8,112
	market share	4%	9%	11%	10%	32%	29%	100%

Source: BMELV (2006)

The German flour mill industry is dominated by two main companies: VK-MÜHLEN AG in Hamburg and WERHAHN MÜHLEN GMBH & CO. KG in Neuss. Both together handle almost half of the milled crop. VK-MÜHLEN AG has an approximated market share of 25%, followed by WERHAHN MÜHLEN GMBH & CO. KG with a market share of nearly 20%. Number three and four are the companies ENGELKE (5% market share) and ROLANDMÜHLE EHRLING & CO. GMBH (3% market share). (GIESCHEN, OTTEN, 1997; DAUS-SPEICHER, 1998; KAMPFFMEYER, 2000)

2.6 Conclusion

The business of a flour mill is to grain wheat and rye to flour of different granulations. Milling wheat is of main importance and increased during the last ten years by 16%. As a consequence the flour production increased, too. The most important flour types are type 550+630 (proportion of 78%) and the type 405 (proportion of 12%). The flour mill industry is characterised by a persistent consolidation process. The 25 largest mills have a market share of more than 60%. In 2005/06 in Germany 318 mills remained. Market leader are the companies VK-MÜHLEN AG and WERHAHN MÜHLEN GMBH & CO. KG.

The given information is important to get an idea of the flour mill business in Germany. The problem definition (chapter 1.1) argues that a main part of the research concentrates on the investigation of the product chain from the flour mill to the end-consumer. Therefore the following chapter presents theoretical background on supply chain management.

THEORETICAL FRAMEWORK

3 Supply Chain Management

3.1 Introduction

Supply chain management (SCM) is no longer a new term in business management and research; it has become a popular topic. SCM theory recognizes the importance of establishing beneficial relationships to increase competitive advantage and to optimize the results of the chain; i.e. to increase efficiency and inter-firm synergy. These connections are related to internal as well as to external processes; i.e. the entire length from the initial supplier to the end-consumer that creates products and delivers them to the customer. (COOPER AND TRACEY, 2005) This is of special regard in food supply chains, because of food products' susceptibility to contaminations and the increased consumer attention for safe and environment/animal-friendly production methods. (VAN DER VORST ET AL., 2005)

This chapter represents the state-of-the-art of Supply chain management. To give the theoretical background for analysing and understanding product chains of flour mills' products, in the following supply chain definition and recent theories are discussed.

3.1.1 Definition

To better satisfy consumers demand at lower cost, since the 1980's literature on Logistics and Information and Communication Technology (ICT) stresses the need for collaboration in supply chains. (LAMBERT ET AL. 1998) Nowadays individual business no longer competes as solely autonomous entities; furthermore management has to think in supplier-brand-store entities. In this complex fast growing business environment success of the single business will depend on management's ability to integrate the company's intricate network of business relationships. Thus, managing multiple relationships across the supply chain is being referred to as supply chain management. (LAMBERT AND COOPER, 2000)

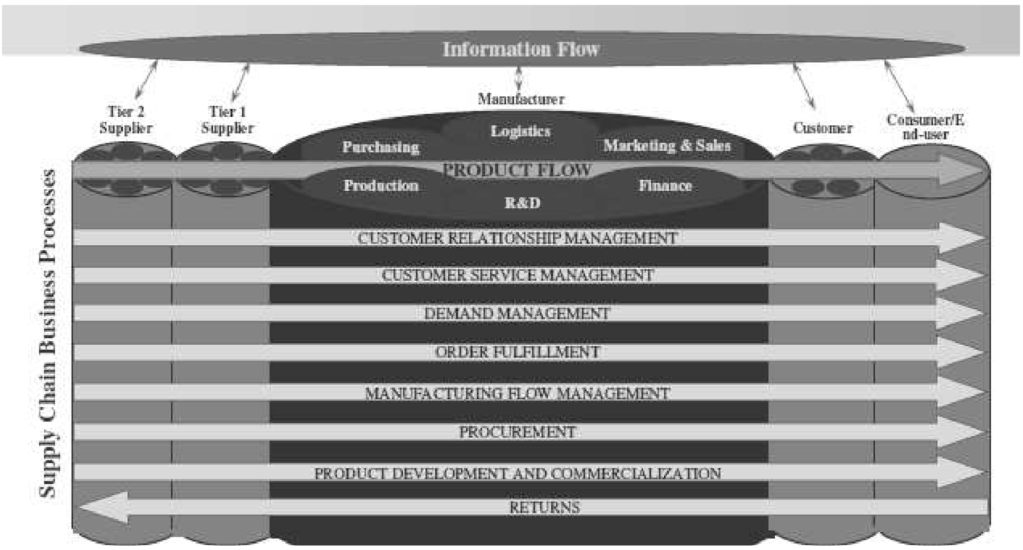
Discussing aspects of SCM a problem could be the use of different terms, or giving the same terms different meanings. The reason for this is that the function called ‘supply chain management’ emerged from a combination of formerly different disciplines with its own terms. A basic explanation of SCM could be that SCM is concerned with the flow of materials through supply chains. (WATERS, 2007)

The GLOBAL SUPPLY CHAIN FORUM (GSCF) has developed and uses the following definition of SCM:

> *Supply Chain Management is the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders.*

Figure 3.1-1 illustrates this broader understanding of the SCM concept by LAMBERT AND COOPER (2000). It depicts a simplified supply chain network structure; the information and product flows; and the key supply chain business processes penetrating functional silos within the company and the various silos across the supply chain. Accordingly, business processes become supply chain business processes linked across intra- and inter-company boundaries. (LAMBERT AND COOPER, 2000)

Figure 3.1-1 Integrating and managing business processes across a SC



Source: Lambert and Cooper (2000)

Another definition of supply chain management is given by VAN DER VORST (2000):

> *SCM is the integrated planning, co-ordination and control of all business processes and activities in the supply chain to deliver superior consumer value at less cost to the supply chain as a whole while satisfying the variable requirements of other stakeholders in the supply chain (e.g. government and NGO's).*

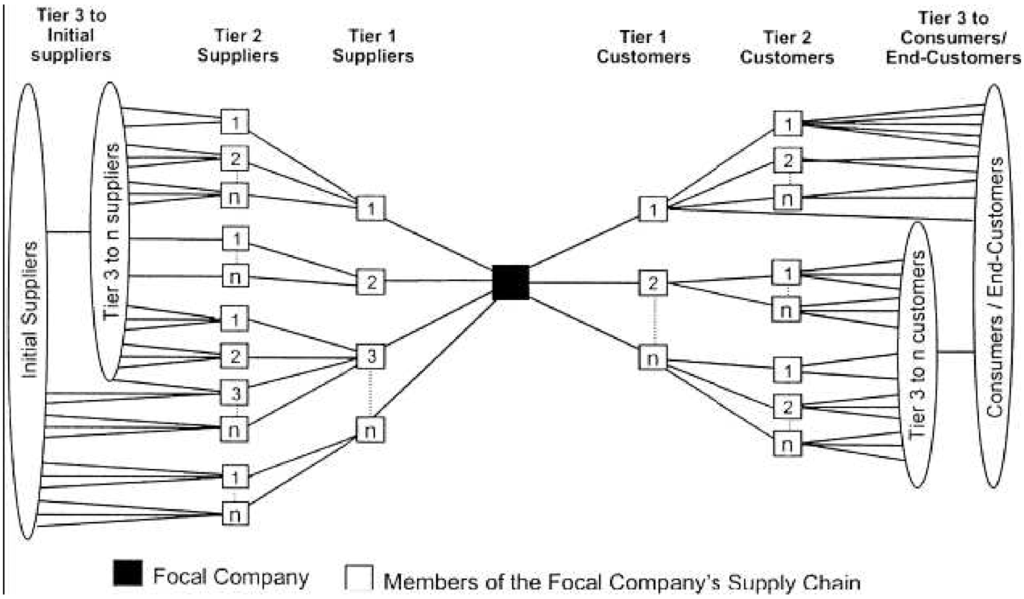
In this definition a supply chain is a series of physical and decision making activities connected by material and information flows and associated flows of money and property rights that cross organisational boundaries. A business process is defined as a structured, measured set of activities designed to produce a specified output for a particular customer or market (DAVENPORT, 1993). The term value incorporates the financial performance (the amount consumers are willing to pay for what a company provides), the social performance (the policy of the producing companies) and the environmental performance (e.g. biologically produced products). The concept 'value-added activity' originates from Porter's 'value chain' framework and characterises the value created by an activity in relation to the cost of executing it (PORTER, 1985). VAN DER VORST ET AL. (2005) talk about an advanced value concept, the so called 'Triple P': People, Planet and Profit. This is synonymic for the social performance, the environmental performance and the financial performance. (VAN DER VORST ET AL., 2005)

3.1.2 SC structure

According to LAMBERT AND COOPER (2000) the SCM framework consists of the following three interrelated elements: the supply chain network structure, which consists of the member firms and the links between these firms; the supply chain business processes, which are the activities producing a specific value to the customer; and the supply chain management components, which are the managerial variables integrating and managing the business processes across the supply chain. The supply chain management components will be discussed in the next chapter, whereas the supply chain business processes should not be accounted for. Because the research focuses mainly on the members of the network structure and on the characteristics of their interactions, the business processes will not be investigated.

Figure 3.1.2-1 depicts a detailed map of the supply chain from the raw material to the ultimate consumer. For most manufacturers the supply chain does not look like a pipeline but more like an uprooted tree, where the branches and roots illustrate the customers and suppliers. LAMBERT AND COOPER (2000) suggest that the primary aspects of a company's supply chain structure are: the members of the supply chain, the structural dimension, and the different types of process links.

Figure 3.1.2-1 Supply chain network structure



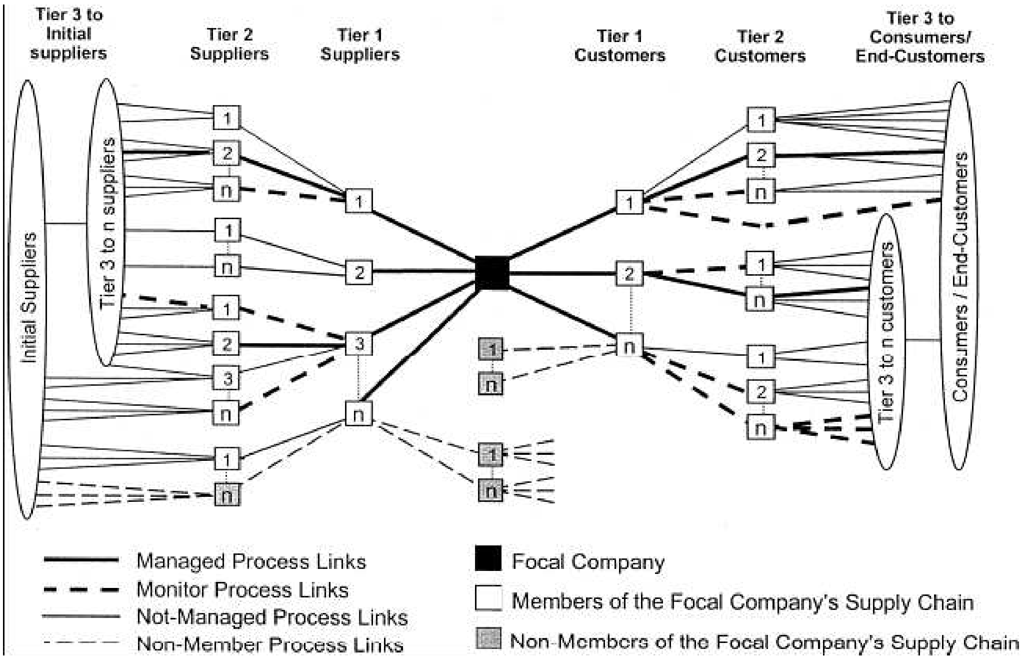
Source: Lambert and Cooper (2000)

Regarding all kind of members of the chain network may lead to a high complex and counterproductive network. The key is to sort out which members are critical to the company and the supply chain and, thus, should be allocated managerial attention and resources. To do so LAMBERT AND COOPER (2000) divide between primary and supporting members. They define primary members of a supply chain to be *all those autonomous companies or strategic business units who carry out value-adding activities (operational and/or managerial) in the business processes designed to produce a specific output for a particular customer or market.* Supporting members are *companies that simply provide resources, knowledge, utilities, or assets for the primary members of the supply chain.*

The structural dimension consists of the horizontal structure, which refers to the number of tiers across the supply chain; the vertical structure, which refers to the number of suppliers/customers represented within each tier; and the company's horizontal position between the initial source and the ultimate customer.

Because managing all business process links is not practical, it can be distinguished between: managed business process links, which are links that the focal company finds important to integrate and manage; monitored business process links, which are not that critical, so that the focal company, as frequently as necessary, monitors and audits the process links; not managed business process links, which are links that the focal company is not actively involved in, nor monitor them; and not-member business process links, which are links between members of the focal company's supply chain and non-members of the supply chain. Non-member links do not belong to the focal company's supply chain structure, but they can affect the focal company and its supply chain. Figure 3.1.2-2 illustrates the different types of inter-company business process links.
(LAMBERT AND COOPER, 2000)

Figure 3.1.2-2 Types of inter-company business process links



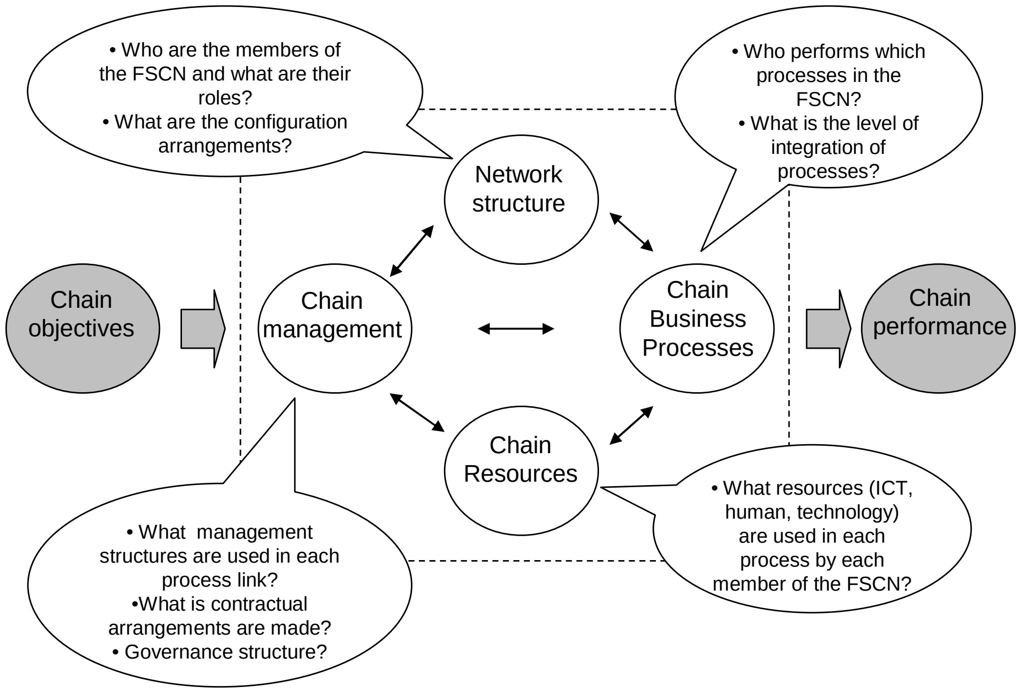
Source: Lambert and Cooper (2000)

VAN DER VORST ET AL. (2005) elaborated in line with LAMBERT AND COOPER (2000) a framework to describe supply chains' participants, processes, products, resources and management (see figure 3.1.2-3). The framework constitutes of the following four elements:

1. The *Network Structure* which demarcates the boundaries of the supply chain network and describes the main participants or actors of the network, accepted and/or certified roles performed by them and all the configuration and institutional arrangements that constitute the network.
2. *Chain Business Processes* are structured, measured sets of business activities designed to produce a specified output (consisting of types of physical products, services and information) for a particular customer or market.
3. *Network and Chain Management* which typifies the coordination and management structures in the network that facilitate the instantiation and execution of processes by actors in the network making use of the chain resources with the objective to realise the performance objectives formulated by the supply chain network.
4. *Chain Resources* which are used to produce the product and deliver it to the customer. These enablers include people, machines and ICT.

(VAN DER VORST ET AL., 2005)

Figure 3.1.2-3 Framework for chain/network development



Source: Van der Vorst et al. (2005)

LAZZARINI ET AL. (2001) refer to the concept of a netchain. This is a set of networks comprise of horizontal ties between firms within a particular industry or group, such that these networks (or layers) are sequentially arranged based on the vertical ties between firms in different layers. Netchain analysis by LAZZARINI ET AL. (2001) differentiates explicitly between horizontal ties, which are transactions in the same layer; and vertical ties, which are transactions between layers.

3.1.3 SC management components

As stated above, according to LAMBERT AND COOPER (2000) the SCM management components are the third element of the SCM framework. The level of integration and management of business processes is dependent on the number and intensity of management components added to that business process. LAMBERT AND COOPER (2000) identified the following nine management components, which major affect the outcome of a supply chain:

Planning and control of operations are of key importance to move a supply chain in a desired direction. Joint planning through the whole supply chain should enable to transcend phases of different priorities of the single supply chain members. The control aspect operationalises the supply chain performance to measure the supply chain success.

The *work structure* indicates how the organisation performs its tasks and activities, measured by the level of integration of processes across the supply chain.

The *organisational structure* of the individual company and the supply chain; it has to be the more integrated the more a team has to work across organisational boundaries.

Product flow facility structure refers to the network structure for sourcing, manufacturing, and distributing. Improving handling of inventory is a key aspect.

Information flow facility structure influences the information passed among channel members and the frequency of information updating, which determines the efficiency of the supply chain.

Management methods include the corporate philosophy and management techniques, which have to be integrated along the supply chain; e.g. top-down and bottom-up structure.

The *power and leadership structure* across the supply chain will affect its form and direction. In most chains there are one or two strong leaders, which affect the level of commitment of the other members.

The allocation of *risks and rewards* across the chain affects long term commitment of channel members.

Compatibility of *culture and attitude* are important considerations; they are necessary to perform as a chain.

These management components can be divided into two groups. The first group includes the physical and technical components, which are most visible, tangible, measurable, and easy-to-change: planning and control methods, work structure, organisational structure, information flow facility structure, and product flow facility structure. The second group consists of the managerial and behavioural components, which are less tangible and visible and are often difficult to asses: management methods, power and leadership structure, risk and reward structure, and culture and attitude. The managerial and behavioural components influence how the physical and technical components can be implemented. All these interrelated components build the groundwork for successful SCM.

(LAMBERT AND COOPER, 2000)

Also VAN DER VORST ET AL. (2005) point out the importance of joining supply chains, effective participation in, and control of supply chains for future competitiveness. He focuses on food supply chains and emphasises food safety and high quality products as a precondition for consumer acceptance of the entire supply chain. Having each their own role in ensuring product safety and quality, the activities of the different food supply chain members should be closely coordinated. According to VAN DER VORST ET AL. (2005) this complexity can be facilitated by the help of efficient logistic systems and information exchange between the chain participants. Here, the following two technologies are of key importance: first the developments in ICT, which enable a rapid and intensive information gathering and exchange; and second the development of mathematical algorithms, which enables the processing of all that data in decision support models.

3.1.4 Food SC specifics

Food supply chains operate in a complex, dynamic and time critical environment where product integrity is vital. Food supply chains are different from other supply chains. Managing successfully a food supply chain, the associated characteristics have to be considered.

Following specifics of food products and production processes influence product quality and quality assurance in production processes:

- Quality variation between different producers and between different lots of produce, due to e.g. weather conditions, biological variation and seasonality, but also as a possible result of variations in production
- Perishability of produce and fresh products; for many materials shelf-life constraints apply
- Production yields are often uncertain due to, e.g., weather conditions and quality variation within and between lots
- There are special demands for storage and transportation, such as cooling facilities and hygienic measurements

Due to these characteristics some quite specific hazards exist in the production and distribution of food. (TRIENEKENS AND ZUURBIER, 2006)

According to BOURLAKIS AND WEIGHTMAN (2003) there are six key factors that play an influential role in the evolution and development of modern food supply chains: quality, technology, logistics, information technology, the regulatory framework and the consumers.

Quality is the degree of congruence between customers' expectations and their realisation. In general consumers are looking for quality as well as lower prices. Product quality and its assurance have become even more important in food supply chain management. Nevertheless, the structure of some supply chains implicates difficulties and challenges; e.g. many producers are separated from customers due to the length of the supply chain.

The technological dimension is a fundamental part of the food supply chain because of its essential innovations and developments, which are of huge importance for its integrity, efficiency and productivity. These include for example accurate weighting, refrigeration, controlled atmospheric bacterial growth inhibition, pasteurisation, micro-element pollution detection, bar coding, electronic recognition of packaging, the use of stabilisers, environmentally and welfare friendly animal housing, and organic crop and animal production systems.

Various researchers have stated that logistics is a key business process that provides increased customer satisfaction. Whilst logistics concerns primarily the processes of a single company, supply chain management also envelopes the external environment of an organisation and subsequently includes the external flows of materials, information and revenues between various businesses.

Information technology applications support the movement of products and product information dissemination in the supply chain. Important examples of such applications are: electronic point of sales (EPoS), to identify products with bar codes; and electronic data interchange (EDI), to transfer information. The use of the Internet in the food supply chain is a relatively recent innovation, its major benefits are that it enables retailers and suppliers to avoid exceeding paperwork and that each stage of the system is more visible.

The food supply chain is affected by the socio-political environment like no other supply chain. The regulatory framework defined by national and international law reflects increased consumer concerns about food safety, labelling and product traceability. Also TRIENEKENS AND VAN DER VORST (2006) refer to the social/legal area of influence in addition to the influence by economics, technology and environment.

Consumers drive the food supply chain in terms of type, volume, quality and value of food. A development that advocates this view is efficient consumer response (ECR) where manufacturers, wholesalers and retailers try to meet consumer demands better and more efficient (FIDDIS, 1997).
(BOURLAKIS AND WEIGHTMAN, 2003)

These characteristics demonstrate that food and non-food supply chains are not comparable and that analysing a food supply chain these specialities have to be considered. Furthermore there are also differences in food supply chains itself.

ZUURBIER ET AL. (1996) distinguish between two main types of food supply chains: (1) supply chains for fresh products such as fresh vegetables, flowers and fruit, which in general consist of growers, auctions, wholesalers, importers and exporters, retailers and speciality shops. Basically all stages in this supply chain leave the intrinsic characteristics of the product untouched. The main processes are handling, storing, packing, transporting and especially trading. In (2) supply chains for processed food products such as portioned meat, snacks, desserts and canned food products agricultural products are used as raw materials for producing consumer products with higher added value. (VAN DER VORST ET AL., 2005)

This research focuses on supply chains for processed food products, especially on supply chains of flour mills' products which use wheat as raw material for different consumer products.

3.2 The flour mill's position in the supply chain

3.2.1 Introduction

This chapter presents the flour mill's position in the SC network structure. Both, the suppliers as well as the customers have to be mentioned to get a picture of the whole supply chain network structure, from the initial suppliers to the end-customers as shown in figure 3.1.2-1. This is of importance to bring the possible dimension of product distribution to mind. The chapter is based on industry information of the flour mill industry and the theoretical review on supply chain management given in chapter 3.1.

First the different ways of crop supply of a flour mill will be introduced. Second the main marketing channels will be described in that detail, which is possible at that early stage of the research.

3.2.2 The flour mill's suppliers

In principal there are three possibilities for flour mills to acquire crop: crop retail, other flour mills, farmers or crop imports.

Most of the crop is bought from **crop retail** or also from other **flour mills**. Acquisitions from **farmers** take about 20% of the milled crop, but this varies from wheat to rye. It is more usual that flour mills buy rye directly from farmers than wheat. This is caused in the flour mill sector's structure. Most of the rye is processed in smaller mills which have still a lot of contact to the farmers. Whereas most of the wheat is processed in large flour mills which buy most of the crop from crop retail. In average acquisition of crop **imports** are of less importance, wheat imports as well as rye imports. During the last years the import quota differed from 6% to 10%. For some mills, which are located in the near of inland waterways crop imports could be of interest, if the transport by waterway is cheaper than by land. (RUPULLA, 1997) In addition, the imported amount of crop differs between wheat and rye. Wheat imports are far more important than rye imports, which could be attributed to the smaller amount of milled rye and the flour mill structure as mentioned above.

3.2.3 The flour mill's customers

The flour is market in three different ways: export, further processing in the own company or selling to the home market.

Export

During the last years the average rate of exported flour mill products was about 8% to 9%. In the year 2005/06 it was about 9.3% or 717,000 tons. The export business is dominated by the large flour mills; almost 90% of the exported products are milled in flour mills with more than 100,000 tons capacity per year. (VDM, 2006) Nevertheless for small flour mills, which are not very well located to market, export business can be an important way for sales. (DAUS-SPEICHER, 1999) Normally the export is organised by specialised distribution companies. Only the large flour mills have their own distribution companies; e.g. the export business of WERHAHN MÜHLEN is organised by the distribution company WERHAHN FLOUR MILLS GMBH, which also markets export products of smaller flour mills.

Further processing in own company

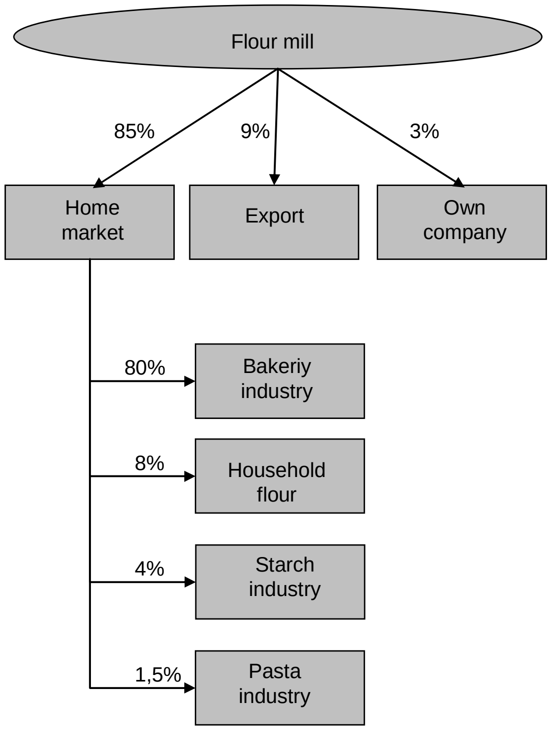
About 3% of the milled crop will be processed in the own company to nutriments, bakery improvers and other products. Also about 3% stays at the flour mill as ending inventory. (HOLLSTEIN, 2001)

Home market

The main amount of milled crop is sold to the home market (85%). (HOLLSTEIN, 2001) Because of the fact that the home market is the most important marketing channel for flour mills this research concentrates on the domestic customers. To follow LAMBERT AND COOPER'S advice not to regard all members of a supply chain to avoid high complexity (see chapter 3.1.2), primary members with a high consumption of flour take centre. Known members, including the flour mill, are arranged in the supply chain network structure of LAMBERT AND COOPER given below (see figure 3.1.2-1).

The **focal company** is the **flour mill**, which produces mainly the typical bakery flour (type 550+630) and the typical household flour (type 405); both together they represent 90% of the flour. The most important customers of flour mills are certainly bakeries with a turnover of flour of about 80%. It is important to distinguish between industrial bakeries and craft bakeries to consider the differences in product distribution. The marketing channel with the second largest turnover of flour is sales of household flour to the food retail, which takes about 8% of the flour. According to HOLLSTEIN (2001) further noteworthy customers are the starch industry (4% of the flour) and the pasta industry (1.5% of the flour). Figure 3.2.3-1 illustrates the mentioned marketing channels. These proportions will be proven in the interviews mentioned in the research framework.

Figure 3.2.3-1 Marketing channels



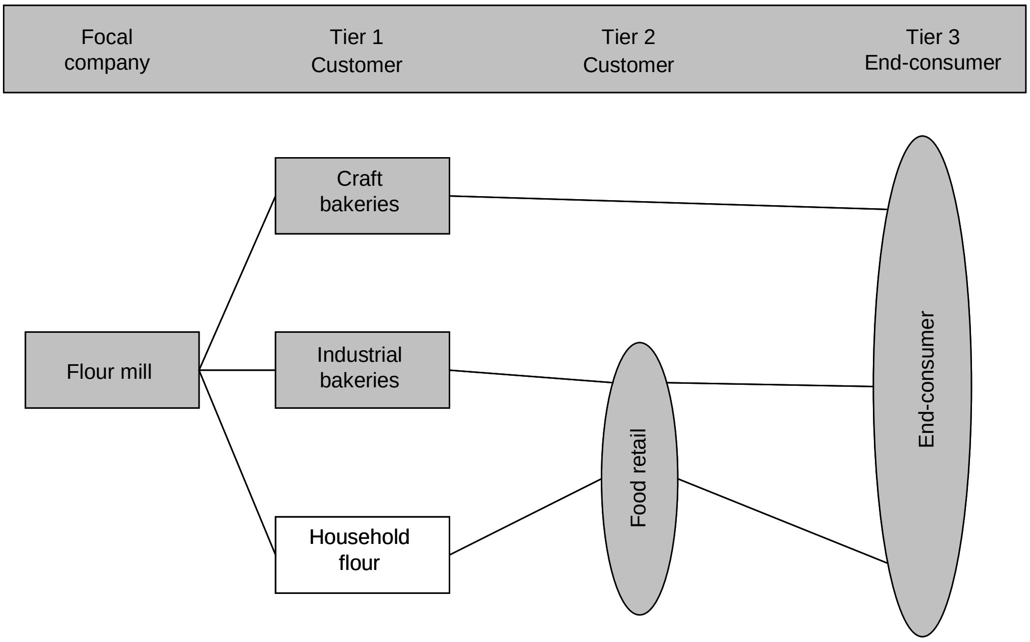
Source: Own illistration

The most important **tier 1 customers** are **craft bakeries**, which take about 52% of the flour market in Germany. (HOLLSTEIN, 2001) The supply of flour is organised by cooperative societies or via wholesale companies to concentrate the demand of the many craft bakeries, e.g. BÄKO MARKEN UND SERVICE EG, which has more than 100 locations in Germany (BÄKO, 2008). The industry of craft bakeries is characterised by a consolidation process. The number of craft bakery firms decreased to about 16,000 in the year 2006, whereas the number of craft bakery locations stayed the same with about 30,000 locations. The business trend is that craft bakeries have one place of production and some local stores, where the products are directly sold to the **end-consumer**. Nevertheless, there are still a lot of craft bakeries, where production and sale is in the same location. (ZENTRALVERBAND DES DEUTSCHEN BÄCKERHANDWERKS E.V., 2007)

Industrial bakeries are also very important **tier 1 customers** with a turn over of flour sold to the home market of about 27%. These companies get their flour directly from the flour mill and market their products via **food retail**, which can be taken as the **tier 2 customer**, to the **end-consumer**. (HOLLSTEIN, 2001)

The third **tier 1 customer** is the **food retail**, which takes about 8% of the flour. (ERNÄHRUNGSDIENST, 1998) Today the amount of household flour is only one third of the amount in the 1960's. This decrease is caused by the relocation of the production of bakery products from household to industrial bakeries. (ZUREK, 1966) Traditionally large flour mills dominated the food retail business with strong own brands or cheaper trademarks. Today both, large and small flour mills produce in equal measure products for food retail. (STEFFEN, 1999) Food retail markets completed household flour, either their own brands or brands of the flour mill, via their local stores to the **end-consumer**.

Figure 3.2.3-2 Preliminary supply chain network



Source: Adopted from Lambert and Cooper (2000)

According to HOLLSTEIN (2001) this three tier 1 customers take almost 90% of the flour market in Germany. Adding the amount of flour used for household flour and for the bakery industry about 40 % of total flour is distributed directly or indirectly via food retail. On this account further research focuses mainly on the supply chains pointed out in figure 3.2.2-2.

3.2.4 Conclusion

According to the supply chain network structure of LAMBERT AND COOPER (2000) flour mills can be arranged in the near of the initial supplier. The number of tier customers until the end-customer depends on the marketing channel of the flour mill. Based on the analysis of SCM and the business information on the flour mill industry the most important members of the supply chain network structure identified so far are presented in figure 3.2.3-2.

The theoretical background of SCM given in chapter 3.1 and the industry information deliver the bases to work out the research objective. Especially, chapter 3 is important to be able to find answers to the research question 1 of the thesis, which is mentioned in chapter 1.3.

Research question 1:

How does the distribution channel from a flour mill to the end-consumer look like?

Research question 2 deals with the risk aligned with the main marketing channels. Therefore the following chapter presents theoretical background on risk management.

4 Risk management

4.1 Introduction

A huge number of events can affect the operations of a long and complicated supply chain. Especially in food supply chains managers have to care about events which threaten companies' performance as well as consumers' health. Supply chain risk management should manage these unexpected events which define the risk. (Waters, 2007)
This chapter presents the theoretical background of risk management. A general definition of risk will be given as well as the understanding of risk management in general terms and referred to supply chains. Furthermore the risk management procedure will be mentioned. To consider food supply chain specifics quality management systems will be presented.

4.1.1 Risk definition

The Association of Insurance and Risk Management (AIRMIC), The National Forum for Risk Management in the Public Sector (ALARM) and The Institute of Risk Management (IRM) (2002) define risk as followed:

> *Risk can be defined as the combination of the probability of an event and its consequences.*

The common view of risk is the chance that an unexpected event can harm an organization. Nevertheless in all types of entrepreneurship there is the potential for events and their consequences that create opportunities for benefits or threats to success. (AIRMIC, 2002)

The fundamental attribute of risk is that unforeseen events may arrive in the future, or with other words, uncertainty about future events creates the risk. In terms of a supply chain risks are due to unforeseen events that might interrupt the smooth flow of material. (WATERS, 2007)

In the safety field, it is generally recognised that consequences are only negative and therefore the management of safety risk is focused on prevention and mitigation of harm. (AIRMIC et al., 2002)

According to WATERS (2007) it is important to point out the differences between risk and uncertainty to avoid confusions.

Uncertainty means that the events that happen in the future can be listed, but that there is no idea about which will actually happen or their relative likelihoods.

Risk means that the events that might happen in the future can be listed and that each event can be given a probability.

4.1.2 Risk management

Risk management becomes more and more one of the key parts of companies' strategic management. It is the process whereby organisations address the risks attaching to their activities with the goal of achieving sustained benefit within each activity and across all activities. The focus of risk management is the identification and the appropriate response of these risks. So, the objective is to add maximum sustainable value to all the activities of the company. To achieve these goals risk management has to be a continuous and developing process which runs throughout the company's strategy. (AIRMIC ET AL., 2002)

The objective of adding sustainable value to all activities of a company can be translated to a supply chain. GRAY AND BOEHLJE (2005) state that in addition to efficiency, inter-firm synergy, and responsiveness, for many supply chain participants managing risks is an important reason of forming a supply chain. The types of risk can be manifold: input/output price risk, quantity/quality risk, and safety/health risk. Especially in food supply chains the recent interest in managing risk associated with food safety requires to form tighter supply chains. (GRAY AND BOEHLJE, 2005)

According to both, AIRMIC ET AL. (2002) and WATERS (2007) much of risk management focuses on the three core activities: identifying risk (risk analysis), evaluating their consequences (risk evaluation) and designing appropriate response (risk treatment), which will be mentioned in the following.

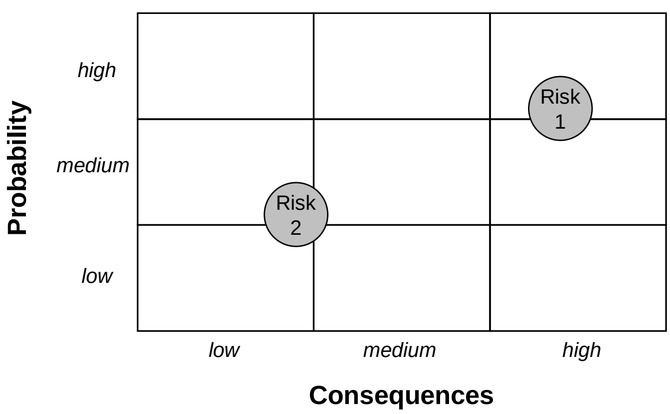
4.1.3 Risk analyses

Risk analysis can be divided into three parts: risk identification, risk description and risk estimation.

Risk identification aims to disclose an organisation's exposure to uncertainty. This requires an in-depth knowledge of the organisation, the market in which it operates, the legal, social, political and cultural environment in which it exists. To surely identify all activities within an organisation and the connected risk, the risk identification process should be in a methodical way.

Risk description should reproduce the identified risk in a structured format; e.g. a table. This is the precondition to allocate the different risks of an organisation to business activities or to categorise the risk in e.g. strategic, tactical and operational risk and so prioritise the key risks.

Figure 4.1.3-1 Example of a 3x3 matrix



Source: Own illistration

Risk estimation accounts for the probability of occurrence and the possible consequences. This can be done quantitative, semi-quantitative or qualitative. The gradation of the measurement of the probability and the consequences depends on the organisation and its needs. Shown in figure 4.1.3-1, one example can be a 3 x 3 matrix where consequences both in terms of threats and opportunities may be high, medium or low and probability also may be high, medium or low. Another possibility can be the use of a 5 x 5 matrix. (AIRMIC ET AL., 2002) According to AIRMIC ET AL. (2002) as well as KLÜGL (2004) a proven method for analysing risks is the Failure Mode and Effect Analysis (FMEA), which will be explained in more detail in chapter 4.2.

4.1.4 Risk evaluation

After analysing the risk, an evaluation is done by comparing the estimated risks against the risk criteria of the organisation, which may include associated costs and benefits, legal requirements, environmental factors, concerns of stakeholders, etc. This allows making decisions about the significance of risks to the organisation and whether each specific risk can be accepted or treated. (AIRMIC ET AL., 2002)

4.1.5 Risk treatment

Risk treatment is defined by THE INSTITUTE OF RISK MANAGEMENT as the process of selecting and implementing measures to modify the risk; i.e. risk mitigation, risk avoidance, risk transfer, risk financing, etc. Risk treatment systems should guaranty at least: effective and efficient operation of the organisation, effective internal controls (the relation of the cost of control to the expected risk reduction benefits) and compliance with laws and regulations. (AIRMIC ET AL., 2002)

According to WATERS (2007) in practise there are basically two ways of treating risk: the first and traditional one is to ignore the risk and try to response appropriate if anything unexpected occurs. Problems with this approach are that not all risks are rare enough to neglect and that a reactive approach to a problem is often to slow to avoid negative effects. The other way of treating risk is to identify risks in advance and prepare a response, which might avoid the risk or reduce its effects. The problem with this approach is that these methods often increase cost and reduce efficiency. (WATERS, 2007)

4.1.6 Quality management schemes

Although food products seem to be safer than ever before, consumers' safety perception has risen significantly. Furthermore the food sector has internationalised quite fast. The food market does not have to care about regional boundaries, so that the food industry is characterised as an interconnected system with a large variety of complex relationships. To deal with these challenges there are standard quality assurance systems which should help to improve quality and safety of products and production processes. Because all suppliers in a chain are responsible for food safety, quality assurance systems are required at each step in the production chain and so show conformance to quality and customer requirements. (TRIENEKENS, ZUURBIER, 2006)

In addition to the more general quality systems like HACCP and ISO there is a strong trend to private safety control systems, standards and certification programs. Especially large Western retailers push practice of these systems. (TRIENEKENS, ZUURBIER, 2006) In the following, an overview of most important quality management systems is given, which can regard to flour mills as wells as to other companies in the product chain.

This chapter should make clear food industry's high significance of food safety and the enormous effort to avoid product failure. Nevertheless quality assurance systems are no guarantee for food safety, so every company must be aware of the fact, that a product failure can occur and be identified too late.

Generic food quality and safety standards

Most important generic quality assurance systems in the food sector are Good Practice, Hazard Analysis of Critical Control Points (HACCP) and International Standard Organization (ISO).

The relevant **Good Practice** systems are the Good Agricultural Practice (GAP), the Good Hygienic Practice (GHP), the Good Manufacturing Practice (GMP) and the Good Trade Practice (GTP). "GAP is a guideline for reducing of chemical, physical and biological hazards. GHP is obligatory for the preventive hygienic arrangements in the firm and GMP is a basis for ensuring that products are consistently produced and controlled according to quality standards. GTP is a guideline for the adequate transport of animals, raw materials and food (KRIEGER, 2002)." (SCHIEFER, RICKERT, 2003)

HACCP (Hazard Analysis of Critical Control Points) is designed for all parts of food production; i.e. from growing, harvesting, processing, manufacturing, distribution and merchandising. (SCHIEFER, RICKERT, 2003) HACCP principals are the basis of most food quality and safety assurance systems. It is a systematic approach to identify, evaluate and control those steps of food production that are critical to product safety. Because HACCP aims at prevention of hazards instead of end-of-pipe inspection, it identifies risks in the production process and tries to reduce these risks to acceptable levels. (TRIENEKENS, ZUURBIER, 2006)

HACCP involves the following seven principals:

- Conduct hazard analysis and identify control measures
- Identify critical control points (CCP)
- Establish critical limits
- Monitor each CCP
- Establish corrective action to be taken when a critical limit deviation occurs
- Establish verification procedures
- Establish a record-keeping system (LUNING ET AL., 2002)

ISO (International Standard Organization) norms are international standards in order to achieve uniformity and to prevent technical barriers to trade throughout the world. Essential for an ISO-based quality system is that all activities are established in procedures with clear assignment of responsibility and authorities. The most used standards are the ISO 9000 standards, which formulate the framework for the quality management. The DIN EN ISO 9000:2000 norm includes basics and definitions of quality management (ISO 9000), demands (ISO 9001) and a guideline for improvements of the quality system (ISO 9004). The ISO 9000 standards are sector independent. Especially for the food and drink industry the DIN EN ISO 15161 was developed, which is a guideline for implementation of ISO 9000 and HACCP in combination. Because of increasing different national certification standards the international norm DIN EN ISO 22000 was developed to standardise these different systems. (SCHIEFER, RICKERT, 2003; TRIENEKENS, ZUURBIER, 2006)

Private food safety and quality standards

According to VELLEMA AND BOSELIE (2005) the major aims of private food safety standarts are:

- to improve supplier standards and consistency and avoid product failure
- to eliminate multiple audit of food suppliers and food manufacturers through certification of their processes

- to support consumer and retailer objectives by ”translating” these demands through the chain
- to provide concise information to assist with a due diligence defence in case of food incidents

Eurep Gap, British Retail Consortium and Safe Quality Food are the most important representatives for private food safety and quality standards.

Eurep Gap is a package of norms that should guarantee environment-friendly, safe and high quality products. Eurep (European Retailer Working Group) is an organisation of more than 20 large European retailers. Gap stands for Good Agricultural Practice. This systems focus on food safety, human resource management and environmental measurements at the stage of primary producers. (TRIENEKENS, ZUURBIER, 2006)

British Retail Consortium (BRC) standard is a set of common criteria for the inspection of suppliers of food products, derived by the UK food retail trade. Today also retailers from other European countries demand from their suppliers inspections according to BRC rules. The inspections are not carried out by the retailers themselves but by certified inspection organisations. (TRIENEKENS, ZUURBIER, 2006) BRC norm combines the HACCP principles with specific parts of GMP and parts of ISO 9000. (KRIEGER, 2002)

The bases of **Safe Quality Food** (SQF) are the HACCP norms and the ISO 9000 series norms. It aims at quality assurance in supply chains. SQF 1000 was designed specially for primary producers, whereas all other companies are certified according to SQF 2000. SQF is developed in Australia and is internationally well accepted. (TRIENEKENS, ZUURBIER, 2006)

According to TUNCER (2001) there are more than 100 different quality assurance systems based on private standards in Europe. He differentiated between certification systems for sustainable agriculture, sector-based quality assurance systems, quality assurance systems initiated by food industries, retailer systems and regional or traditional quality assurance systems. In general, systems initiated by retailers cover the largest part of the supply chain, whereas other systems only cover one or a few stages in the supply chain. (TRIENEKENS, ZUURBIER, 2006)

4.2 FMEA as a risk estimation tool

4.2.1 Introduction

To analyse potential failures and its associated effects an analytical approach is necessary. As mentioned in chapter 4.1.3 this master thesis takes the Failure Mode and Effects Analysis (FMEA) as a tool to study the possible effects of product failures of flour mills' products on the flour mill. The following chapter introduces the FMEA as a tool to analyse and estimate risks.

4.2.2 Description

According to the AMERICAN SOCIETY FOR QUALITY (ASQ, 2008) the Failure Mode and Effects Analysis (FMEA), also called Failure Modes, Effects and Critical Analysis (FMECA) can be defined as followed:

FMEA is a step-by step approach for identifying all possible failures in a design, a manufacturing or assembly process, or a product or service.

"Failure" is the problem, error or challenge. The inability of the system, process or service to perform as intended. (STAMATIS, 1995)

"Failure Mode" is the physical description of the manner in which a failure occurs; the way in which something might fail. (STAMATIS, 1995)

"Effects Analysis" refers to studying the consequences of the failure on the system, process or service. (STAMATIS, 1995)

The definition of OMDAHL (1988) additionally points out the focus of the FMEA to achieve customers' expectations:

The FMEA is an engineering technique used to define, identify, and eliminate known and/or potential failures, problems, errors, and so on from the system, design, process, and/or service before they reach the customer.

To achieve customer satisfaction, quality improvement of the products and services must be a never-ending task. The FMEA is one of the most important early preventive tools, which should avoid that failures and errors occur and reach the customer. It is often used to provide the causes and effects of failures before a system, design, process, or service is finalised. For each failure, an estimate is made of its effect on the system, design, process or service, of its seriousness, of its occurrence, and its detection. In general a FMEA delivers:

- The identification of known and potential failure modes
- The identification of the causes and effects of each failure mode
- The prioritisation of identified failure modes according to the risk priority number, which is the product of frequency of occurrence, severity and detection
- The provision of corrective actions

The starting point of a FMEA is as soon as some information is known. Practitioners should not wait for all the data, because a status of perfect information will never be achieved. As such, the FMEA can be set up at any point between system conception and manufacturing or service delivered. It is a quite dynamic tool to meet the dynamic requirements of improving quality and so it must be continually updated as often as necessary. (STAMATIS, 1995)
To identify and prevent problems from reaching the customer the assumption has to be made that problems have different priorities. There are three components that help to define the priority of failures: occurrence (O), which is the frequency of the failure; severity (S), which delineates the seriousness of the failure; and detection (D), which is the ability to detect the failure before it reaches the customer. The usual way to define the value of these components is to use numerical scales, which can be qualitative and/or quantitative. The ranking of the criteria is not standardised; however there are two common rankings. One is a ranking based on 1 to 5 scale, which offers ease of interpretation, but it does not provide sensitivity. The second is a ranking based on a 1 to 10 scale, which provides ease of interpretation, accuracy, and precision in the quantification of the ranking. The priority of the problems is articulated via the risk priority number (RPN), which is the product of the occurrence, severity and detection. The RPNs of the different failures should only be used to rank these failures. If there are more failures with the same RPN, then severity (and then detection) should be approached first, because it deals with the effect of the failure. Detection should be approached before occurrence, because it affects the customer, which is more important than just the frequency of a failure. (STAMATIS, 1995)

4.2.3 Types of FMEA

Dependent on the point of time, the area and the object of observation, different types of FMEA's can be distinguished. The GERMAN ASSOCIATION FOR QUALITY (DGQ, 2004) differentiates between the three types of FMEA: System-FMEA, Design-FMEA and Process-FMEA. Furthermore STAMATIS (1995) differentiates a fourth type: the Service-FMEA.

A short description of the four types:

1. *System-FMEA*

   A System-FMEA is used to analyse systems and subsystems in the early concept and design stage. It focuses on potential failure modes between the functions of the system caused by system deficiencies. It includes interactions between systems and elements of the system.

2. *Design-FMEA*

   A Design-FMEA is used to analyse products before they are released to manufacturing. It focuses on failure modes caused by design deficiencies.

3. *Process-FMEA*

   A Process-FMEA is used to analyse manufacturing and assembly processes. It focuses on failure modes caused by process or assembly deficiencies.

4. *Service-FMEA*

   A Service-FMEA is used to analyse services before they reach the customer. It focuses on failure modes caused by system or process deficiencies.

   (STAMATIS, 1995)

4.2.4 FMEA procedure

To accomplish a FMEA effectively it is important to follow a systematic approach. All FMEA types are based on the same general procedure. Specific details have to be accommodated to the specific situation and so vary with organisation or industry. According to STAMATIS (1995) and the AMERICAN SOCIETY FOR QUALITY (2008) the procedure is as follows:

- Selection of a cross functional and multi disciplined team.

- Identification of the scope, the boundaries of the FMEA. The question is how detailed the analysis should be. For better understanding a functional block diagram (System- and Design-FMEA) or a process flowchart (Process- and Service-FMEA) is helpful.
- Data collection and analysis. The FMEA form has to be filled in.
    - Identification of the function of the scope
    - Identification of the ways failure could happen
    - Identification of the consequences on the system, process, product, service or customer of each failure
    - Determination of how serious each effect is
    - Determination of all potential root causes for each failure mode
    - Determination of the occurrence rating for each cause
    - Identification of process controls for each cause
    - Determination of the detection rating for each control
    - Calculation of the risk priority number
    - Identification of recommended actions

4.2.5 Conclusion

The theoretical background given presents a structured proceeding on risk management including the FMEA as an effective tool to analyse and estimate risk. Further research restricts on the risk analysing process, mentioned in chapter 4.1.3: risk identification, risk description and risk estimation. The steps risk evaluation (chapter 4.1.4) and risk treatment (chapter 4.1.5) will be not accounted for because they are depending on the individual risk criteria and risk acceptance of the company and are not related to the objective of the thesis. The procedure of the FMEA will be adapted to the given research problem.

Chapter 4 should help to work out the research objective of the thesis and serves as a guidance to be able to answer research question 2, mentioned in chapter 1.3.

Research question 2:

How to assess the risk aligned with the main marketing channels?

The information given in this chapter and the one before will enhanced in the following chapter to elaborate a risk estimation framework.

5 Framework

5.1 Introduction

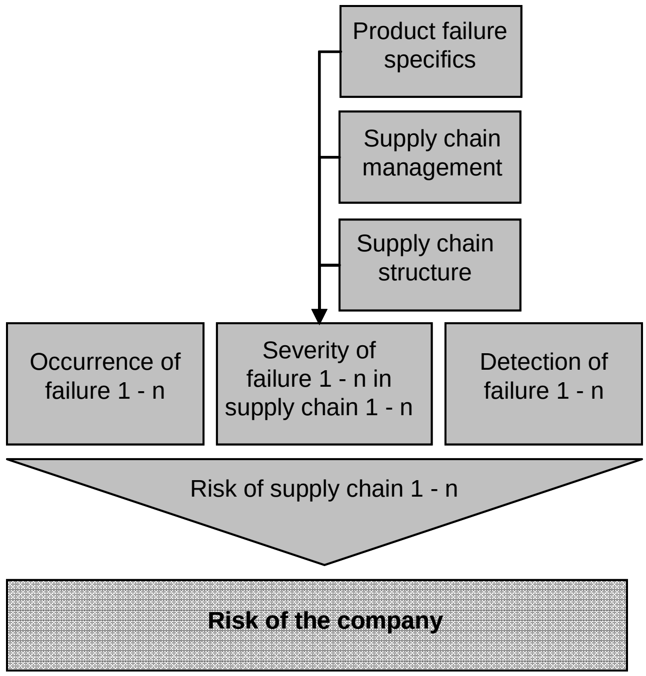
Chapter 3 delivered general information about supply chain management and considered food supply chain specifics. Chapter 4 dealt with risk management as well as introduced the FMEA as a risk estimation tool. Both, the studied concepts in chapter 3 and 4 are taken into account in the following part providing a framework to estimate risk associated with contaminated products in food supply chains. Due to the risk management approach of this thesis the framework focuses on the distributional effects and its magnitude of consequences. Nevertheless, the framework is developed in general terms to make it generally applicable to other food supply chains.

5.2 Risk estimation framework

The framework includes the main components of the FMEA (chapter 4.2.2). The FMEA is arranged in the risk management processes in the step 'risk estimation'. Following the steps of risk analysing, mentioned in chapter 4.1.3, before applying the framework the risk has to be identified and described. For this general purpose it should be sufficient to define the failure as the fact that a contaminated product leaves the focal company and arrives the customer. The effect analysis focuses not on the effect itself but on the possible magnitude of consequences of the effects.

With regard to chapter 4.2.2 the FMEA delivers the following: (1) The identification of failures is of huge importance to consider typical product characteristics, which may influence the distribution of the contaminated product in the supply chain network structure. The failure identification is based on inside information of specialists of the focal company which can be gathered via in-depth interviews. (2) The identification of causes is not of interest, so that it would be sufficient to call the causes 'failure in the production process'. As mentioned in chapter 1.1 the focus of this risk management approach is not on production processes. (3) Via the risk priority number first the failures are ranked within each supply chain; i.e. the risk linked to a special product failure if this product failure reaches a special supply chain. Second, the supply chains themselves are ranked. Regarding to chapter 3.1.2 the focus should be on the most important members of a supply chain network structure, otherwise it would lead to high complexity and affects counterproductive (LAMBERT AND COOPER, 2000). (4) The provision of corrective actions is not content of this research and is left out.

Figure 5.2-1 Risk estimation framework



Source: Own illustration

As mentioned in chapter 4.2.2 the risk priority number bases on the components: occurrence, severity and detection. The occurrence of the failure should be gathered from expert interviews with the focal company. It has to be kept in mind that the rating of the severity of the failures contains difficulties. It is not based on homogeneous and constant information, which might be easy to measure quantitatively. In fact, the rating is based on rough estimates of several experts. Furthermore with regard to chapter 3.1.4 food supply chain specifics have to be considered which may lead to unforeseen changes; e.g. quality variation between different producers and different lots, perishability of products, uncertain production yields. The severity will be influenced by the supply chain structure, the supply chain management components and the failure specifics (e.g. effects on human health). To determine the severity following important assumptions have to be made:

- The faster the contaminated product goes through the supply chain, the higher the magnitude of consequences. This is because the faster the product reaches the end-consumer, the less time remains for emergency measures.

- The broader the regional distribution is, the higher the magnitude of consequences. This is because it is to assume that the more the products are scattered inside a country or over few countries, the more difficult are reactions on the occurrence of contaminated products.
- The more the management components of a supply chain are pronounced, the faster the distribution of failures can be stopped.
- The more organisations and end-consumers are affected, the higher the magnitude of consequences.

The probability of detection should also be gathered from an interview with an expert of the focal company. The ranking of the occurrence, the severity and the detection is based on a 1 to 5 scale, because of its ease of interpretation (see chapter 4.2.2).

The aspects discussed above are put together in figure 5.2-1 to provide a better understanding and to point out the interdependencies.

5.3 Conclusion

This framework should not only help to work out the research objective, but also it should present a general framework to estimate risk with focus on the distributional effects in other food supply chains. Here, it is to note that this framework does not consider all aspects influencing the magnitude of consequences. According to the framework for chain/network development, mentioned in chapter 3.1.2, VAN DER VORST ET AL. (2005) list also chain business processes and chain resources as important factors for chain performance. They are here not taken into account, because they are not content of the research focus.

After elaborating a detailed framework the empirical part of the thesis will follow.

EMPIRICAL STUDY

6 Case study

6.1 Introduction

The empirical part of the research project consists of the description of the case study in this chapter and the analysis of the results in chapter 7.

Before implementing the case study its procedure will be explained. This chapter introduces first the interview partners (chapter 6.2). Furthermore it discusses the case study methodology including the interview questions (chapter 6.3) and the interview procedure (chapter 6.4).

6.2 Interview partners

The most important interview partner is the director of the PLANGE FLOUR MILL in Neuss, which belongs to the **WERHAHN MÜHLEN GMBH & CO. KG**, Neuss. This interview represents the single case of the thesis' case study mentioned in the research strategy, chapter 1.6. On the one hand the company is chosen because of an already existing good relationship between Bonn University and the company. On the other hand because of the company's underneath listed disposition in the flour mill market this interview partner should deliver significant information.

WERHAHN MÜHLEN GMBH & CO. KG is Germany's second largest provider of milled products with a yearly output of roughly 1.1 million tons of grain (20% market share). The industrial and bakery flour product line brings together eight mills. Furthermore there is a bakery convenience product line, which consists of eleven companies in Europe. This is especially of advantage to gather more detailed information of the distributional structure, not only from a flour mill's angle. The retail brands product line consists of the brand DIAMANT and GOLDPUDER which are flours and baking mixtures.

Further interview partners are experts of the following industry associations. They are chosen to gather information with a broad and general character of the most important members of the supply chain network structure. This is of importance to prepare the interview with the director of the flour mill effectively and to have an information source on the macro perspective to validate the outcome of the flour mill interview. These interviews are done before the interview with the flour mill takes place.

The **German flour mill association** (VERBAND DEUTSCHER MÜHLEN E.V.), located in Bonn, represents about 750 flour mill companies with more than 90% of the milled crop in Germany. Its main functions are to advice the flour mills in political, economical, legal and technical questions. Furthermore market analyses are of importance.

The **association of the German craft bakeries** (ZENTRALVERBAND DES DEUTSCHEN BÄCKERHANDWERKS E.V.) is located in Berlin and represents more than 16,000 craft bakeries. The main functions of the association are to act for the craft bakeries in reference to political and economical matters.

The association of industrial bakeries (VERBAND DEUTSCHER GROßBÄCKER E.V.) was also planed to be interviewed, but unfortunately the director was not interested in this research project, so that an interview falls through.

The **association of producers of bakery improver** (VERBAND DER BACKMITTEL- UND BACKGRUNDSTOFFHERSTELLER E.V.), which is located in Bonn, represents at least 98% of the companies in its industry. Members of this association are producers of e.g. bakery improver, baking flavours, convenience products, and starch. The companies are all assigned to the supplying industry; i.e. they only deliver to other producing companies of the food industry. The main functions of this association are advisory activities and market analyses.

6.3 Interview questions

The case study aims at answering the research questions with the help of the theoretical framework given in chapter 5. In order to be consistent in the entire report the structure of the interview questions is geared to the research questions (chapter 1.4) and the components of the theoretical framework.

In the following the content of the interview questions for the flour mill are reflected. The interview questions for the associations were adapted each time, based on the outcome of the previous interview. As regards contents all interviews have the same focus.

The interview starts with short general questions on the company and the respondent, which should deliver a kind of background and control information.

The second part of the questionnaire deals with the supply chain network structure. The questions are mainly based on the theoretical information of the SCM framework given in chapter 3.1.2. The respondent is asked to name the most important marketing channels and the main branches of the supply chain network with their characteristics; i.e. number of companies and degree of homogeneity. Furthermore transactions of flour products between flour mills are of interest as well as processes in the supply chains which are managed or monitored by the flour mill. Main focus is on the time horizon of the product flow from the flour mill to the end-consumer and on the regional distribution until the product reaches the end-consumer. This part should deliver the information to answer research question 1, given in chapter 1.4, and to fill in the framework component ‘severity’ (see figure 5.2-1)

The interview questions in part three are based on the supply chain management components in chapter 3.1.3. Following management components will be observed: Questions on the organisational structure, especially if employees are working across organisational boundaries, e.g. field service, should give more details about the business relationship between companies. As to the product flow facility structure, product distribution and company crossing inventory management are of main importance. The information flow facility structure is of interest, i.e. the modality of information (IT-based, personal) and the frequency of information, because in concern of product failures a frequent information exchange is important. This part should deliver information to help to answer research question 2 (see chapter 1.4) and to fill in the framework component ‘severity’.

Part four of the questionnaire contains questions on the product failure, which are based on the theoretical background of risk management given in chapter 4.1 allowing for the food supply chain specifics of chapter 3.1.4. First the kinds of product failure, their effects on human health and the probability of occurrence are asked for. Additionally there is a question about the failure detection methods. Furthermore food specifics which advance the distribution are considered, e.g. possibilities of cross-contamination. At least the probability that a customer of the flour mill detects the product failure is asked. This part should deliver the rest of the information to answer research question 2 and to fill in the framework components ‘occurrence’ and ‘detection’, shown in figure 5.2-1.

The following table summarises the parts of the interview questionnaire and illustrates their targeted information.

Table 6.3-1 Interview questions

Parts of the interview	Targeted information
1. Profile of the company / respondent	Background and control information
2. SC network structure	RQ 1 and framework component ‘severity’
3. SC management components	RQ 2 and framework component ‘severity’
4. Product failures	RQ 2 and framework components ‘occurrence’ and ‘detection’

Source: Own illustration

The complete questionnaire is shown in the appendix. With regard to the research focus the most important questions are about the distributional effects which are asked in part 2 of the questionnaire. To stress their importance they are listed up below.

> *How would you assess the time horizon of the product flow from the flour mill to its customer? How would you assess this time horizon at the following tiers in the supply chain network structure?*
>
> *How would you assess the regional distribution of the flour mill products by each tier in the supply chain network structure?*

6.4 Interview procedure

All interviews were accomplished based on interview protocols to increase the reliability of this research. The protocol of the interview with the flour mill is included in the appendix and consists of an introduction document and the real interview questions.

In order to give the respondent the necessary information to prepare the interview the introduction document was sent some days before the interview would take place. This introduction document explains the research problem and gives the topics of each part of the interview.

The document with the real interview questions was used during the interviews as a guideline to finish all important questions and to visualise the questions by figures.

The interview protocols of the interviews with the industry associations are structured in the same way. Nevertheless each questionnaire differs a little bit from the others because each questionnaire is influenced by the output of the previous one. Thus, the interview with the German flour mill organisation was first, than the interviews with the association of the craft bakeries and the association of the producers of bakery improver and at least the interview with the flour mill. This enabled to formulate the interview with the flour mill most effectively, based on theoretical background as well as on the expert information.

The interviews with the flour mill as well as the interview with the German flour mill association were done face to face. The interviews with the association of the craft bakeries and with the association of the producers of bakery improvers were done on demand of the respondents via telephone.

6.5 Conclusion

This chapter presented a clear case study methodology. This shows that the required groundwork is elaborated to carry out effective interviews. The results of the interviews are presented in the following part.

7 Results

7.1 Introduction

The previous chapter discussed the case study methodology and explained how the empirical research has been implemented.

The objective of chapter 7 is to provide the results of the interviews carried out during the case study research. After explaining the investigation the case study results are given. The results are presented in the order of the risk analysing steps discussed in chapter 4.1.3; i.e. risk identification, risk description and risk estimation. This chapter completes with the outcome of the FMEA.

7.2 Entry to the investigation

The in the following represented results are mainly based on the information of the director of the PLANGE FLOUR MILL in Neuss, who is not only well informed about the business of the PLANGE FLOUR MILL itself, but also about other flour mills of the WERHAHN MÜHLEN GMBH & CO. KG. Of course, all results are aligned and supplemented by the other interviews and the literature research if necessary. Furthermore results with explicitly general character are noted as such.

As mentioned in chapter 6 the structure as well as the content of the interview questions is geared to the research questions and the risk estimation framework given in chapter 5. To be consistent and to present the results in a logical order the following parts of this chapter are based on the risk estimation framework arranged in the risk analysing steps (see chapter 4.1.3).

The purpose of chapter 7.3 and 7.4 is to make clear that the flour mill is confronted with risk. Furthermore the risk is described well arranged in failure classifications to get a better understanding.

Chapter 7.5 contains the most important results of the case study. In this chapter the risk estimation framework is adopted to the flour mill. Following the framework, the first part contains the probability of occurrence and the probability of detection of each failure classification. These two components of the risk estimation framework are put together in one part because there are strong interrelationships between occurrence and detection, and for this research focus it is not helpful to describe these components separately. The second part describes the severity, which is measured by the supply chain structure, the supply chain management components and the failure specifics, mentioned in chapter 5.2. At last the results of the FMEA are presented in chapter 7.6.

7.3 Risk identification

Starting a risk analyses process a methodical way to identify all risks is advised in chapter 4.1.3. Here, this is not required, because the focal risk is already known and can be explained in the following way.

According to the definition of risk in chapter 4.1.1, risk is the *combination of the probability of an event and its consequences.*

The event is that a product failure will occur and be not detected by the flour mill and so leaves the company. POIGNÉE AND HANNUS (2003) refer in their case study to specific production processes of flour mills and examples of aligned product failures, which are expressed below.

- *Crop purchase*: contamination by foreign material, residua of pesticides and heavy metals can be above the legal maximum, contamination by moulds with creation of Mykotoxin.
- *Crop cleaning*: contamination by foreign materials like stones, wood, straw, etc., or seed of pest plants
- *Preparation*: increase of micro organisms
- *Crop milling*: contamination by moulds
- *Packaging*: contamination by foreign material
- *Transport*: contamination by damaging

This list of typical product contaminations should help to imagine what kinds of product failures can occur. As mentioned in chapter 4.1.6, to deal with the challenges of consumers' high safety perception companies use different quality management systems, which should increase product quality and avoid product failures. The bases of quality management systems, which are implemented in all flour mills, are Good Hygienic Practice, Good Manufacturing Practice, HACCP and ISO. Especially large flour mills, which deliver directly to large retailers or to the food industry, whose customers are retailers, implemented also private quality standards like BRC to achieve their customers' demand. To sum up, the most flour is produced in flour mills, where generic quality systems as well as private quality systems are part of the risk management. As mentioned above quality management systems should avoid product failures, but they do not control the end-product. To analyse the crop and the flour the PLANGE FLOUR MILL has its own laboratory. There, the product is tested for 250 different contaminations. Because of a laboratory's high cost this additional product control can only be carried out by large flour mills. Nevertheless, a product failure can never be eliminated. The probability of the event that a product failure occurs and will not be detected will be discussed in chapter 7.5.

As regards the consequences, it is to assume that the product failure will be detected at any stage in the supply chain network structure. If the product failure causes the interruption of the smooth flow of the products, as WATERS stated in chapter 4.1.1, there will be consequences for the flour mill; e.g. product recalls, production stops. Furthermore in the safety field consequences are always negative (WATERS, 2007). The magnitude of these consequences will be discussed in chapter 7.5.

The existence of an event (product failure occurs and will be not detected), with a probability of more than zero and its possible consequences clearly define that there is a risk.

7.4 Risk description

After identifying the risk the research focuses on, it should be displayed in a structured format as mentioned in chapter 4.1.3.

For the further research a very detailed product failure classification is not required. Also, the relation of the product failures to the production processes is not of interest, because the focus of this research is not on the probability of failures in production processes. According to ELLES AND LENDLE (2006), for this research the contaminated products are classified into three for the food industry typical types:

- *Biological contaminations*, e.g. bacteria, fungi, toxin
- *Chemical contamination*, e.g. pesticides, toxicities
- *Physical contaminations*, e.g. glass, metal, wood, stones

Following the advice of AIRMIC ET AL. in chapter 4.1.3, to clarify the risk in a structured way, some results of the interview questions on product failures are presented in the tables below. There the following information on biological contamination (table 7.4-1), chemical contamination (table 7.4-2) and physical contamination (table 7.4-3) are given. The nature of the risk depicts if the risk can be characterises as e.g. operative, strategic or financial. In this initial stage of researching on this risk management approach the nature is an operative one, because first the occurrence depends mainly on failures in production processes and the severity depends on the production flow. The filed 'origin' lists typical examples of flour contaminations to assign the failure classifications to single contaminations. The failure classification divides the risk based on the kind of contamination between biological, chemical and physical contamination. As mentioned in the introduction not only the flour mill might has to face consequences, but also the end-consumer. To make the possible consequences more concrete examples of consequences for the flour mill as well as for the end-consumer are listed for each failure classification. Finally the factors influencing the magnitude of the consequences are given, because they represent the fundamental part of this research. Here it is divided between the factors based on the network structure and based on the contaminations influence on humans' health.

Table 7.4.-1 Risk description of a biological contamination

Name	Biological contamination occurs and will not be detected by the flour mill
Nature	Operative
Origin (example)	Micro organisms go into in the flour Creation of moulds Parts of little insects go into the flour, e.g. little beetles
Failure classification	Biological contamination of the flour
Possible consequences for the flour mill	Product recalls, production stop, liability suits, damage to image of the flour mill
Possible consequences for the end-consumer	Diseases
Influence on the magnitude of consequences	Dimension of affected organisations and end-consumers Degree of the risk to health

Source: Own illustration

Table 7.4.-2 Risk description of a chemical contamination

Name	Chemical contamination occurs and will not be detected by the flour mill
Nature	Operative
Origin (example)	An origin in the flour mill can be excluded There is the possibility of chemical contaminated crop
Failure classification	Chemical contamination of the flour
Possible consequences for the flour mill	Product recalls, production stop, liability suits, damage to image of the flour mill
Possible consequences for the end-consumer	Diseases
Influence on the magnitude of consequences	Dimension of affected organisations and end-consumers Degree of the risk to health

Source: Own illustration

Table 7.4.-3 Risk description of a physical contamination

Name	Physical contamination occurs and will not be detected by the flour mill
Nature	Operative
Origin (example)	Foreign materials go into in the flour, e.g. stones, glass, screws, waste
Failure classification	Physical contamination of the flour
Possible consequences for the flour mill	Product recalls, production stop, liability suits, damage to image of the flour mill
Possible consequences for the end-consumer	Injuries and diseases
Influence on the magnitude of consequences	Dimension of affected organisations and end-consumers Degree of the risk to health

Source: Own illustration

7.5 Risk estimation

7.5.1 Occurrence and detection

In general, the flour mill industry is not confronted with a lot of product complaints. This constitutes that during the last 10 years there was no food scandal caused by flour in Germany. On the one hand the product itself is not that vulnerable to deterioration like other food, e.g. meat. On the other hand the production processes of a flour mill are quite simple and do not contain processes which could act on the flour in a very harmful way.

The occurrence and the detection of contaminated flour are mainly affected by the quality of the delivered crop and the degree of the technical conditions of the flour mill. The quality of the crop is affected by the producer and the environment, and so can vary on each delivery. The technical conditions of a flour mill depends often on the size of the company; i.e. that large flour mills, like the flour mills of WERHAHN MÜHLEN, have better technical conditions to avoid and detect product contamination. The PLANGE FLOUR MILL has its own laboratory to analyse the delivered crop and the produced flour. The laboratory enables the company to test the product on 250 different contaminations. Precondition for testing is to know exactly on what contamination the product should be tested. Besides analysing the delivered crop, the quality of the flour is tested by control samples before leaving the flour mill.

In the PLANGE FLOUR MILL **biological contaminations** are mainly caused by little animals respectively parts of little animals; e.g. beetles. It can not be eliminated that little animals enter the flour mill via the crop. The detection rate is quite high, because of high technical standard of the control techniques; e.g. filters, magnetic separators, video technology.

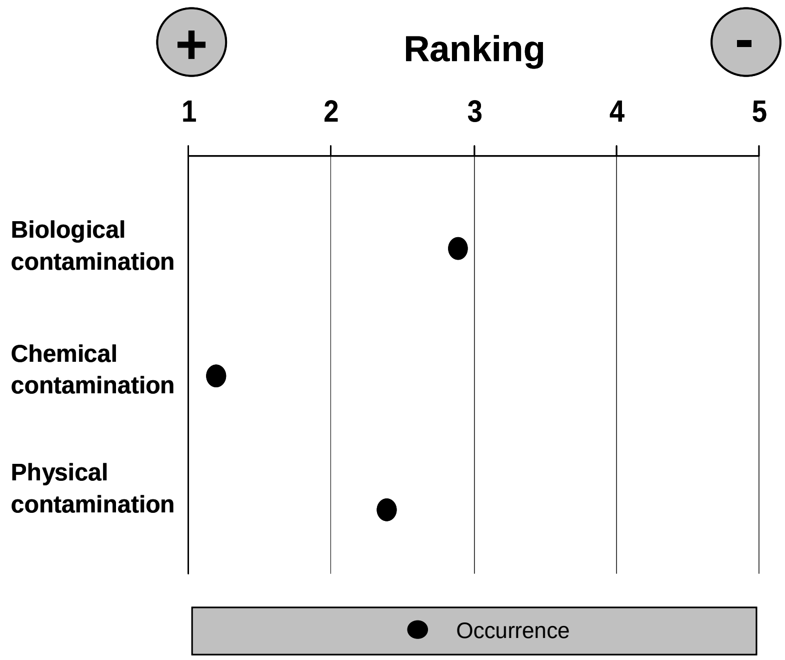
Chemical contaminations caused by the flour mill itself can nearly be excluded. If there are chemical contaminations, they are in all likelihood caused by chemical contaminated crop. For example in 2002 there was a nitrofen scandal in contaminated crop in East Germany. There, crop was stored in a hall where it was contaminated by pesticides, especially by nitrofen. Parts of the contaminated crop reached feed for animals and so with nitrofen contaminated meat arrived at food retail. Even if in this case the contaminated flour was not sold to a flour mill, nevertheless it could also have reached flour mills. Flour mills with an own laboratory can test a sample of each delivery on contamination. Thus all known contaminations should be detected. Important to note is that the laboratory can test only on known contaminations. Unknown contaminations will probably not be detected.

A **physical contamination** is mainly caused by stones, glass or other foreign materials which enter the flour mill via the crop deliveries. Furthermore particles of machines of the flour mill can enter the flour. The detection rate is also quite high, because of the above mentioned high technical standard of the control techniques (filters, magnetic separators, video technology). It is also possible that foreign materials like cigarettes or rubbish enter the flour. This can be caused by carelessness of the employees of the flour mill or because of sabotage.

According to the director of the PLANGE FLOUR MILL it can be summarised that the occurrence of chemical contamination is very small and that the detection rate because of a modern laboratory is quite high. Physical contaminations are more often, but because of the high technical standard of the flour mill the detection rate is also high. Biological contamination are also much more often than chemical contaminations, but the detection rate is here very high, too. The product contaminations can be ranked according their probability of occurrence and detection as follows. Biological contaminated flour has the highest probability of occurring and not detecting by the flour mill, followed by physical contaminated flour. The most improbable event is that chemical contaminated flour leaves the flour mill. Thus, the character of risk that events which might happen in the future can be listed is fulfilled (see chapter 4.1.1). In the following the probability of occurrence and of detection is considered only combined; i.e. in the following the term ‘occurrence’ refers to the situation that a contaminated product occurs and will not be detected so that it leaves the flour mill. Figure 7.5.2-1 presents the ranking of the risk classifications.

This ranking as well as the following rankings represents the aggregation of the assessment by the different interview partner.

Figure 7.5.1-1 Ranking of the risk classifications by occurrence



Source: Own illustration

7.5.2 Severity

According to the risk estimation framework explained in chapter 5.2 the severity of a failure is influenced by the supply chain structure, the supply chain management and the product failure specifics.

Supply chain structure

Chapter 3.2.4 already presented roughly the main customers of a flour mill based on literature research. In the following the results of the interviews should give a more detailed and reality based picture of the supply chain network structure with the flour mill as focal company.

The consolidation process during the last decades comes along with a specialisation process; i.e. a lot of flour mills concentrate on producing specialties or usual kinds of flour in large amounts. Thus, today it is very common that flour mills do not produce all kinds of flour they sell by their own, but purchase some kinds of flour by other flour mills. Especially large flour mill companies like VK MÜHLEN and WERHAHN MÜHLEN, which consist of multiple flour mills transactions of flour between each flour mill are usual. The customers of the flour mill can be divided into four groups. The most important customer group is represented by craft bakeries, which take about 46% of the flour. This group includes very little craft bakeries as well as bakery chains with a lot of shops. The next customer group consists of industrial bakeries which take about 24% of the flour. The third group is represented by the food retail which takes about 8% of the flour. The rest of the flour is sold to other food processing companies which can not be merged into one business. In chapter 3.2.4 the starch industry was mentioned as a main fabricator of flour. This is true, but the starch industry is not a customer of the flour mills, because most companies of the starch industry mill the flour by them selves.

The flour mill delivers a lot of craft bakeries directly, especially the large ones. The smaller craft bakeries get their flour often from the wholesale. Industrial bakeries are always served directly by the flour mill. These companies market their products via food retail. It is obvious that the number of craft bakeries is much higher than the number of industrial bakeries. Nevertheless, it can be assumed that craft bakeries have the same proportion of flour consumption to end-consumer than the industrial bakeries, because of a comparable range of products. Thus, via craft bakeries twice as much end-consumers are served than via industrial bakeries.

The supply of food retail happens either directly, i.e. the flour mill delivers to the shop, or indirectly, i.e. the flour mill delivers to a distribution centre. This depends on the retail company.

The fourth group of ‘other food processing companies’ are always delivered directly by the flour mill. The companies usually sell their products to a further food processing company and than via food retail to the end-consumer. The proportion of flour on the end product is very small, so that much more end-consumers are reached compared to craft bakeries, industrial bakeries and the direct marketing via food retail.

The **main tiers** from the flour mill to the end-consumer can be summarised as followed:

- Flour mill – (wholesale) – craft bakeries (46%) – end-consumer
- Flour mill – industrial bakery (24%) – food retail – end-consumer
- Flour mill – food retail (8%) – end-consumer
- Flour mill – food industry – food industry – food retail – end-consumer

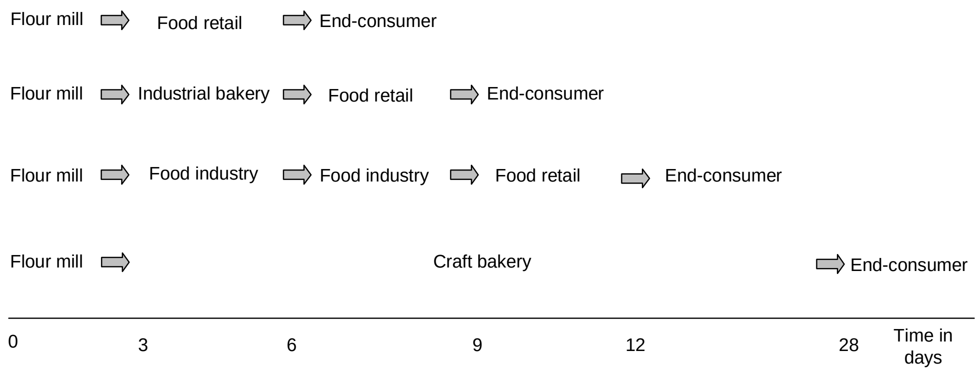
The PLANGE FLOUR MILL delivers different companies of the food industry which can not be merged. It is very important to note that the flour mill avoids customers which produce cake or pizza. This is because the flour has only a very small part of the value chain of the final product. If the final product has not the right quality caused by the flour the damage of the flour mill would be enormous. This important aspect of the flour mill's risk management will be picked up in the recommendations at the end of the thesis.

As stated in the summary of the interview questions (chapter 6.3) an important part of this research is to figure out the time horizon of the product flow from the flour mill to the end-consumer as well as the regional distribution of the flour by each tier in the supply chain network structure.

The **time horizon** of the product flow from the flour mill to the end-consumer is influenced by the particular involved businesses. The PLANGE FLOUR MILL is continually served with crop. The flour mill needs about 20 minutes to mill one grain of crop to flour. In 60 minutes all small parts and rests of that grain have left the milling process. Normally, bulk flour stays for one to two days in the flour mill. The flour mill has a silo capacity to stock bulk flour up to four days. Bagged cargo stays in the flour mill up to 30 days. The frequency of supply varies the most at craft bakeries. Large craft bakeries get bulk flour in intervals of a few days. Small craft bakeries get normally bagged cargo in intervals up to four weeks. Thus, large craft bakeries consume their flour into a few days, whereas very small bakeries need some weeks to consume the delivered amount of flour. The supply frequency of industrial companies is quite the same. Industrial bakeries, food retail and other food companies are served in intervals up to three days, some companies even daily. All industrial companies try to avoid stocks of flour. Thus, it is to assume that these companies also market their products into a few days.

To illustrate the differences in time, flour needs to go through each marketing channel the most important members of the supply chain network structure are arranged in the following time table (7.5.3-1). As mentioned above the time specifications can vary, nevertheless tendencies between the different marketing channels can be identified.

Figure 7.5.2-1 Time horizon of the product flow



Source: Own illustration

The **regional distribution** of the flour is mainly influenced by the regional concentration of the customers and the very high proportion of transportation costs on the value of the flour. In Germany there are huge differences in the transportation distance between West and East because of the differences in settlement of people and companies. The customer of the PLANGE FLOUR MILL in West Germany is on average 80km afar from the flour mill. The customer of one of the flour mills of the WERHAHN MÜHLEN in East Germany is on average 250km afar from the flour mill. In general most customers buy their flour from the nearest flour mill, because of the high transportation cost. As already mentioned craft bakeries are very heterogeneous. The very small craft bakeries are served by the wholesale, so that the flour mill delivers the flour to a distribution centre and than it is passed out to the bakeries. Larger bakeries are served directly by the flour mill. Because of the central position of the PLANGE FLOUR MILL in West Germany most of the customers in the craft bakery business are located in the near of the flour mill.

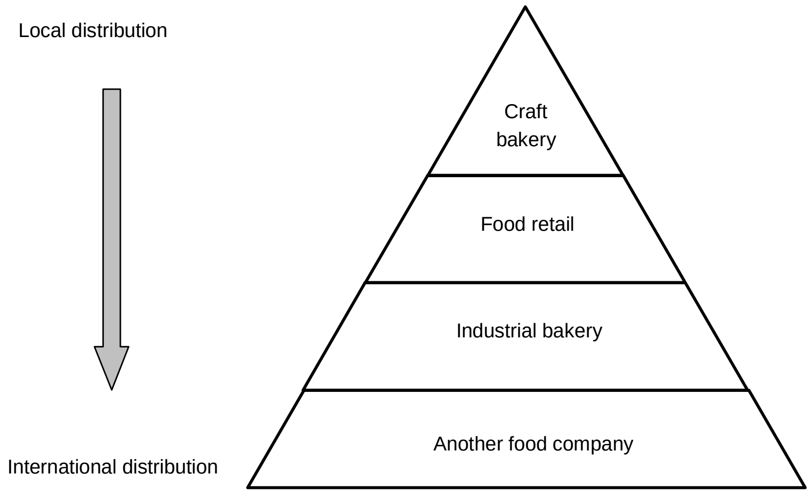
In the case of the PLANGE FLOUR MILL a lot of industrial bakeries are located in the near of the flour mill. Here, it is also to assume that the industrial bakeries try to buy there flour from the nearest flour mill because of the relatively high proportion on flour of the final product. These companies market their products via food retail, so that they can be located throughout the country, or partly in other countries.

The distribution of flour by food retail as the flour mill's customer can not be defined clearly. The own brands of the flour mills are distributed to different food retailers in the whole country. It can be assumed that the retailers get the most flour for trade names from the nearest flour mill to avoid transportation costs.

Selling the flour to other companies in the food industry, the distribution can not be restricted and is only hard to reconstruct. For most companies of this customer group the proportion of flour on the value chain is quite small, so that these companies do not have to care so much about transportation costs than other companies. Furthermore these companies mostly sell their product to a further food producing company and than it is market via food retail, so that it is possible that the flour moves around the country and is market in whole Germany or almost whole Europe. For example, the largest producers of bakery improver market only about 50% of their products on the home market.

To sum up, the regional distribution of flour is mainly influenced by the regional conditions; i.e. the number of possible customers in the flour mill's vicinity, and the flour's proportion on the value chain of the final product. It can be assumed, that the most flour which is market to craft bakeries is the fewest distributed, followed by the flour market to food retailers. Industrial bakeries are expected to market their products at least in the whole country. The flour, which is sold to other companies of the food industry, can probably be located at end-customers in different countries. The pyramid underneath (figure 7.5.2-2) visualises the general differences in the regional distribution of flour throughout the customer groups: craft bakery, industrial bakery, food retail and another food industry.

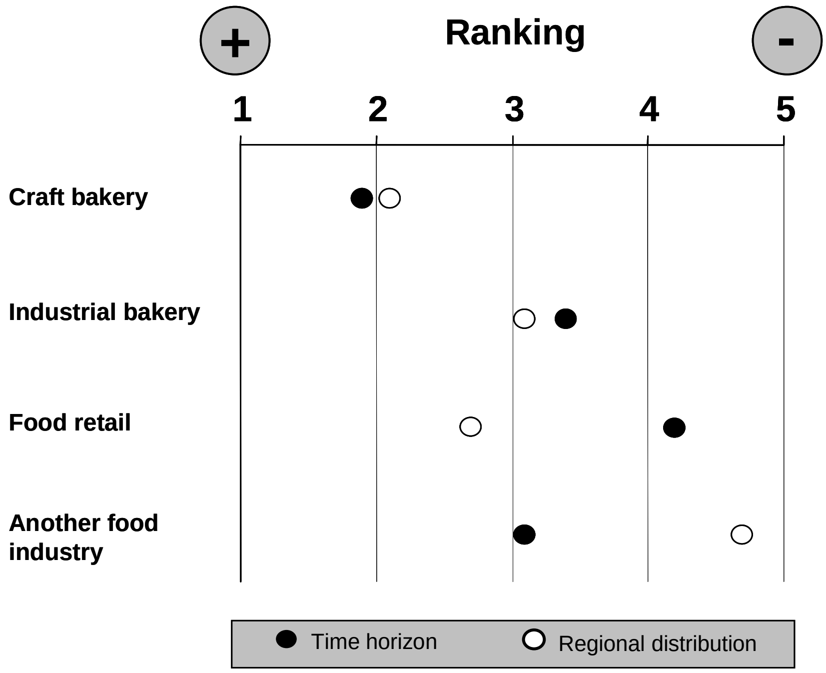
Figure 7.5.2-2 Flour distribution throughout the marketing channels



Source: Own illustration

To be able to fill in the FMEA analysis and to follow the risk estimation framework each marketing channel has to be ranked. The following ranking (7.5.2-3) visualises the differences in the time horizon of the product flow from the flour mill to the customer; i.e. craft bakery, industrial bakery, food retail and other food industry, and than to the end-consumer, as well as the differences in regional distribution. As mentioned above it is to assume that the faster the contaminated product goes through the supply chain, the higher the magnitude of consequences. This is because the more time the flour takes to reach the end-consumer, the more time the flour mill has to react on product failures and so limit the magnitude of consequences. Furthermore, the broader the regional distribution is, the higher is the magnitude of consequences. This is because more organisations or even more end-consumer have to be informed. Based on the interviews the risk assessments can be summarised as follows.

Figure 7.5.2-3 Ranking based on regional distribution and time horizon

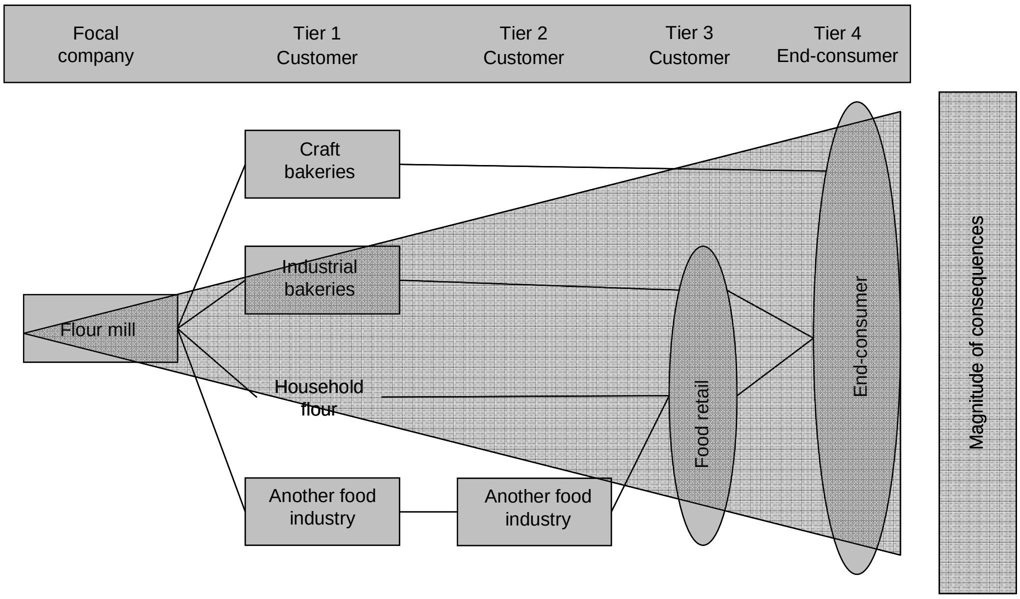


Source: Own illustration

SC management components

The answers on the questions about the SC management components describe how deep the flour mill is integrated in the supply chain network structure. As stated in chapter 3.1.2 the SC management components have a direct influence on the supply chain output. In the elaborated risk estimation framework (chapter 5) it is assumed that the more the management components are pronounced, the faster the distribution of failures can be stopped. Furthermore it is assumed that the more organisations and end-consumers are affected, the higher the magnitude of consequences. The following figure (7.5.2-4) visualises the correlation between the number of affected organisations and end-consumers and the magnitude of consequences.

Figure 7.5.2-4 Growth of the magnitude of the consequences



Source: Own illustration

The information about management components in the supply chain network structure gathered by the interviews are as followed. Most information corresponds to the flour mill, because this interview enabled the most detailed information.

There is no regular joined planning and control through one of the single supply chains. The flour mill is very good informed about their customers. Especially the production processes and the value chain are of interest. The business of the customers is looked at in regularly basis to be informed of usage of the flour and to identify possible tendencies. This means not that the flour mill controls each single company, but the processes, costs and prices of typical companies in each business are of interest. The information is gathered by individual discussions between the flour mill and its customers; i.e. the director of the PLANGE FLOUR MILL often visits his main customers. The flour mill is also interested in the business of the following tiers until the end-consumer; i.e. the customers of the flour mill's customers. But this information is in general much less detailed.

Questions on the organisational structure of the flour mills and the other main members of the SC network structure showed that the organisational structure focuses only on the own organisation. The flour mill and also its customers have no teams, which work continually across organisational boundaries. An exception is, if customers demand a new kind of flour the product development of the involved companies work together. Furthermore producers of bakery improver have a very strong relationship to its customers based on their filed workers, which do a lot of consultatory work.

As to the product flour facility structure, a long stocking of huge amounts throughout the whole SC network structure takes place only at flour mills and the upstream wholesale. The direct customers and the following tiers prefer just in time supply to avoid costs. The distribution of the flour to the customer is always organised by the flour mill; the flour is delivered either in bulk or in bags. However there is no customer oriented charge management, so that the flour mill does not produce special charges for special customers. Furthermore large flour mills prefer large batch sizes for a better handling, but they also have more complex warehouse systems. Small companies on the other hand can produce in small batches. In the majority of cases the flour mill also does not control the inventory of its customers. Most customers are not willing to allow the flour mill any insight in their company.

The information flow between the flour mill and its customers is characterised by a personal relationship to most customers. The flour mill industry as well as the bakery industry consists mainly of small and medium sized businesses with a conservative character. The contact to the customers is quite regularly to guarantee the required product quality and for customer care. This relationship between the flour mill and the customer enables an unproblematic handling of possible product failures. For example, if the customer is served with a contaminated product he can directly call the director of the flour mill so that a fast answer can be found. To sum up, the information flow between the flour mill and its customers can account for quite positive, personal, and in regular frequencies. Organisation overlapping IT-systems are not jet introduced.

As to the power and leadership structure, a direct leader in the different supply chains can not be identified. In fact it is more important to know if the flour mill has the chance to choose between marketing channels and between companies in each marketing channel. As stated in the part about the SC structure the flour mill has three definable customer channels (craft bakeries, industrial bakeries, and food retailers) and a fourth one which includes different companies of the food industry. All customer channels are very heterogeneously. The flour mills, especially the large flour mills, have the chance to choose their customers and so influence the distribution channel; e.g. the PLANGE FLOUR MILL avoids to serve cake and pasta producers.

Above, the good relationship between the flour mill and most of its customers is already mentioned. Due to the fact that the flour mill business as well as the bakery business and a lot of other companies in the food industry are often still medium-sized companies it can be assumed that there is a compatibility of business culture between the flour mill and its customers, especially the smaller ones.

In the risk estimation framework in chapter 5 the SC management components were introduced as one criterion to assess the severity of each marketing channel respectively the supply chain of the marketing channel. The results of the interviews show that it is not possible to compare the different supply chains with regard to the SC management components. In none of these supply chains any management components are in general integrated throughout the whole chain; i.e. from the flour mill to the end-customer. It can be ascertained, that managerial and behavioural components, especially the compatibility of culture and attitude, between the flour mill and its customers have a huge influence on the business relationship. Compatibility between the flour mill and its customer is often given by medium-sized companies with long business tradition. Here, it is to conclude that trust is the most important factor that influences the interactions between the flour mill and its customer.

Each marketing channel until the end-consumer consists of very heterogeneous companies, so that a classification is not possible. On this account the SC management components will not be considered in the risk estimation framework.

Product failure specifics

Chapter 7.4 already described the three product failure classifications in general: bacterial contamination, chemical contamination and physical contamination. During the interview it was asked for characteristics of each product failure which could increase the distribution of the contaminated product or which could influence the magnitude of consequences. The results are as follows.

As to biological contaminations it has to be differentiated between micro organisms, such as mould, and little animals or parts of those, such as little beetles. Micro organisms can dispread and contaminate more flour, whereas parts of little animas are normally individual cases and do not increase by its own. The effect on human health is to assess in general as not that dangerous. Thereby it is to keep in mind that the bacterial contaminated flour, if it will not be detected, runs through production processes where it is very strong heated. The predominant cases are contaminations with little insects or parts of little insects.

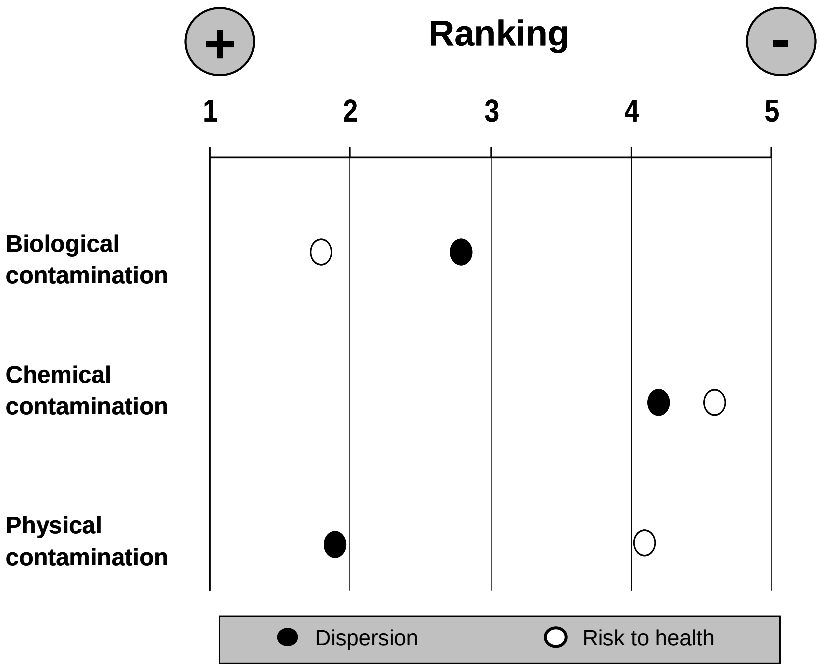
As to chemical contaminated flour it can not be excluded that the contamination dispreads. Furthermore the effects on human health can be assumed as higher than the effects of a bacterial contamination.

As to the physical contaminated flour in general this are also single cases, like a little stone, so that it is to assume that only the particular unit is affected. The effect on human health is to assess as more critical. For example glass or other sharp and peaked foreign materials can hurt the end-consumer.

The question if one of the product contaminations can be easily detected by one of the customer groups can be negated. In general the flour mill's customers do not control the incoming flour. The exception is at flour which food retailers sell without further processing via brand names to the end-consumer. Here retailers control intensively every delivery by random inspection, to protect the image of the brand.

The product failure specifics are described in the risk estimation framework as the third element to determine the severity and to fill in the FMEA. Following figure compares a bacterial contamination, a chemical contamination and a physical contamination based on their characteristics of distribution and their effects on human health.

Figure 7.5.2-5 Ranking based on the product failure specifics



Source: Own illustration

7.5.3 FMEA outcome

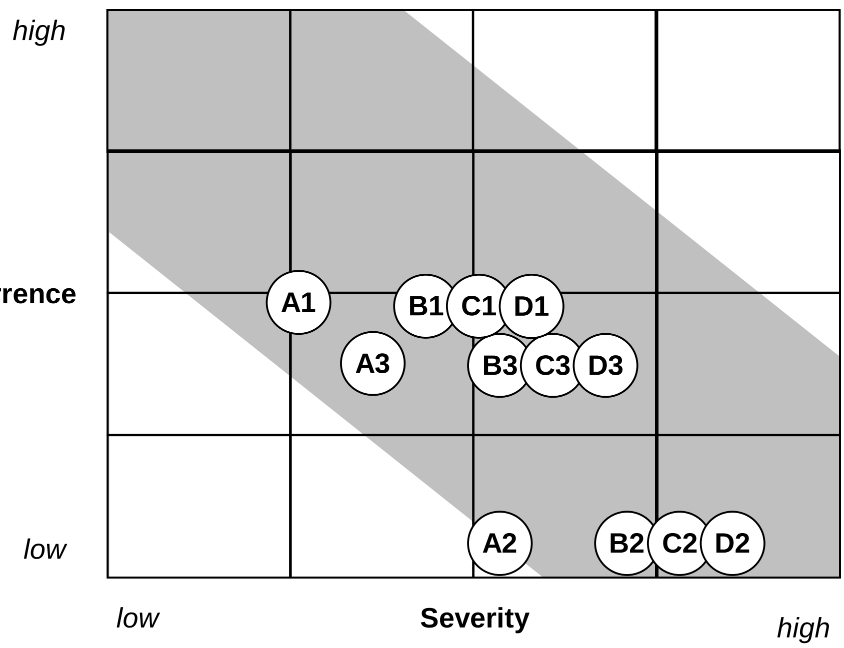
As mentioned in chapter 5.2 the elaborated risk estimation framework includes the main steps of the FMEA. The prior part delivered the results, which are the bases for the framework. In the following the results are filled into the FMEA and the outcome is presented. The FMEA forms and a detailed proceeding is deposit in the appendix.

The FMEA form restrict to the main components, which this research is interested in. The term ‘system’ names the respective supply chain. The term ‘potential failure mode’ lists the failure classifications. Further components of each FMEA are: severity, occurrence, the RPN, and the total RPN. In chapter 7.5.2 it is said that in this case the term ‘occurrence’ refers to the situation that a contaminated product occurs and will not be detected so that it leaves the flour mill. Thus, also the FMEA form is adopted and combines ‘occurrence’ and ‘detection’ both together in the term ‘occurrence’. For this research four FMEA forms are filled in, one for each identified supply chain. The first FMEA focuses on the risk in the craft bakery SC, the second one focuses on the risk in the industrial bakery SC, the third one focuses on the risk in the food retail SC and the fourth one focuses on the risk in another food industry. This procedure enables to compare the three failure classifications among each other (biological, chemical and physical contamination) as well as the four marketing channels.

The occurrence of the potential failure modes is ranked on a scale from 1 – 5 and is based on the results given in chapter 7.5.2. The severity of the potential failure mode is also ranked on a scale from 1 – 5 and is based on the results given in chapter 7.5.3. The severity is composed by the influence of first the supply chain structure; i.e. the time horizon that a product needs to go through the chain and the regional distribution of a product, and second the product failure specifics; i.e. the dispersion of the contamination and the risk to health of the contamination. The RPN is the product of the severity and the occurrence and ranks the failure classifications in each supply chain. The total RPN is the product of the single RPNs and ranks the supply chains among each other.

To visualise the carried out assessments which influence the risk of the flour mill a risk assessment portfolio is prepared (figure 7.5.3-6). There, the occurrence and the severity of each contaminated product in each supply chain are mapped.

Figure 7.5.3-1 Risk assessment portfolio



Source: Adopted from Klügl (2004)

The circles in the portfolio represent the following combination of supply chain and type of contamination:

- A1: Biological contaminated products enter the craft bakery Sc
- A2: Chemical contaminated products enter the craft bakery SC
- A3: Physical contaminated products enter the craft bakery SC
- B1: Biological contaminated products enter the industrial bakery SC
- B2: Chemical contaminated products enter the industrial bakery SC
- B3: Physical contaminated products enter the industrial bakery SC
- C1: Biological contaminated products enter the food retail SC
- C2: Chemical contaminated products enter the food retail SC
- C3: Physical contaminated products enter the food retail SC
- D1: Biological contaminated products enter another food industry SC
- D2: Chemical contaminated products enter another food industry SC
- D3: Physical contaminated products enter another food industry SC

The given portfolio visualises the **probability of occurrence** of the single failure classifications, which was already presented in the ranking 7.5.1-1. A biological contamination has the highest probability of occurrence, followed by a physical contamination and a chemical contamination. Furthermore the portfolio visualises the severity in the single marketing channels combining all taken criteria. This enables to rank the **magnitude of consequences** in the marketing channels. The magnitude of consequences is the highest if a contaminated product reaches the marketing channel ‘other food industries’, followed by marketing channel ‘food retail’, ‘industrial bakeries’, and at last the marketing channel ‘craft bakeries’ contains the fewest magnitude of consequences.

The **RPN** of each FMEA form shows that a biological contamination associates with the highest risk for the flour mill. The second highest risk is associated with a physical contamination followed by a chemical contamination. The **total RPN** reveals that marketing the flour products to craft bakeries represents the least risk, followed by marketing the products to industrial bakeries and food retail. The highest risk associates with marketing the flour products to another food industry. There, it is to say that the craft bakery SC is by far the one with the fewest risk and the SC of another food industry is by far the one with the highest risk. The risk of the industrial SC and the food retail SC are to assess similar.

7.6 Conclusion

At the beginning of chapter 7 the composition of the risk a flour mill has to face is highlighted (chapter 7.3 and 7.4). Although in the flour mill industry a lot of quality management systems are involved and large flour mills also have laboratories to avoid and detect product contaminations there is no guaranty for product safety. Additionally, if the contaminated product will be detected at any stage in the SC network consequences for the flour mill will follow. This corroborates not only the existence of risk but also the relevance of this research approach.

The risk estimation (chapter 7.5) is based on the risk estimation framework given in chapter 5. The component 'occurrence' combines the probability of occurrence and of not detecting the contaminated product in the flour mil, because first the interview made a careful division not possible and second it simplifies the estimation. The interviewee pointed out that the probability of occurrence of a contaminated product is in general very small. Nevertheless the occurrence of the risk classifications can be ranked as follows: (1) biological contamination, (2) physical contamination, and (3) chemical contamination. Thus, the following subquestion of RQ 2 is answered.

RQ 2.1: What is the probability of occurrence of a safety deficiency in a flour mill?

The severity is influenced by the SC structure, the SC management components and the product failure specifics. Based on the interviews the main tiers from a flour mill to the end-consumer could be identified as well as the importance of the different marketing channels in relation to their flour consumption.

- Flour mill – (wholesale) – craft bakeries (46%) – end-consumer
- Flour mill – industrial bakery (24%) – food retail – end-consumer
- Flour mill – food retail (8%) – end-consumer
- Flour mill – food industry – food industry – food retail – end-consumer

Thus, the following subquestion of RQ 1 is answered:

RQ 1.1: What are the different tiers from a flour mill to the end-consumer?

Because of the mentioned heterogeneity of the flour mill industry and of the flour mills' customers a range of the number of affected participants on each tier can not be listed. The consumption of flour by each customer group can serve as a kind of indicator. Thus, the following subquestion of RQ 1 is not answered:

RQ 1.2: How many participants might be affected by contaminated flour on each tier?

The time horizon of the product flow from the flour mill to the end-consumer varies much depending on the length of the supply chain and the size of the companies; it varies from 2 to 28 days. In general, if flour is sold to an industrial bakery it reaches the end-consumer in at least 9 days; if flour is sold to a food retailer it reaches the end-consumer in at least 6 days; if flour is sold to another food industry it reaches the end-consumer in at least 12 days. If flour is sold to a craft bakery it can take up to 28 days until it reaches the end-consumer. Thus, the following subquestion of RQ 1 is answered:

RQ 1.3: What does the time horizon look like from one product stage to the other?

The study on the regional distribution results that the main factors are the regional concentration of the customers and the high transportation costs of flour. It is to assume that if flour is market to craft bakeries the regional distribution is the lowest, followed by food retail, industrial bakeries and other food industries. Thus, the following subquestion of RQ 1 is answered:

RQ 1.4: What does the regional distribution of flour from one tier to the next tier look like?

Based on the interviews none of the management components seem to be generally integrated throughout a supply chain. In fact, trust seems to be the most important factor influencing the interactions between the flour mill and its customers. On this account the SC management components are not taken into account.

The product failure specifics are the last component of the risk estimation framework. Based on the dispersion of the contamination and the risk to health the product contaminations are ranked as follows. Incipient with the worst attributes: (1) biological contamination, (2) physical contamination, and (3) chemical contamination.

The risk assessment portfolio (figure 7.5.3-1) visualises the magnitude of consequences in the single marketing channels. As to the magnitude of consequences the marketing channels can be ranked as follows: the marketing channel ‘other food industries’ involves the highest magnitude of consequences, followed by the marketing channel ‘food retail’, ‘industrial bakeries’, and at last the marketing channel ‘craft bakeries’. Thus, the following subquestion of RQ 2 is answered:

RQ 2.2: How is the magnitude of the effects of a safety deficiency to assess in the main marketing channels?

According to the FMEA outcome the following ranking of the flour mill’s customers with regard to the associated risk can be presented. Rank 1 lists the one with the fewest risk.

1. Craft bakery
2. Industrial bakery
3. Food retail
4. Another food industry

EVALUATION

8 Conclusion and recommendation

8.1 Research conclusion

In the following, first the research methodology will be discussed. The preliminary research on the flour mill business enabled to try to understand the business. The study on the theories of SCM and risk management offered enough information to elaborate the risk estimation framework. Nevertheless the interviews showed that the framework did not consider enough the specialties of the flour mill business; i.e. the heterogeneity of the flour mill industry and of the flour mills' customers. Especially the component 'SC management', which theoretically influences the severity, was hard to study throughout different supply chains in the network structure. As mentioned in chapter 7.5.2 investigating SC management components a system can not be identified because of the enormous heterogeneity. Furthermore an aggravating factor is that the interview partners as well as the customers of the flour mill seem to have difficulties with giving a detailed insight in these kinds of SC management components. Here it seems to be wise to concentrate on a few samples of the flour mill's customers. As mentioned above the interviews were divided into the interviews on the macro perspective (industry associations) and on the micro perspective (flour mill). Unfortunately the industry associations did not deliver always the desired objectivity, but tried to present their members only in a positive way. Nevertheless, grouping the interviews enabled to increase the quality of the interviews and delivered information to control the results of the flour mill interview.

Having a clear and logical methodology is very important to lead the research in the right direction and to work out the objective. Furthermore it is a precondition to make the research understandable for not involved readers. This is given in this research.

As to the content of the research, now at the end the general research question, presented in chapter 1.4, can be answered.

> The **general research question** is:
> *Granted that a safety deficiency is detected too late, how does a product failure affect the flour mill's risk?*

The answer to this question depends mainly on the type of contaminated product and the chosen marketing channel. The research showed that biological contaminated products contain the highest risk potential especially because of their comparatively high probability of occurrence. On rank two and three are physical contaminated products and chemical contaminated products. Although a chemical contamination is aligned with the highest magnitude of consequences it is ranked at last because of its very small probability of occurrence. As stated in the problem statement (chapter1.1) good risk management includes the selection of marketing channels. The outcome of the FMEAs presented sales to craft bakeries as the marketing channel with the lowest risk for the flour mill. This is mainly caused by the comparatively low regional distribution and the slow product flow from the flour mill to the end-consumer. The marketing channels with a medium risk for the flour mill are industrial bakeries and food retail. The flour mill has to face the highest risk by marking the flour to other food industries, because of the often international distribution of the products.

This research did not consider the proportion of flour in the final product, which the end-consumer buys. The effects on human health are also affected by the concentration of contaminated flour in the final product. It can be stated that the higher the concentration of contaminated flour the more negative the effects on human health. It is to assume that the marketing channel 'another food industry', which is ranked by the FMEA as the customer with the highest risk potential, produces final products with the lowest concentration of flour.

Furthermore, the interviews showed explicitly that the flour mill industry as well as the customers of the flour mills are very heterogeneous. This is the reason why not all subquestions of the research questions could be answered very exactly. This is also a reason to be careful with generalisations of the research results. Nevertheless with regard to the flour consumption the case study should have delivered representative results which at least depict tendencies.

Finally it is to say that the interviewed flour mill already select its marketing channels for risk management reasons. This selection is not based on the regional distribution of the flour but on the proportion of the flour on the value chain until the final product. The flour mill avoids to market flour to e.g. cake and pizza producers.

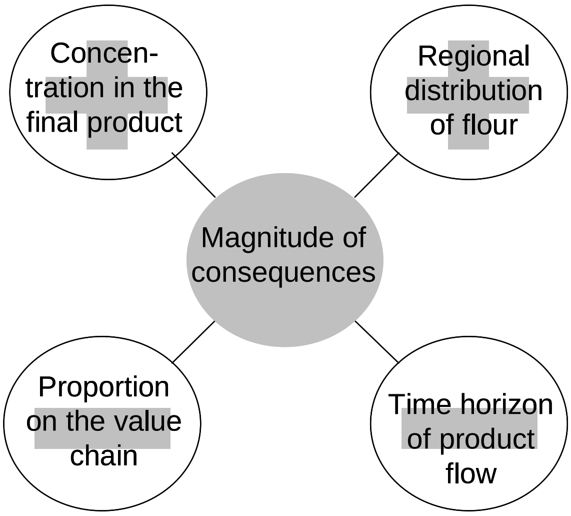
8.2 Management conclusion

After concluding the results with regard to the research objective, in the following the results are concluded with regard to managerial aspects.

As mentioned in the problem statement (chapter 1.1) good risk management considers choosing marketing channels with controllable risk. Therefore the main marketing channels and the further product flow have to be known in detail. The network structure of the flour mill is characterised by high heterogeneity, which makes it even more complex.

The risk assessment portfolio given in chapter 7.5.3 visualises very well the risk aligned with each marketing channel as a combination of occurrence and severity. For decision making a ranking only based on the risk is not adequate. The probability of occurrence and mainly the severity have to be considered separately. If the severity of a risk is that high, that a flour mill can not bear the costs even a small probability of occurrence has to be excluded. Therefore investigating the factors on the magnitude of consequences have to be of main interest. This research estimated the severity mainly on the regional distribution of flour and the time horizon the flour needs to go through the chain. The results are here not visualised again, because the interview with the flour mill showed that there are more important factors so that the results of this research are not sufficient for decision making. Beside the regional distribution of flour and the time horizon from the flour mill to the end-consumer the following factors are important: the concentration of flour in the final product, which affects the risk to health; and the proportion of flour on the value chain of the final product, which shows the financial damage if the final product is contaminated. The following figure visualises the detected factors influencing the magnitude of consequences.

Figure 8.3-1 Factors on the magnitude of consequences



Source: Own illustration

Decision making in real business is mainly led by financial performance. Therefore a cost-benefit analysis is essential to rank each marketing channel according to its magnitude of consequences if a safety deficiency is detected too late.

8.3 Recommendation

General recommendations

Further research should analyse each tier in more detail to disclose the huge differences between companies in the single industries; i.e. to consider more the heterogeneity in the industries. Therefore concentrating on one marketing channel it is to advice. Following other recommendations can be listed without giving a rank order:

- The identification of the concentration of the flour in the final product is important to assess the possible risk to health.
- Trust between the flour mill and the customer should be taken into account as an important factor on the interactions of the companies.
- This research accounted for the network structure and the chain management as impact on the magnitude of consequences. According

to VAN DER VORST ET AL. (2005), also chain business processes and chain resources influence the chain performance.

- As mentioned in chapter 7.5.2 the flour mill already selects its marketing channels based on the value of the flour in relation to the total value chain. The smaller the proportion of the flour on the total value chain of the final product, the higher the financial risk for the flour mill. Up to now the risk management of the flour mill is more interested in the product's value chain in the different marketing channels than in the distributional structure. On this account the flour proportion on the value chain should be considered for further research.

Outline of a recommended adjacent case study

As mentioned above it is to recommend investigating each marketing channel in more detail. The following part presents an outline of a possible adjacent case study.

The results of this research show that the craft bakery marketing channel covers about 46% of the mill's flour. Thus, as measured by the flour consumption craft bakeries are the most important customers of a flour mill. Additionally because of the small turn over of each single craft bakery this marketing channel represents the most number of customers. A further reason for an in-depth investigation is that this marketing channel is the most heterogeneous one as explained in chapter 3.2 and 7.5. Craft bakeries are served either directly by the flour mill or by a wholesaler. The flour is delivered in bulk or in small bags. The time horizon until the final product reaches the end-consumer can reach up to about 4 weeks.

This case study should also be based on in-depth interviews. The interview partner should be chosen systematically. Considering the heterogeneity of this industry the craft bakeries are divided into three groups. The first group represents craft bakeries which have only one shop. The second and third group present craft bakery chains, which are divided by the number of shops. To choose the accurate group characteristics, the association of the German craft bakeries is to contact. At least two companies of each craft bakery group should be interviewed to make the results more representative. Furthermore it is wise to interview the wholesaler BÄKO, who is market leader in Germany according to the interview with the association of the German craft bakeries.

As to the interviews a structured interview protocol with open-ended questions is to advice. The questions must be more specifically matched to the craft bakery business but here also the time horizon of the product flow and the regional distribution has to be on spotlight. Questions on the following topics have to be prepared.

As to the supply of flour:

- Which suppliers of flour does the bakery have, flour mill or wholesale?
- Where are the suppliers located?
- Is the bakery served in bulk or in bags?
- For how long does the bakery store the flour?
- How often did the craft bakery get contaminated flour?
- How would the craft bakery assess the probability that it can detect contaminated flour?

As to the final products:

- For how long does the final product stay in the bakery?
- Who are the customers of the bakery, where are they from?
- What is the proportion of the flour on the final product?
- What is the proportion of the flour on the value chain of the final product?

The questions for the interview with the wholesaler have to be prepared separately. This interview has to investigate the product flow between the flour mill and the craft bakeries and so it has to focus mainly on the regional distribution and the time horizon.

For the next step the risk estimation framework given in chapter 5 is used. The results of the interviews are to adapt to the framework as it is done in this research. The component ‘occurrence’ is filled in based on the interview with the flour mill. The component ‘severity’ considers the product failure specifics based on the interview with the flour mill and the supply chain structure based on the interviews with the craft bakeries.

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Appendices

Appendix 1: Interview introduction document

Interview abstract

Introduction

This interview abstract aims at giving you the necessary information to be able to prepare for the coming interview. The contents is used for scientific research only; i.e. a master thesis. The interview will take about one to one and a half hours.

Problem statement

The topic of the master thesis is:

Risk management in product channels: how much does the distributional structure of flour mills' products influence the risk associated with contaminated products?

In discussions on risks of food safety, usually the focus is on identifying the risk of failures in enterprise production processes, and so only the probability of failure is considered. However, an idea of the magnitude of consequences if deficient products move along the distribution channel is missing. The objective of this master thesis is to investigate the impact of the distribution channel's structure on the flour mill's risk associated with contaminated products. This implies an in-depth analysis of the main distribution channels; i.e. the tiers and its participants from the flour mill to the end-consumer.

Questions

Part 1: Questions on the profile of the company

Part 2: Questions on the structure of the supply chains

- Members of the supply chain network structure
- Time horizon of the product flow
- Regional distribution of the products

Part 3: Questions on management components

- Charge management
- Information exchange

Part 4: Questions on the product failure

- Classification of contaminated products
- Probability of occurrence and detection of contaminated products

Appendix 2: Interview document

Interview questions

Name of the interview partner:
Company:
Position in the company:
Place, date:

Problem statement

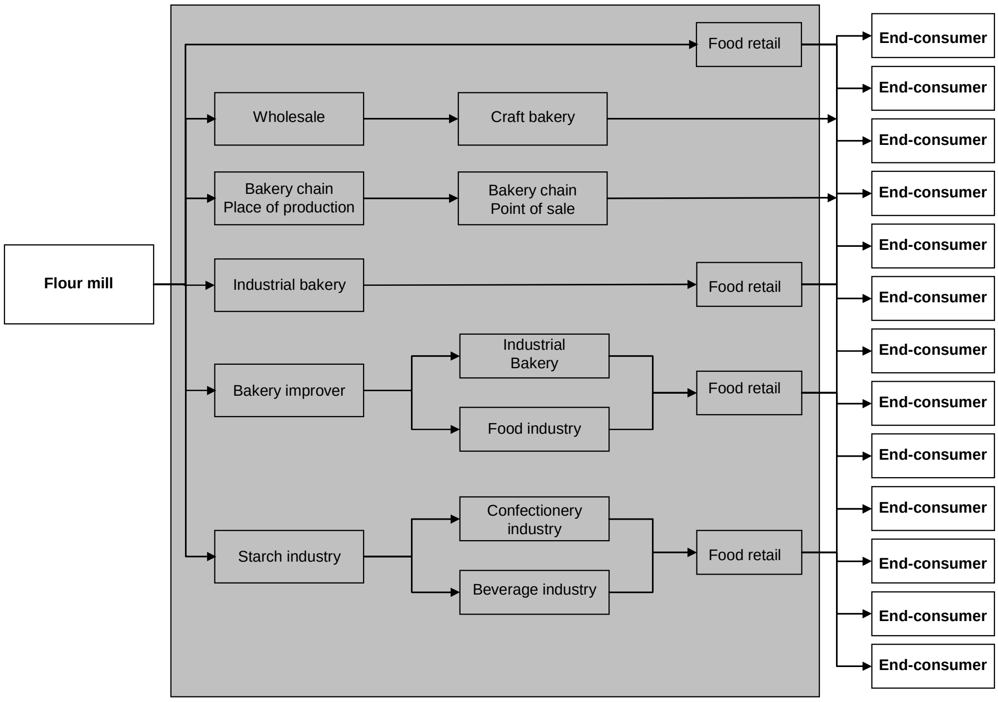
The topic of the master thesis is:
Risk management in product channels: how much does the distributional structure of flour mills' products influence the risk associated with contaminated products?
In discussions on risks of food safety, usually the focus is on identifying the risk of failures in enterprise production processes, and so only the probability of failure is considered. However, an idea of the magnitude of consequences if deficient products move along the distribution channel is missing. The objective of this master thesis is to investigate the impact of the distribution channel's structure on the flour mill's risk associated with contaminated products. This implies an in-depth analysis of the main distribution channels; i.e. the tiers and its participants from the flour mill to the end-consumer.

Part 1: Questions on the profile of the company

1. How would you describe the following characteristics of the company?
   a. Main business
   b. Number of employees
   c. Annual turnover
   d. Market share

Part 2: Questions on the structure of the supply chains

1. Does the following figure show the main distribution channels of the company's products? Are their any important market participants or marketing channels missing? What proportion does each main group of customers have?



Source: Own illustration

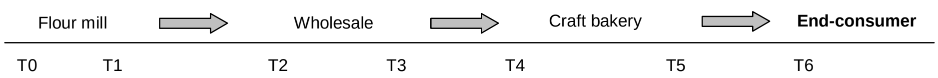
2. How many companies of each marketing channel named above are in general the company's customers? Is there a possibility of choosing and rejecting certain customers? Can the customers of the single industries be characterised more as heterogeneous or homogeneous?

3. In which percental quantities does the flour mill market their flour mill to other flour mills?

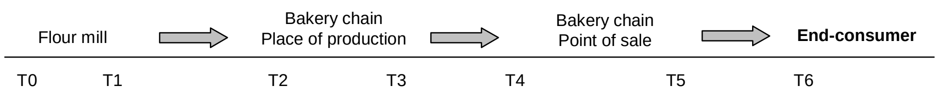
4. Are there business processes in the whole supply chain which are managed or monitored by the flour mill?

5. How would you assess the time horizon of the product flow from the flour mill to its customer? How would you assess this time horizon at the following tiers in the supply chain network structure?

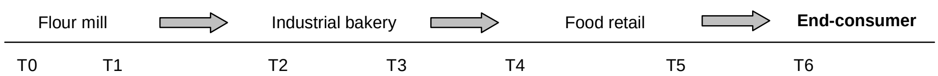
Marketing channel: Craft bakery



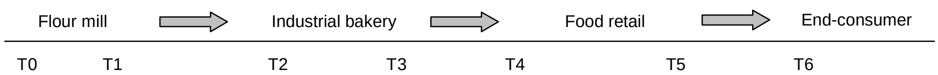
Marketing channel: Bakery chain



Marketing channel: Industrial bakery



Marketing channel: Food retail



Marketing channel: Producer of bakery improver

Flour mill → Producer of bakery improver → Food industry → Food retail → **End-consumer**

T0 T1 T2 T3 T4 T5 T6 T7

6. How would you assess the regional distribution of the flour mill products by each tier in the supply chain network structure?

Marketing channel: Craft bakery

Flour mill → Wholesale → Craft bakery → **End-consumer**

Marketing channel: Bakery chain

Flour mill → Bakery chain Place of production → Bakery chain Point of sale → **End-consumer**

Marketing channel: Industrial bakery

Flour mill → Industrial bakery → Food retail → **End-consumer**

Marketing channel: Food retail

Flour mill → Industrial bakery → Food retail → End-consumer

Marketing channel: Producer of bakery improver

Flour mill → Producer of bakery improver → Food industry → Food retail → **End-consumer**

Part 3: Questions on management components

1. Does the organisational structure of the flour mill show divisions which often work company overlapping; e.g. does the marketing division often work in the field?

2. Does the charge management make arrangements to avoid the distribution of contaminated products? Is there a customer oriented charge management? Is there a company overlapping charge management?

3. Is the flour mill involved in the inventory management of its customers or of other members of the chain?

4. How would you assess the information exchange between the flour mill and its customers with regard to modality (mainly IT based or more face-to-face) and the frequency (regular intervals or on demand)?

5. To what extent is the flour mill informed about the detailed distribution of its products in each marketing channel?
   The ranking is based on a 1 to 5 scale, in which 1 rank the best and 5 ranks the worst.

Marketing channel	Ranking (1 – 5)
Craft bakery	
Bakery chain	
Industrial bakery	
Food retail (household flour)	
Producer of bakery improver	

Part 4: Questions on product failures

1. What are typical examples of biological, chemical and physical contaminated products in a flour mill?

2. How would you assess the effects of the above mentioned contaminations on human health?
   The ranking is based on a 1 to 5 scale, in which 1 rank the best and 5 ranks the worst.

	Effects (1 – 5)
Biological contamination	
Chemical contamination	
Physical contamination	

3. Which methods and QM-Systems the above mentioned product contaminations can be detected?

	Method of detection
Biological contamination	
Chemical contamination	
Physical contamination	

4. How would you rank the probability of occurrence of each product contamination in the flour mill? How would you rank the probability of detection of each product contamination in the flour mill?
   The ranking is based on a 1 to 5 scale, in which 1 rank the best and 5 ranks the worst.

	Occurrence	Detection
Biological contamination		
Chemical contamination		
Physical contamination		

5. Are there specifics aligned with each contamination which may increase the distribution of the contaminated product, e.g. cross-contamination?

6. How would you assess the probability that a customer detects a contaminated product?
   The allocation of the customers is shown in the table. The ranking is based on a 1 to 5 scale, in which 1 rank the best and 5 ranks the worst.

	Craft bakeries	Bakery chain	Industrial bakery	Food retail (household flour)	Producer of bakery improver
Biological Contamination					
Chemical Contamination					
Physical Contamination					

Appendix 3: FMEA results

FMEA 1					
Focus: Risk of the craft bakery SC					
System	**Potential failure mode**	**Severity 1 – 5**	**Occurrence 1 – 5**	**RPN 1 – 25**	**Total RPN**
Craft bakery supply chain	Biological contaminated product leaves the flour mill	(2+2.3)/2 = **2.2**	**2.9**	(2.2x2.9) = **6.4**	(6.4x3.8 x6) = **146**
	Chemical contaminated product leaves the flour mill	(2+4.4)/2 = **3.2**	**1.2**	(3.2x1.2) = **3.8**	
	Physical contaminated product leaves the flour mill	(2+3)/2 = **2.5**	**2.4**	(2.5x2.4) = **6**	

Entry to the FMEA 1

The FMEA 1 analysis the risk of the craft bakery supply chain; i.e. the flour mill's risk, if a biological, a chemical, or a physical contaminated product leaves the flour mill and enters the supply chain: flour mill – craft bakery – end-consumer.

The ranking of the severity is based on chapter 7.5.3. In the process it is account for the supply chain structure and the product failure specifics. The ranking of the occurrence is based on chapter 7.5.2.

The ranks are calculated as follows:

Based on figure 7.5.3-3
Severity of the supply chain structure = (time horizon + regional distribution)/2
Severity of craft bakery SC = (1.9 + 2.1) / 2 = 2

Based on figure 7.5.3-5
Severity of the product failure specific = (dispersion + risk to health)/2
Severity of a biological contamination = (2.8 + 1.8) / 2 = 2.3
Severity of a chemical contamination = (4.2 + 4.6) / 2 = 4.4
Severity of a physical contamination = (1.9 + 4.1) / 2 = 3

Based on figure 7.5.2-1
Occurrence of a biological contamination = 2.9
Occurrence of a chemical contamination = 1.2
Occurrence of a physical contamination = 2.4

FMEA 2					
Focus: Risk of the industrial bakery SC					
System	**Potential failure mode**	**Severity 1 – 5**	**Occurrence 1 – 5**	**RPN 1 – 25**	**Total RPN**
Industrial bakery supply chain	Biological contaminated product leaves the flour mill	(3.3+2.3) /2= **2.8**	**2.9**	(2.8x2.9) = **8.1**	(8.1x4.7 x7.7) = **293**
	Chemical contaminated product leaves the flour mill	(3.3+4.4) /2= **3.9**	**1.2**	(3.9x1.2) = **4.7**	
	Physical contaminated product leaves the flour mill	(3.3+3)/2 = **3.2**	**2.4**	(3.2x2.4) = **7.7**	

Entry to the FMEA 2

The FMEA 2 analysis the risk of in the industrial bakery supply chain; i.e. the flour mill's risk, if a biological, a chemical, or a physical contaminated product leaves the flour mill and enters the supply chain: flour mill – industrial bakery – food retail – end-consumer.

The ranking of the severity is based on chapter 7.5.3. In the process it is account for the supply chain structure and the product failure specifics. The ranking of the occurrence is based on chapter 7.5.2.

The ranks are calculated as follows:

Based on figure 7.5.3-3
Severity of the supply chain structure = (time horizon + regional distribution)/2
Severity of industrial bakery SC = (3.4 + 3.1) / 2 = 3.3

Based on figure 7.5.3-5
Severity of the product failure specific = (dispersion + risk to health)/2
Severity of a biological contamination = (2.8 + 1.8) / 2 = 2.3
Severity of a chemical contamination = (4.2 + 4.6) / 2 = 4.4
Severity of a physical contamination = (1.9 + 4.1) / 2 = 3

Based on figure 7.5.2-1
Occurrence of a biological contamination = 2.9
Occurrence of a chemical contamination = 1.2
Occurrence of a physical contamination = 2.4

FMEA 3					
Focus: Risk of the food retail SC					
System	**Potential failure mode**	**Severity 1 – 5**	**Occurrence 1 – 5**	**RPN 1 – 25**	**Total RPN**
Food retail supply chain	Biological contaminated product leaves the flour mill	(3.5+2.3) /2= **2.9**	**2.9**	(2.9x2.9) = **8.4**	(8.4x4.8 x7.9) = **319**
	Chemical contaminated product leaves the flour mill	(3.5+4.4) /2= **4**	**1.2**	(4x1.2) = **4.8**	
	Physical contaminated product leaves the flour mill	(3.5+3)/2 = **3.3**	**2.4**	(3.3x2.4) = **7.9**	

Entry to the FMEA 3

The FMEA 3 analysis the risk of the food retail supply chain; i.e. the flour mill's risk, if a biological, a chemical, or a physical contaminated product leaves the flour mill and enters the supply chain: flour mill – food retail – end-consumer.

The ranking of the severity is based on chapter 7.5.3. In the process it is account for the supply chain structure and the product failure specifics. The ranking of the occurrence is based on chapter 7.5.2.

The ranks are calculated as follows:

Based on figure 7.5.3-3
Severity of the supply chain structure = (time horizon + regional distribution)/2
Severity of food retail SC = (4.2 + 2.7) / 2 = 3.5

Based on figure 7.5.3-5
Severity of the product failure specific = (dispersion + risk to health)/2
Severity of a biological contamination = (2.8 + 1.8) / 2 = 2.3
Severity of a chemical contamination = (4.2 + 4.6) / 2 = 4.4
Severity of a physical contamination = (1.9 + 4.1) / 2 = 3

Based on figure 7.5.2-1
Occurrence of a biological contamination = 2.9
Occurrence of a chemical contamination = 1.2
Occurrence of a physical contamination = 2.4

FMEA 4					
Focus: Risk of another food industry SC					
System	**Potential failure mode**	**Severity 1 – 5**	**Occurrence 1 – 5**	**RPN 1 – 25**	**Total RPN**
Another food industry supply chain	Biological contaminated product leaves the flour mill	(3.9+2.3) /2= **3.1**	**2.9**	(3.1x2.9) = **9**	(9x5x8.4) = **378**
	Chemical contaminated product leaves the flour mill	(3.9+4.4) /2= **4.2**	**1.2**	(4.2x1.2) = **5**	
	Physical contaminated product leaves the flour mill	(3.9+3)/2 = **3.5**	**2.4**	(3.5x2.4) = **8.4**	

Entry to the FMEA 4

The FMEA 4 analysis the risk of another food industry supply chain; i.e. the flour mill's risk, if a biological, a chemical, or a physical contaminated product leaves the flour mill and enters the supply chain: flour mill – food industry – food industry – food retail – end-consumer.

The ranking of the severity is based on chapter 7.5.3. In the process it is account for the supply chain structure and the product failure specifics. The ranking of the occurrence is based on chapter 7.5.2.

The ranks are calculated as follows:

Based on figure 7.5.3-3
Severity of the supply chain structure = (time horizon + regional distribution)/2
Severity of an other food industry SC = (3.1 + 4.7) / 2 = 3.9

Based on figure 7.5.3-5
Severity of the product failure specific = (dispersion + risk to health)/2
Severity of a biological contamination = (2.8 + 1.8) / 2 = 2.3
Severity of a chemical contamination = (4.2 + 4.6) / 2 = 4.4
Severity of a physical contamination = (1.9 + 4.1) / 2 = 3

Based on figure 7.5.2-1
Occurrence of a biological contamination = 2.9
Occurrence of a chemical contamination = 1.2
Occurrence of a physical contamination = 2.4