



MEASURING SUPPLY CHAIN VULNERABILITY

A Case Study

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ABSTRACT

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This thesis was conducted on a case-study basis to provide insight on how companies measure supply chain vulnerability by providing new comprehension in the form of completing a Failure Mode and Effect Analysis for the supply chain processes of one individual product to be launched in the summer of 2014.

By applying information retrieved from previous studies and literature references this thesis examined different ways and tools to measure supply chain vulnerability as well as explained the essential theoretical concepts of supply chain management, risk management and finally supply chain risk management. Several methods of determining risk and categorizing risks were introduced.

Primary results were derived from unstructured face to face interviews and once combined with supply chain risk management theory it was possible to conduct an extensive Failure Mode and Effect Analysis covering each process of the case company's supply chain related to pre-market launch of one new product.

Based on the technique, the case company's supply chain risks were first identified, assessed and analyzed. Finally the risks were prioritized by a combination of severity, occurrence and detection which together created a Risk Priority Number. The analysis revealed that the portion of very high RPNs was rather low and, therefore, a majority of the suggested developments were not intensive in nature and not demanding big investments. As a result a full action plan was developed to provide support for the case company's management in their strategic decisions concerning the new product for the future.

Key words: supply chain; risk management; Failure Mode and Effects Analysis; measurement techniques; action plan; RPN

CONTENTS

1	INTRODUCTION	8
2	RESEARCH DESIGN	10
3	SUPPLY CHAIN MANAGEMENT.....	11
4	WHAT IS A RISK?.....	15
	4.1 Experiencing Risk.....	15
	4.2 Risk Categorization.....	16
	4.3 Risk and Opportunity.....	17
5	RISK MANAGEMENT	18
	5.1 Different Approaches.....	18
6	SUPPLY CHAIN RISK MANAGEMENT	20
	6.1 Risk Analysis Methods	21
	6.1.1 Scenario Analysis.....	22
	6.1.2 Simulation	22
	6.1.3 Network Models.....	23
	6.1.4 Failure Mode and Effect Analysis.....	23
7	THE CASE COMPANY	25
	7.1 Operating Principe	25
8	PROOF OF SELECTION: WHY FAILURE MODE AND EFFECTS ANALYSIS	27
9	FAILURE MODE AND EFFECTS ANALYSIS	29
	9.1 System FMEA.....	30
	9.2 Service FMEA	31
	9.3 Design FMEA (DFMEA)	31
	9.4 Process FMEA (PFMEA)	31
	9.5 The Main Steps in FMEA.....	32
	9.5.1 Determining Processes	34
	9.5.2 Determining Potential Failure Modes	35
	9.5.3 Determining Potential Effects	35
	9.5.4 Determining Potential Causes	37
	9.5.5 Determining Current Controls	38
	9.5.6 Calculating the Risk Priority Number (RPN)	39
	9.5.7 Assessing Risks and Developing Action Plan	41
	9.5.8 Assess Action Result.....	43
10	FAILURE MORE AND EFFECTS ANALYSIS FOR THE CASE COMPANY	44
	10.1 Business Process Model.....	44

10.2 Process Step: Forecasting	46
10.2.1 Potential Failure Modes	46
10.2.2 Potential Effects	47
10.2.3 Severity Rating.....	48
10.2.4 Potential Causes	48
10.2.5 Occurrence Rating.....	48
10.2.6 Current Controls.....	49
10.2.7 Detection Rating.....	49
10.2.8 Risk Priority Number Calculation.....	49
10.2.9 Risk Assessment and Action Plan Development	50
10.2.10 Action Result Assessment.....	50
10.3 Process Step: Production Planning	50
10.3.1 Potential Failure Modes	51
10.3.2 Potential Effects	51
10.3.3 Severity Rating.....	52
10.3.4 Potential Causes	52
10.3.5 Occurrence Rating.....	53
10.3.6 Current Controls.....	53
10.3.7 Detection Rating.....	53
10.3.8 Risk Priority Number Calculation.....	54
10.3.9 Risk Assessment and Action Plan Development	54
10.3.10 Action Result Assessment.....	55
10.4 Process Step: Raw Material Procurement.....	55
10.4.1 Potential Failure Modes	55
10.4.2 Potential Effects	57
10.4.3 Severity Rating.....	58
10.4.4 Potential Causes	58
10.4.5 Occurrence Rating.....	59
10.4.6 Current Controls.....	59
10.4.7 Detection Rating.....	59
10.4.8 Risk Priority Number Calculation.....	60
10.4.9 Risk Assessment and Action Plan Development	60
10.4.10 Action Result Assessment.....	60
10.5 Process Step: Raw Material Receipt.....	61
10.5.1 Potential Failure Modes	61
10.5.2 Potential Effects	61
10.5.3 Severity Rating.....	62
10.5.4 Potential Causes	62
10.5.5 Occurrence Rating.....	63

10.5.6 Current Controls.....	63
10.5.7 Detection Rating.....	63
10.5.8 Risk Priority Number Calculation.....	63
10.5.9 Risk Assessment and Action Plan Development.....	63
10.5.10 Action Result Assessment.....	64
10.6 Process Step: Production.....	64
10.6.1 Potential Failure Modes.....	65
10.6.2 Potential Effects.....	65
10.6.3 Severity Rating.....	66
10.6.4 Potential Causes.....	66
10.6.5 Occurrence Rating.....	67
10.6.6 Current Controls.....	67
10.6.7 Detection Rating.....	69
10.6.8 Risk Priority Number Calculation.....	69
10.6.9 Risk Assessment and Action Plan Development.....	69
10.6.10 Action Result Assessment.....	70
10.7 Process Steps: Quality Assurance and Release.....	70
10.7.1 Potential Failure Modes.....	70
10.7.2 Potential Effects.....	70
10.7.3 Severity Rating.....	71
10.7.4 Potential Causes.....	71
10.7.5 Occurrence Rating.....	71
10.7.6 Current Controls.....	71
10.7.7 Detection Rating.....	71
10.7.8 Risk Priority Number Calculation.....	72
10.8 Process Steps: Packaging and Storage.....	72
10.8.1 Potential Failure Modes.....	73
10.8.2 Potential Effects.....	73
10.8.3 Severity Rating.....	74
10.8.4 Potential Causes.....	74
10.8.5 Occurrence Rating.....	74
10.8.6 Current Controls.....	74
10.8.7 Detection Rating.....	75
10.8.8 Risk Priority Number Calculation.....	75
10.8.9 Risk Assessment and Action Plan Development.....	75
10.9 Process Steps: Loading and Invoicing.....	76
10.9.1 Potential Failure Modes.....	76
10.9.2 Potential Effects.....	77
10.9.3 Severity Rating.....	77

10.9.4 Potential Causes	77
10.9.5 Occurrence Rating.....	78
10.9.6 Current Controls.....	78
10.9.7 Detection Rating.....	78
10.9.8 Risk Priority Number Calculation.....	78
11 DISCUSSION	79
11.1 Action plan summary.....	79
11.2 Conclusions.....	82
REFERENCES.....	84
APPENDICES	86
Appendix 1. Interview questions.....	86
Appendix 2. Failure Mode and Effects Analysis for Process Step: Forecast.....	87
Appendix 3. Failure Mode and Effects Analysis for Process Step: Production Plan	88
Appendix 4. Failure Mode and Effects Analysis for Process Step: Raw Material Procurement	89
Appendix 5. Failure Mode and Effect Analysis for Process Step: Raw Material Receipt	90
Appendix 6. Failure Mode and Effects Analysis for Process Step: Production.....	91
Appendix 7. Failure Mode and Effects Analysis for Process Steps: Quality Assurance, Release, Packaging, Labelling, Storage, Loading and Invoicing	92

ABBREVIATIONS AND TERMS

SCM	Supply Chain Management
JIT	Just In Time
FMEA	Failure Mode and Effects Analysis
SCRM	Supply Chain Risk Management
MBO	Management buyout
DFMEA	Design Failure Mode and Effects Analysis
PFMEA	Process Failure Mode and Effects Analysis
MTS	Make To Stock
MTO	Make To Order
ETA	Estimated Time of Arrival
FIFO	First In, First Out
MSDS	Material Safety Data Sheet
QA	Quality Assurance

1 INTRODUCTION

“When you find yourself in a hole, stop digging.” This very straight-forward piece of advice was given by an American actor and philosopher Will Rogers (1879-1935) (Commentary on Risk and ERM 2014) long before the science of supply chain management (SCM) was introduced let alone anyone was talking about identifying potential risks in the chain. Metaphorically it could be argued that a well-planned supply chain is the key factor for a company to find a way out of a hole whereas a carefully maintained risk management practice is to ensure the upcoming holes are identified and assessed in advance to avoid falling in the first place.

This case-study thesis will invite the reader into the exciting world of supply chain risk management. The topic has been widely researched from different viewpoints and contextual backgrounds; therefore, this case-study will examine the subject matter from a slightly different angle by providing insight on a selected case company’s current way of measuring supply chain risks by conducting a Failure Mode and Effects Analysis (FMEA) on one specific product which is to be launched in the summer of 2014..

Supply chain in the process industry is the flow of material, information and/or money initially from a raw material supplier all the way to the customer. Businesses find it increasingly important to focus on effective supply chain management because the markets are becoming global to a greater extent and extremely competitive while customers’ expectations are growing simultaneously (Simchi-Levi, Kaminsky & Simchi-Levi 2003, 1).

Risk itself is nothing new to anyone and as Donald Waters suggests there might not be a formal definition for risk as such but in general risk is perceived to be something unpleasant that might happen (Waters 2007, 1).

The thesis will familiarize the concepts of supply chain management and risk management as such as well as introduce the case company. Furthermore, various risk management techniques are introduced and based on the need arising from the case company one technique – FMEA – will be detailed and applied. The results of the case com-

pany risk analysis will be presented and conclusions and future recommendations will be made.

2 RESEARCH DESIGN

The research method chosen is qualitative research as there is no need for further quantitative generalizations and the purpose is more to explore the phenomena of supply chain vulnerability.

In order to discover the features and factors that are of importance to the topic a case study is used. Primary data is gathered by unstructured face to face interviews in the form of field notes. There were a few predefined questions but for the most part the interviewees spoke freely. The sampling method is quota sampling due to the size of the company and the number of key people aware of process level details. Secondary data consists of multiple sources including books, journals, on-line articles, theses and presentations.

There is no reason to believe that the respondents would have confined any information, therefore, the results are valid. The only potentially limiting factor is the fact that the entire process of new product set up is very fresh thus making some information volatile to presumptions.

In the beginning of the interview critical terms were described and discussed by the interviewer to eliminate possible misunderstandings. Also the scope of the study was explained to avoid getting into details with topics out of initial exclusion. The research questions can be found from appendix 1 in the end of the report. Interview data was used to compile the FMEA analysis.

3 SUPPLY CHAIN MANAGEMENT

Supply chain as a concept refers to the flow of materials, money and information all the way from a raw material supplier to the customer. There are different functions inside the umbrella of supply chain: sourcing & procurement for raw material acquiring, demand planning to meet the customers' needs, logistics for covering transportation and inventory management, operations management to cover the production process, cost allocations and control to mention a few.

To avoid a common confusion: logistics is a management function inside a company. It is the function in the company which is responsible for all movements of materials. Supply chain, in turn, can be defined as a flow of goods, money and information that pass within and between organizations, connected by a range of tangible and intangible originators which include processes, activities, relationships and integrated information systems. (Waters 2007, 37.)

There are two decisions that have to be made about a supply chain. The first is strategic and includes designing the best structure for a supply chain. The second is about execution and includes the most efficient ways of moving materials through the chain. Logistics has to bring together a series of functions to achieve this. These functions are responsible for different aspects of the movement of materials and performed by many different parties. Supply chain management includes several core activities which are for example procurement, transport, warehousing, stock control and returns. Furthermore, SCM includes many other activities besides these and it is important to recognize that they must all work together to get a sufficient flow of materials. Problems in one, will cause problems in others. (Waters 2007, 43-44.)

Logistics in general can be divided into two parts: inward (or inbound) logistics and outward (or outbound) logistics as seen on figure 1. Inbound logistics includes material flow from the supplier into the organization and outward logistics, on the other hand, consists of moving materials out of an organization and on to the customer. The material flow within the organization is usually called materials management. Interestingly enough, every company acts as a customer and as a supplier in certain parts of the supply chain: first as a customer purchasing raw materials from another organization and

then as a supplier selling goods to a different organization. Products go through several organizations as they move from the original suppliers of raw materials to the final customer. (Waters 2007, 36.)

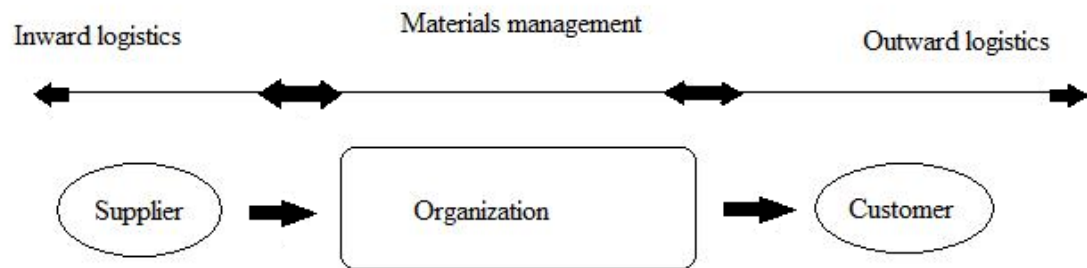


FIGURE 1. Logistics and material movement (Waters 2007, 36, modified)

The parties operating in inward logistics can be divided into tiers of suppliers. First-tier supplier is the supplier that sends materials directly to the organization. Second-tier supplier is the one that sends materials to a first-tier supplier and so on. This can be done on the other side of the organization as well. In outward logistics the customers can also be divided into similar levels. A first-tier customer is the one that gets the product directly from the organization and second-tier customer is the one that gets the product from a first-tier customer, all the way to the final end-users. (Waters 2007, 39.) This contextual concept will draw attention to the fact how complex and often times global the modern supply chains are.

Supply chain management emphasizes the importance of integrating activities between parties. It is the function responsible for storage and transport of materials when they move from an original supplier through intermediate operations to the final customer. Each of the organizations that the product goes through adds value to the product. (Waters 2007, 38.)

Furthermore, there are several forms of structures for a supply chain. Some models might be short and simple, but others long and very complex. Every product has its own unique supply chain. Most of the organizations buy materials from many different suppliers and they sell products to many different customers. What is more, each of these suppliers works with many other organizations. This can definitely make the supply chain hard to perceive. (Waters 2007, 39.)

The broad complexity of supply chains makes them particularly vulnerable to risks. The complexity also causes risks to accumulate. The large number of links between different parties of the chain enables the risks to spread throughout the chain. This may lead to a small event in one remote area to cause major consequences in other areas. These risks may be caused by internal factors or external factors. (Waters 2007, 11.) An interesting viewpoint to supply chain vulnerability is as Waters (2007, 10) suggests the leaner a chain is becoming the more it is exposed to risks. For example moving out of stock holding and towards just-in-time (JIT) operations will make the supply chain more effective but a lot less resilient to sudden changes in demand.

Supply chain management faces an enormous range of characteristic risks. There is also a risk in changing the operations of logistics. Logistics managers may try to make the supply chain more efficient at a cost of increasing vulnerability. What makes risks in supply chain extraordinary is the fact that each party (supplier, sub-contractor, the organization itself, customer and end user) is not only susceptible to its own risks but also may face risky events affecting other parties. The nature of a supply chain is that even a relatively small problem may cause massive affects. This recognition of the high costs of supply chain risks has made logistics managers to consider formal methods of supply chain risk management (SCRM). (Waters 2007, 49.) Managers are only just starting to recognize the importance of supply chain risk management and, therefore, most organizations are still at a very early stage of development. (Waters 2007, 50.)

Disruption to the flow of materials is the main risk to a supply chain. This disruption may occur in every step of the chain itself. There might be disruptions in production, delivery failures or quality problems. (Waters 2007, 13.) Successful delivery of products is one of the prerequisites for a positive cash flow. Schedule failures or delivery time fluctuation include contractual risk. Supply risks may occur either because of product quality problems or stock shortage. (Sakki 2003, 73-74.)

Reliability is one of company's main competitive edges. Stock optimization is one of the supply chain risk management instruments and the means of such optimization are proactive actions. However, stocks are often associated with many problems and optimization can, therefore, be very difficult. (Sakki 2003, 73-74.) While on one hand the stocks are needed, unnecessary stocks should, on the other hand, be avoided as high

stocks complicate management of material flow and tie up capital. Drawing the line between stock optimization and excessive amount of inventory may be difficult. Managing supply disruptions can thus be argued to consist of balancing between stock levels, rotation speed, and minimizing the cost of capital. (Sakki 2003, 73-74.)

Managing stock is not the most significant of supply chain risk management tools. Sakki (2003, 75-76) argues that reliable deliveries can be achieved even with low stock by improving material flow management. Material flow management is a part of the company's logistics and supply chain process. Its aim is to ensure the availability of raw materials and reliable deliveries of sold products. The higher the stocks are, the slower the information about consumption and its changes passes down the supply chain. (Sakki 2003, 71-72.) The company's delivery performance depends on the skills and ability to control the material, rather than stocks. What is important is that the stocks consist of right products in relation to future sales. (Sakki 2003, 75-76.) For such an approach to work in reality, it will need an extensively sophisticated forecasting tools as well as a wide array of suppliers to purchase raw materials from.

Finally, Gustafsson, Jönson, Smith and Sparks (2006, 2-3) underline that the potential of a well-managed supply chain is slowly becoming noted. So far logistics and supply chain management have largely been only an afterthought within organizations and it has been believed that it is sufficient enough to just let logistics proceed with a lower level management – if even that – on its own behind the scenes. It is clearly argued that such views are misguided and that logistics and supply functions present real potential to enhance business performance. In the long run improving, enhancing and developing supply chain activities will provide a winning advantage in terms of service and costs. (Gustafsson et al. 2006, 3.)

4 WHAT IS A RISK?

According to Hetland (2003, 59) risk is an implication of a phenomenon being uncertain. Uncertainty and risk, to be precise, do not have an equal meaning. Waters (2007, 17) suggests that that difference can be seen as uncertainty referring to that we can list things that might happen at some point in the future but we cannot tell which of the events will actually happen nor can we determine any relative likelihoods. Whereas, risk means that we can list the things that might happen at some point in the future as well as being able to give each event a probability.

Consequently, the main difference of the two terms is that risk has some quantifiable measure for forthcoming events but uncertainty does not. Waters (2007, 17) provides a great example of this: When you feel that your new product might be having great sales, this is uncertainty; whereas, when a market study indicates that there is a 70 per cent possibility of that product selling well, that is a risk.

4.1 Experiencing Risk

There are three factors that affect how risk is experienced: uncertainty, expectations and scope. Basic principle for a risk is that there is uncertainty about an event. If the outcome of an event is known it does not include risk. Another risk factor is expectations. It influences how people experience risk and its possible consequences. In addition to expectations, the scope and relevance also affect how people experience risks. (Juvonen et al. 2008, 7-8.)

Risk can include both possibility and a danger aspect. When risk is being evaluated computationally the expectations are being left out from the calculations. This means that the risk is being calculated by using probability and significance as per the below equation:

$$\textit{Risk} = \textit{Probability} \times \textit{Severity}$$

This is a commonly used definition of risk. Risk probability is usually calculated using the probability distribution. (Juvonen et al. 2008, 8.)

4.2 Risk Categorization

According to Juvonen et al. 2008, 16) in a simplified form two kinds of risks can be defined

- risks that can be insured
- risks that cannot be insured

Insurable risks are events that are repeatable and predictable. Non-insurable events are unique events that cannot be predicted. Insurable and non-insurable risks can also be called static and dynamic risks. Static risks are proportionally unchangeable risks, like fire risk, whereas dynamic risks change according to economics and circumstances. Furthermore, risks can also be divided into clean risks and speculative risks. It is typical for a clean risk that there is only possibility for a loss whereas speculative risks aim for profit with a possibility of a loss. Static and clean risks are usually insurable risks whereas dynamic and speculative risks are events that are rarely insurable. (Juvonen et al. 2008, 16)

When considering speculative risks the actor himself can influence on them and this type of risks usually are not transferrable. There can only follow loss but not profit from static risks. This means that there is no positive outcome to anyone from static risks realization. Technical, economic and political risks are usually financial risks because their outcome can be either profit or loss. The probability of static risks is easier to predict than the probability of dynamic risks. (Kuusela & Ollikainen 2005, 33-34.)

Juvonen et al. (2008, 17) also present a different approach in grouping risks. This viewpoint suggests that risks can be divided into three groups according to how one has prepared for their consequences:

- 1) natural risks
- 2) controlled risks
- 3) eliminated risks

Natural risks are risks that have not been intervened. Risk is being controlled when it has been intervened but has not been able to be eliminated. Eliminated risks are risks where targeted actions have effected completely. This three component risk model is being used in quality management to insure the quality of a product. (Juvonen et al. 2008, 17.)

4.3 Risk and Opportunity

Businesses are constantly facing situations where they have to make decisions with an uncertain outcome. To understand the uncertainty can help to make better decisions. Generally, it can be perceived that there are two forms of uncertainty to be dealt with in risk analysis. The first one is an overall sense that the quantity to be estimated has some uncertainty attached to it. On the other hand, there are risky events which are random events that might or might not occur. These also include some impact of interest for the organization. (Vose 2008, 3.)

Consequently, two types of events can be differentiated. A risk is a random event, which might possibly occur and in case it did occur it would have a negative impact on the organization. Therefore, a risk can be seen to compose of three elements which are: the scenario, its probability to occur and the size of the impact if it did occur. Whereas an opportunity, too, is a random event which might take place. But if it did occur it would have a positive impact on the organization. Hence, an opportunity is also composed of the same three elements as a risk. It could be said that risk and opportunity are the opposite sides of a coin. (Vose 2008, 4.)

5 RISK MANAGEMENT

Risk management is decision making and execution that are based on risk evaluation and calculation (Juvonen et al. 2008, 18). Risk management includes all the activities that are dealing with situations of uncertainty. Risk management focuses mainly on three core activities. These core activities are identifying risks, analysing their consequences and designing appropriate responses as indicated in figure 2. Simply put it: risk management is about knowing what to do when an organization is starting to do something. Aim of risk management is not necessarily about avoiding risk taking but to control it and its possible consequences. (Juvonen et al. 2008, 18.)

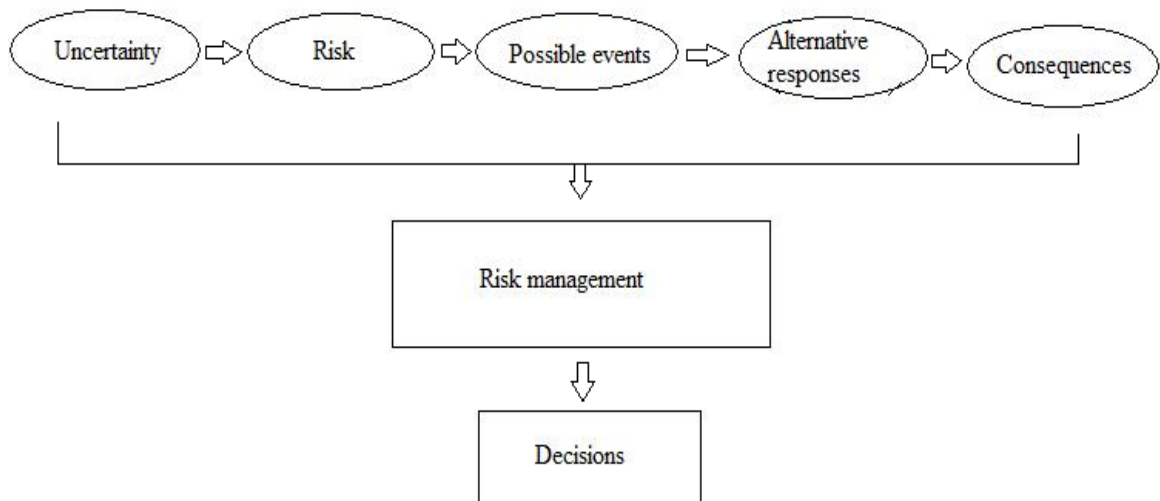


FIGURE 2. The basic process of risk management (Waters 2007, 32)

5.1 Different Approaches

There are two ways of dealing with risk. The first one is to ignore it. However, there are some problems related to this approach. One of those problems is the assumption that risky events are rare enough to ignore. It is true that some risks are rare but others are common. And most importantly being risky is not the same as being rare. (Waters 2007, 15.) The second problem is the fact that a reactive approach to problems in general is just too slow. When managers first wait to see what happens, then understand that something has to be done, next plan the response and finally implement it and then wait for the recovery, substantial damages can already have occurred (Waters 2007, 16.)

The second way of dealing with risk is a proactive approach where the organization is striving to identify risks in advance and then prepare the best possible response should the risk realize. This response might be avoiding the risk or reducing its effects. Working examples of a proactive approach to risks is holding stock to avoid risks disrupting the material flow, using multiple sourcing to manage risks from supplier's inability to perform, having spare capacity to avoid risks to operations etc. But the common feature in all of these is cost. (Waters 2007, 16.) Managing risk is an expense as it will both increase costs as well as reduce efficiency.

Kuusela and Ollikainen (2005, 15-16) are arguing that it is important to acknowledge risks and understand that there are several tools to manage them. These tools are avoidance of high-risk activities, conscious risk taking, living with risk and relying on luck, careful protection and limiting the potential damage of risk, and transferring the risk to someone else by insuring it.

To sum it up: risk is a potential harm from an unforeseen event. There are risks in all operations of the company and they have to be properly managed. The alternative of ignoring them leaves the company vulnerable to risky events and a much longer time to recover. (Waters 2007, 11.)

6 SUPPLY CHAIN RISK MANAGEMENT

When considering supply chain vulnerability Christopher (2005, 234) categorizes risks in two groups: external to the supply chain and internal risks. External risks can arise e.g. from governmental rules and regulations, wars or natural hazards whereas internal risks come from the way the supply chain is planned and managed. Essentially, external risks cannot be influenced by the business itself whilst internal risks can.

Waters (2007, 98), however, proposes a few different categorization models. One notion, which goes a little bit into more detail than the earlier mentioned approach, is to divide supply chain risks in internal risks, supply chain risks and external risks.

Internal risks arise from within the organization itself and could include

- inherent risks in operations consisting of accidents, human errors, quality issues and reliability of equipment
- risks resulting from managerial decisions such as safety stock levels, financial problems, delivery schedules and choice of batch sizes

Supply chain risks, in turn, are external to the organization but still within its supply chain. These types of risks occur from interactions between participants of the supply chain containing

- supplier risks e.g. reliability, lead times, delivery problems and availability of products
- customer risks e.g. variable demand, customized requirements and payments

Finally, external risks are coming from outside of the organization and the supply chain. These kinds of risks are result of interactions with environment and could include

- extreme weather conditions, legislation, wars, crime, accidents and natural disasters

Yet another approach to classifying risks is to divide risks into the three flows within a supply chain: materials, money and information and add a fourth type of risk based on the ways that the flows are organized. This type of division is as per below:

- Physical risks are connected to the movement and storage of materials and include risk to transport, storage, delivery, material management, inventory systems and other alike.
- Financial risks are related to the flows of money including risks to payments, cash flows, debt, investments and so on.
- Information risks are linked to systems and flows of information therefore including for example risk to data capture and transfer, integrity, information processing and system failure.
- Organizational risks arise from the various links between the different parts of the supply chain and include e.g. relationship between suppliers and customers, alliances and shared benefits. (Waters 2007, 99.)

Risks come in a variety of forms originating from several different sources. Supply chain risks include for example unclear customer expectations which can lead to disrupt a very lean chain with little obsolete stocks or production capacity. Other types of risks arise from inside the processes which can be poorly designed or too complex, the process capability might be low or not measured well enough. The supply chain can also contain risks caused by specifications not developed well enough and in addition there can be variation in measurements as well as materials. Furthermore, potential safety hazards both in terms of work safety and appropriate handling of e.g. chemicals are risks to be recognized. The list could go on and on as Waters (2007, 101) suggests that a risk is basically any issue which might cause some anxiety and points out the fact that modern supply chains are global to an extent that can result the risk diversity to grow exponentially.

6.1 Risk Analysis Methods

There are two types of assessing the impact of a risk: a qualitative description of risk features and a quantitative analyses providing detailed and objective information (Waters 2007, 146). The way to go depends on the required information, field of industry

and possibility to find competitive people to perform the analysis. Most likely, however, it would be beneficial to incorporate the two rather than choosing only one or the other.

6.1.1 Scenario Analysis

A scenario analysis is conducted by analysing the potential effects of a series of decisions. Usually, a group of experts is gathered and they construct a likely series of decisions and then build another set of probable future conditions which might follow from the decision series. Finally, by analysing the future conditions and adjusting the decisions accordingly, it is possible to deduct reasonable decisions that will probably give the preferred results. (Waters 2007, 142.)

Such an analysis focuses on bigger problems in a longer term and is essentially qualitative in nature as scenario building uses expertise, judgement, brainstorming, analyses and assessment – all very subjective attributes. Most likely the team of experts would not be able to make any precise probabilities to their scenarios but for sure key features and further understanding in terms of the future options would be gained. (Waters 2007, 143.)

6.1.2 Simulation

As a risk analysis, simulation goes further than the previously described scenario analysis. This type of an analysis is more quantitative in nature as it will give a more detailed view of events that might take place. The basic idea is to use a computer model to imitate real operations of a process. Based on the simulation a large number of typical results are retrieved based on which the performance can be analysed, variations can be found and results can be compared. (Waters 2007, 143.)

Essentially there will be a wide range of information. Simulation is a way to explore different options for operations without actually disturbing the real process. The challenge lies in designing and building a simulation, which will require a lot of time. (Waters 2007, 143.)

6.1.3 Network Models

Often times supply chains can be perceived in terms of networks with risk occurring to the connections. Basically, the analysis considers the maximum amount of material that can flow through a network. Managers can then use this to determine the maximum flow through a fully functioning supply chain and then repeat the analysis with different parts of the chain removed. The difference will show them impact of losing specific parts of the chain. (Waters 2007, 145.)

The most important idea of the network models is that each link has a fixed capacity and the capacity for the whole chain will, therefore, be set by the capacity of each link and the way that the links are configured. Furthermore, one part of the chain is always set up as the bottle neck whereas other parts have spare capacity. From this data it can be deducted which areas of the supply chain are most vulnerable to risks. (Waters 2007, 145.)

6.1.4 Failure Mode and Effect Analysis

Failure Mode and Effect Analysis is a useful technique to utilize when striving to recognize where to focus attention to with regards to supply chain risk management (Christopher 2005, 246). One factor differentiating the FMEA technique from other analyses is the highlighted customer focus and perspective: risks are assessed in terms of effects not only to the internal process vulnerability but also based on the potential impact on the customer. Pollock (2005) distinguishes that FMEA should be applied to perform risk assessment in order indicate what the customer will experience if a key process input would fail. The customer viewpoint was the key factor why the case company preferred FMEA implementation to some other techniques of risk assessment.

There are, of course, studies criticizing the method. Puente, Pino, Priore and de la Fuente (2002, 141) argue e.g. that calculation of the risk priority number based on three measures (occurrence, severity and detection) can be distorted and that risk evaluation using RPN could not always be evaluated by detection. Furthermore, it is stated that different scores for occurrence and detection can end up having the same RPM even though the risks involved are totally different and finally, there is no precise rule to determine the probability of neither detection nor occurrence (Puente et al. 2002, 141).

The key to understanding supply chain risk management is that there are no clear rules and boundaries inside which to operate and form undisputable scenarios from. As Waters (2007, 146) points out both probability and consequences can be challenging to assess so often times broad estimates, subjective values or agreed categories are being utilized. There is one critical factor in the FMEA system as it should include the following components to make sure process will remain effective: implementation of a good system; maintaining that system; and most importantly assessing the system's effectiveness over time (Stillings 2011).

A further statement by Stillings (2011) is that all the high risk failure modes must be addressed and improved – not only high RPN figures but also any individual ratings (i.e. severity or severity x occurrence = criticality) with a high value. And in order to retrieve reduction in failures the system must be controlled and maintained as only to implement development procedures based on the analysis is not sufficient (Stillings 2011).

7 THE CASE COMPANY

The case company is operating in the field of chemical industry selling various services related to hazardous materials and inflammable fluids. The service portfolio includes warehousing, logistics and manufacturing of hazardous materials and inflammable fluids as well as related services requiring special knowledge and expertise.

The case company has been operational in the current form for nine years but in the background there is another organization from the field of chemical industry which via a management buyout (MBO) was transferred into ownership of the current owners.

There is plenty of different types of warehousing capacity and production equipment at the case company's premises. Also, as operating with chemicals, all appropriate and required official permits have been granted for safe handling and warehousing of inflammable risks and hazardous materials. The staff composes of highly experienced professionals who in the MBO arrangement were transferred from the previous organization's payroll. The total annual turnover is some 6 million € and staff consists of altogether 50 people.

7.1 Operating Principle

The general business idea of the case company is to provide highly specialized and customized overall solutions to businesses operating in the field of chemical industry. The corporate strategy utilizes specified expertise and a specific branch of industry. At present the volumes of own production are low, however, potential scale-ups are possible especially due to the new product. The core of the business will in any case be contract manufacturing as a share of the tailored service complex for the customers. Potential customers are perceived to consist of organizations either in need of outsourced manufacturing services or, on the other hand, chemical importing companies which require warehousing capacity, "mix and pack" type of services or for example official reporting administration arising from the chemical legislation.

The case company is utilizing an operation system as a tool to support in performance management. In the system the case company has described its operations in terms of

quality, environment, health and safety perspectives. The case company is certified for the following standards: ISO 9001, ISO 14001 as well as OHSAS 18001. Certifications for the operation system are a necessity as the international customers consider certificates as a prerequisite to starting any business in the first place. In the chemical industry it is crucial for the service providers, too, to be operating in a way which is safe for people and for the environment.

Further to the above described certificates, one of the main customers of the case company is requiring a so called 5S procedure to be implemented in order to promote work safety and efficiency in all functions. The procedure is based on systematically and visually organizing work to reduce waste and improve work safety. This method has been developed in Japan and it is designed to transform the work environment pleasant and productive at the same time. The five S letters indicate sort, set in order, shine, standardize and sustain.

8 PROOF OF SELECTION: WHY FAILURE MODE AND EFFECTS ANALYSIS

Prior to full market launch of a new product the company wanted to conduct an FMEA process analysis to determine the potential risks within the supply chain for this particular item. Several different risk management tools were evaluated and FMEA was chosen as it was seen to provide the most valuable type of information for the rather specified need. FMEA was viewed to be a tool which will enable the company to minimize supply chain related risks in a preventative and cost-effective manner. The type of analysis is superior in terms of assessing and evaluating risks within the supply chain processes as well as prioritizing the revealed risks and thus supporting in allocating preventative measures to correct locations.

One important aspect in choosing FMEA to be the tool to analyze the supply chain for the new product was the concept of preventative quality management where identifying and managing risks prior to them actually realizing is focal. The risk of failure is always present especially considering the circumstances of launching a new product in the market – and without knowing the potential risks within the chain one will not be able to control them. Furthermore, the sooner a risk is identified the easier it will be to control thus reducing the effects of such a failure mode. There was a clear desire in the case company to move away from reactive risk management and the so called “fire extinguishing” towards a more proactive approach. It was, however, fully noted that measuring the utility as well as observing the value of such preventative actions is challenging (Stamatis 2003, 21-22).

FMEA in its nature is one of the most effective risk management techniques in the early stages of product life cycle. In general, it can be argued that preventative measures in terms of quality management is more efficient and cost-effective than reactive responses. The latter approach can only improve the quality of the outbound flow from the organization whereas by conducting a Failure Mode and Effects Analysis at an early stage of market launch it is possible to reduce the critical failure modes and deviations within the process already before the final product is delivered to the customer thus improving the quality within the organization and in best scenarios also within the supply chain scope including also suppliers and customers as well as end users.

Within an organization Failure Mode and Effect Analysis can be applied in process, product design, systems or service based on the data and information needed. The analysis will provide information on various failure modes thus improving quality, reliability, customer satisfaction and product safety. In addition, the tool will reduce product development and process turnaround time, cut costs as well as decrease defect remedying and waste figures. Moreover, one important feature for the case company is the documentation of performed procedures and prioritization of defects in terms of further actions to be taken. (Karjalainen & Karjalainen 2002, 168-169.)

Figure 3 exemplifies the benefits of Failure Mode and Effects Analysis.

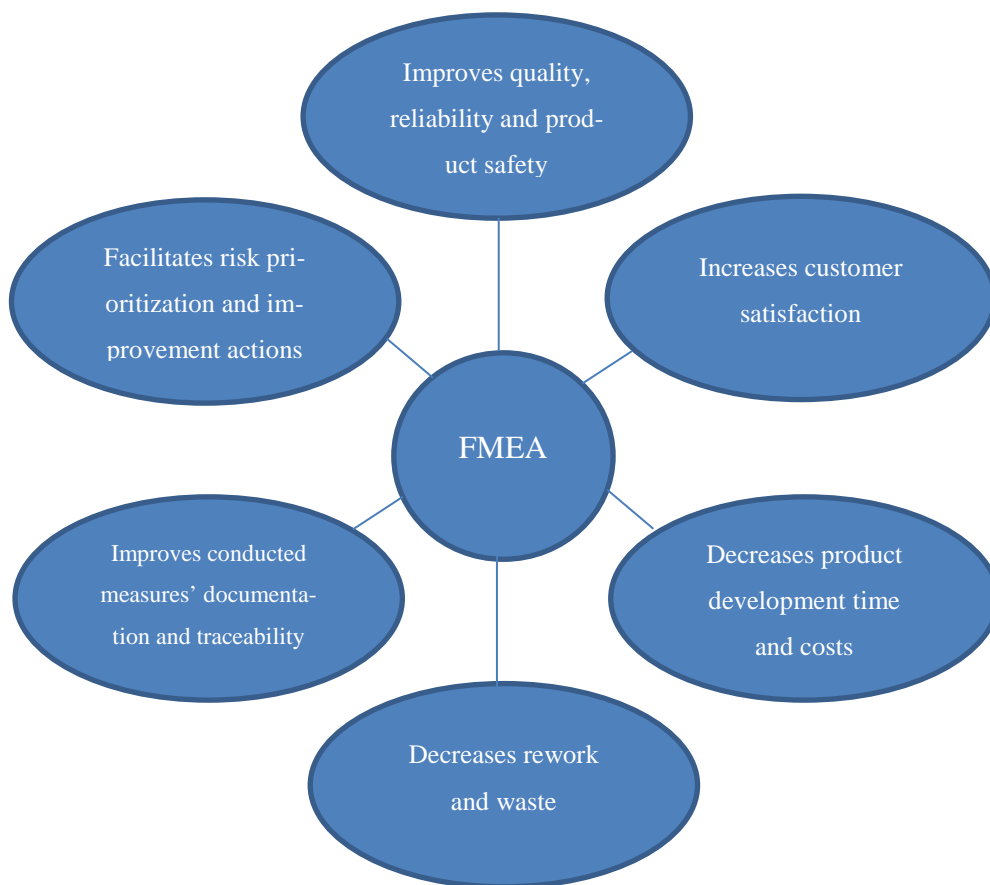


FIGURE 3. Benefits of FMEA (Karjalainen & Karjalainen, 2002, modified)

9 FAILURE MODE AND EFFECTS ANALYSIS

The FMEA is a proactive, team oriented risk management technique which systematically identifies potential types of failure. The place to start is from mapping each process step after which FMEA can be used to identify opportunities for defects or waste to occur. Usually these risks are divided into hardware (including for example failures in machinery and production equipment) and activities (meaning problems starting to arise when a certain activity cannot be performed) (Waters, 2007, 142).

Stamatis (2003, 40-43) suggests that there are four types of FMEA analyses that can be categorized; all of them are related to one another but can easily be conducted on their own as well. Each analysis is focusing on different stages of a manufacturing process as indicated in figure 4. There types are: System FMEA, Service FMEA, Design FMEA (DFMEA) and Process FMEA (PFMEA). The type of analysis performed in this thesis is in fact a Process FMEA, which is in the coming chapters referred to only as an FMEA.

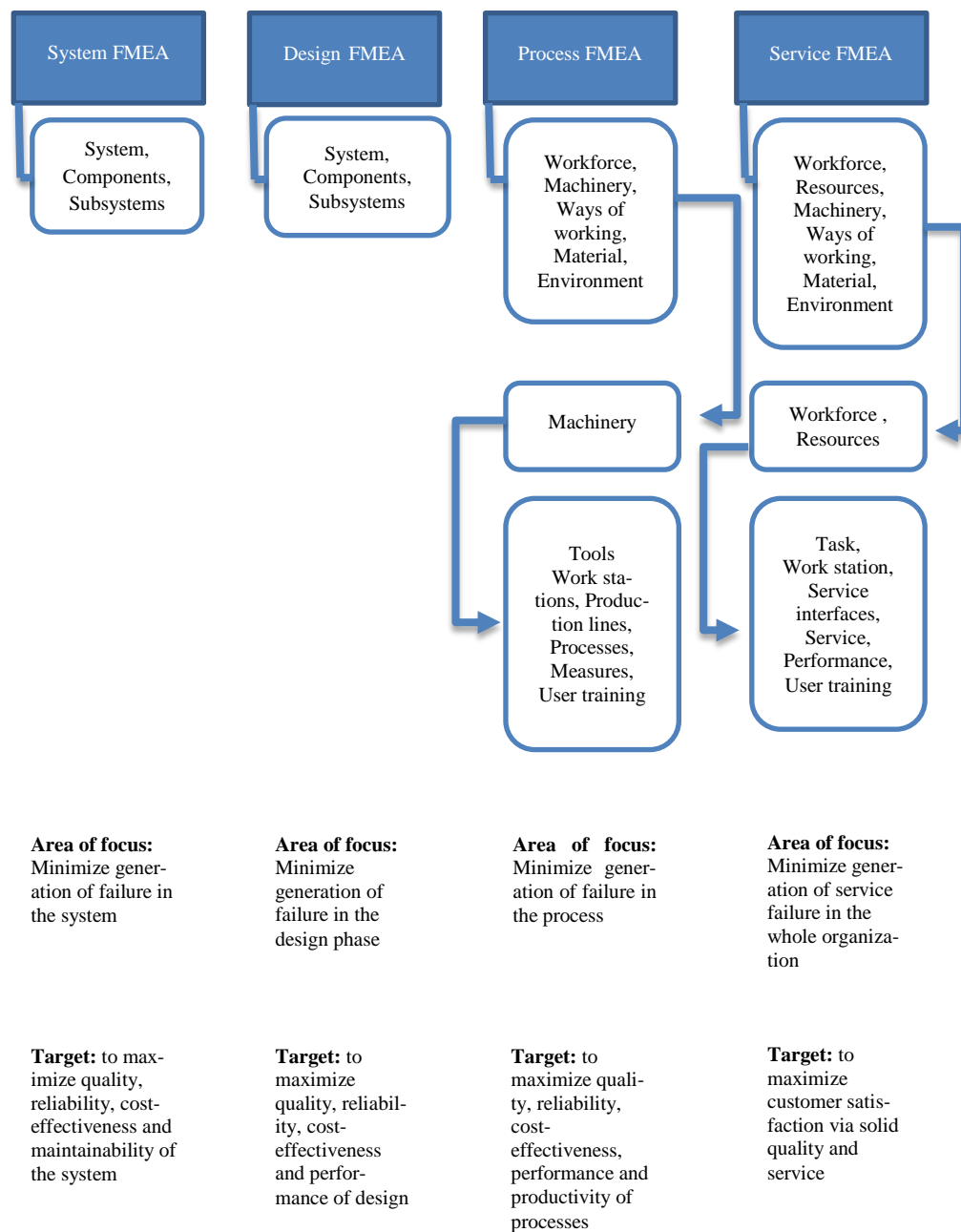


FIGURE 4. FMEA type descriptions (Stamatis 2003, 42, modified)

9.1 System FMEA

A System FMEA is focusing on systems and subsystems at an early planning stage in the product life cycle. It is used to find any system-related weaknesses that might result in defects or failure in the product at a later stage. This type of an analysis will support in choosing optimal practices in early planning and help reduce overlapping. It will also

define the system's fault diagnostics procedure, reduce potential failures and identify any underlying flaws inside the system. (Stamatis 2003, 40.)

The target of a System FMEA is to critically examine and to gradually enable developing and expanding the system. The reasoning and developmental ideas will be documented and prioritized.

9.2 Service FMEA

As the name suggests a Service FMEA is to be used to analyse services prior to customer delivery. Such an analysis will emphasize potential failures in practices, systems or processes. It will support the analysis of the amount of work in relation to the system or process by highlighting possible failures in the tasks. Furthermore, by the support of this tool it is possible to assign the most significant duties or process parts as well as creating an inspection plan. As with a System FMEA all improvement needs and their prioritization criteria will be documented. (Stamatis, 2003, 41.)

9.3 Design FMEA (DFMEA)

A Design FMEA is to be conducted at a design stage prior to production in order to find deficits which might later on cause a failure in the end product. DFMEA is a highly proactive tool in improving the product reliability and quality. Undoubtedly, possible failures within a product can be later on discovered via customer feedback or at the prototype testing phase, however, the financial gain lies in identifying any defects beforehand. (Stamatis, 2003, 42)

9.4 Process FMEA (PFMEA)

A Process FMEA is a technique to utilize in analysing the production and assembly process. Ideally, such an analysis is performed at a pilot stage prior to actual production. Examination of the process before concrete production will begin is important as at this point making any changes would still be relatively easy and inexpensive. PFMEA will look at each process variable individually taking into account all the relative factors such as the worker and his tools, ways of working, testing and the environment. Each single variable will have active factors that are either directly, indirectly, together or in

series influencing the variable thus creating potential failure modes. In its nature, PFMEA is more complex and time-consuming and therefore, more difficult to perform than a System or Design FMEA. (Stamatis, 2003 42-43.)

According to Smallpeice Enterprises Ltd (2010) in the context of process improvement FMEA is used to:

- Identify where improvement actions are required in order to reduce process risks.
- Identify where data needs to be collected in order to better understand process risks.
- Assess risks relating to process improvements.
- Provide focus in the development of an ongoing process control plan.

Furthermore, Failure Mode and Effects Analysis is used to identify weaknesses inside the process that could potentially lead to failures. The goal is to remove or minimize possible failures by activities or controls. As a result of a PFMEA a list of potential failure modes is generated together with an RPN figure. In addition, a list of recommended actions is formed in order to avoid potential failure modes inside the process. This type of an analysis will detect process failures as well as possible errors as well as listing them based on their criticality assigned in the RPN values. The tool will conclude corrective actions as well as an implementation plan for the most critical risks to be worked on. At the same time, all grounds for the decisions made will be documented and this data is something to act as history reference to ensure that the same mistakes will not reoccur in the future and/or by which means the failure mode was eliminated. (Stamatis, 2003, 42-43.)

9.5 The Main Steps in FMEA

Failure Mode and Effects Analysis technique follows a clear and structured pattern of stages. Each stage concentrates on a different viewpoint of the process and related risks. The analysis is quantitative and measures the impact of risk to the business or the customer (S), failure probability (O), and the capacity of testing mechanisms already in place to detect a potential failure (D). (Segismundo & Cauchick 2008, 905.)

The core of the technique is to identify, assess and rate all potential risks in the supply chain processes. Simplified the basic idea of the analysis is as per below:

What can go wrong → Failure mode

What would be the result → Effect

How serious is it → **Severity (S)** → Rate from 1 - 10

What could cause the failure → Cause

How often will it happen → **Occurrence (O)** → Rate from 1 – 10

How might it be found → Current Controls

How effective is that method → **Detection (D)** → Rate from 1 – 10

The risks are then categorized by priority as per the below equation:

$$RPN = S \times O \times D$$

Where S is Severity, O is Occurrence and D is Detection

The calculated risk priority number will indicate to business managers which processes include the highest risks and are in need of development first. FMEA will also act as a tool to assist in root cause drill down – i.e. help explain where the risks are really coming from inside the process – as will it support to give direction for further statistical investigation. (Smallpeice Enterprises Ltd, 2010.) The information retrieved by this technique can also be incorporated with Six Sigma metrics to further refine the processes and variation within set specifications inside each process step.

Figure 5 illustrates the big picture behind the FMEA technique and following chapters will discuss each phase in detail.

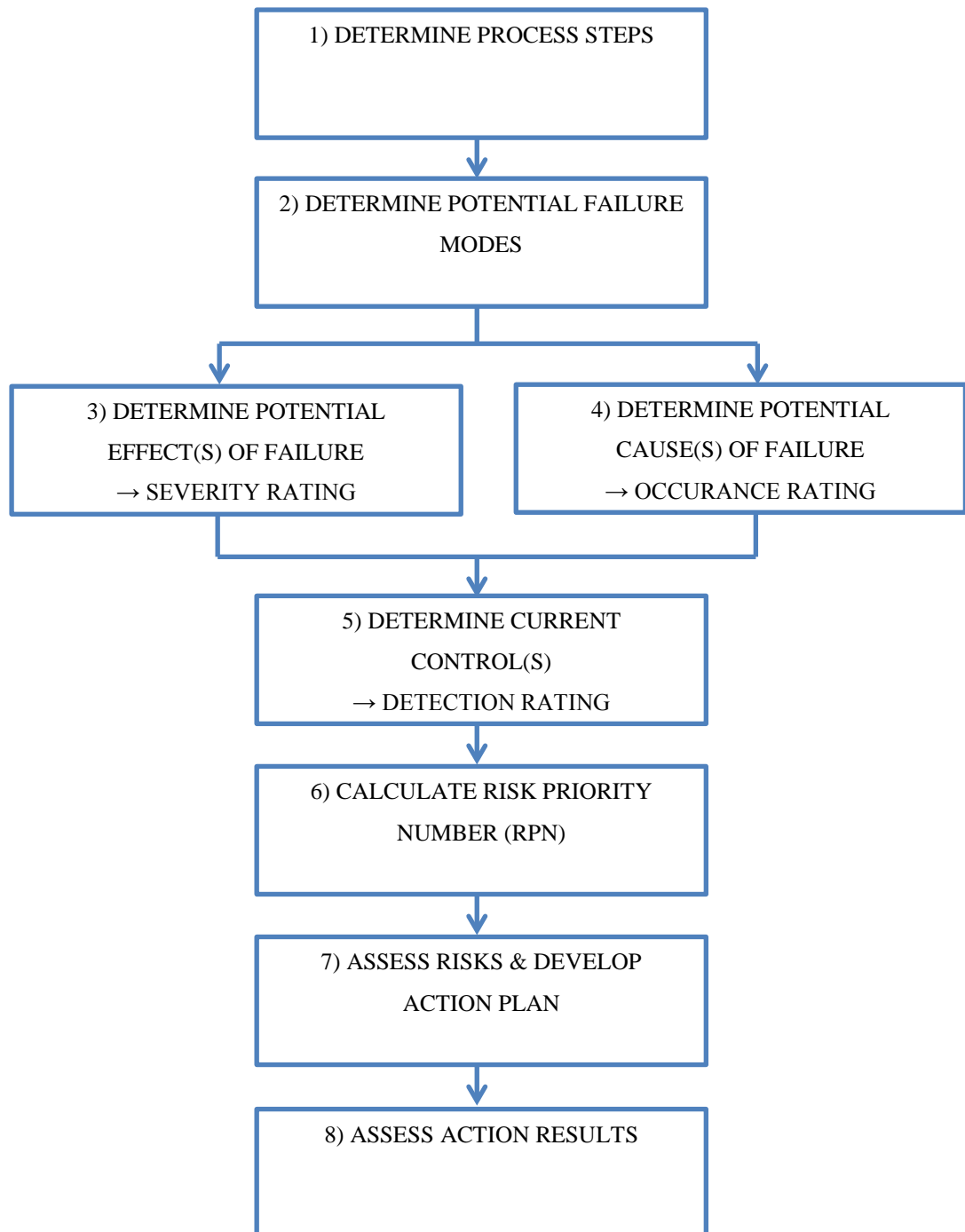


FIGURE 5. The Main steps in FMEA (Smallpeice Enterprises, 2010, modified)

9.5.1 Determining Processes

The very beginning of the analysis is define phase. This is a section where the processes are identified and later on potential risks are specified.

Firstly the process steps should be determined. These steps should come from the process map and be specified at a fairly high level. Details should be drilled down to only if absolutely necessary in order to understand the risks associated. (Smallpeice Enterprises Ltd, 2010.)

9.5.2 Determining Potential Failure Modes

Next potential failure modes should be determined. A failure mode is something that could go wrong and for each process step it should be separately questioned what could go wrong here. All types of possible errors should be considered in a realistic but not restrictive manner. Each step can have multiple failure modes. (Smallpeice Enterprises Ltd, 2010.)

Essentially the process map should be reviewed and have everything listed which could realistically go wrong with the process.

9.5.3 Determining Potential Effects

After defining both process steps as well as identifying possible failure modes the next section of the analysis is measure phase. Current risks are to be assessed before improvements are made. Furthermore, identification of high risk process steps can lead to urgent temporary containment (Smallpeice Enterprises Ltd 2010) in cases where actions are needed immediately e.g. when facing vulnerability in work safety. Moreover, FMEA can help identify the need for data collection to better understand process risks (Smallpeice Enterprises Ltd, 2010) for example when introducing new products in the manufacturing range.

Potential risks are to be rated based on the effects a failure would have as well as what is causing the failure to occur and finally how such risks are currently being monitored. These ratings will create an index upon which each risk's prioritization will later on be based.

First it is to determine potential effects. For each individual failure mode it should be asked what effect these would have on the customer or business. The impact on the

thing or value to the customer is to be considered in particular. Once the effect has been determined the severity of impact can be rated. (Smallpeice Enterprises Ltd, 2010.)

In other words it is to be evaluated how big an impact the potential failure would have on the business or customer. The severity scale in process FMEA should contain effects of failure throughout the supply chain. Rating should be done by using the following scale:

1 = Minor impact (or no impact)

E.g. the customer would not notice that anything had gone wrong.

5 = Medium impact

E.g. the customer would be inconvenienced by the incident and it may result in a customer concern.

10 = Serious impact

E.g. the incident would result in significant financial loss to the customer or to the business. The incident breaches regulatory requirements. (Smallpeice Enterprises Ltd, 2010.)

This is called the severity rating and table 1 illustrates an example of the scale.

TABLE 1. Exmple of Severity Ratings. Reproduction of the QS9000 Severity Table (Smallpeice Enterprises Ltd, 2010)

Effect	Criteria: Severity of Effect	Ranking
Hazardous - without warning	May endanger machine or assembly operator. Very high severity ranking when a potential failure mode effects safe product operation and/or involves non-compliance with government regulation. Failure will occur without warning.	10
Hazardous - with warning	May endanger machine or assembly operator. Very high severity ranking when a potential failure mode effects safe product operation and/or involves non-compliance with government regulation. Failure will occur with warning.	9
Very High	Major disruption to production line. 100% of product may have to be scrapped. Product/item inoperable, loss of primary function. Customer very dissatisfied.	8
High	Minor disruption to production line. Product may have to sorted and a portion (less than 100%) scrapped.	7

	Product operable, but at a reduced level of performance. Customer dissatisfied.	
Moderate	Minor disruption to production line. A portion (less than 100%) of the product may have to be scrapped (no sorting). Product/item operable but some comfort/convenience item(s) inoperable. Customer experiences discomfort.	6
Low	Minor disruption to production line. 100% of product may have to be reworked. Product/item operable but some comfort/convenience item(s) operable at a reduced level of performance. Customer experiences some dissatisfaction.	5
Very Low	Minor disruption to production line. The product may have to be sorted and a portion (less than 100%) reworked. Fit and finish/squeak & rattle item does not conform. Defect noticed by most customers.	4
Minor	Minor disruption to production line. A portion (less than 100%) of product may have to be reworked on-line but not out-of-station. Fit and finish/squeak & rattle item does not conform. Defect noticed by average customers.	3
Very Minor	Minor disruption to production line. A portion (less than 100%) of product may have to be reworked on-line but in-station. Fit and finish/squeak & rattle item does not conform. Defect noticed by discriminating customers.	2
None	No effect.	1

9.5.4 Determining Potential Causes

Following stage contributes to determining potential causes. The question to find answers to at this particular stage is what could cause this failure mode to happen. Again, there might be several reasons behind one failure and all of them should be listed. For this reason, brainstorming is proposed. After noting down all possible causes it should be questioned how likely is this to occur and each cause is to be rated based on the probability of happening. The rating should be done by using the following scale:

1 = Unlikely to happen

E.g. less than once in five years; less than 0.1% of volume.

5 = Quite likely to happen

E.g. once in three months; less than 2% of volume.

10 = Will definitely or almost definitely happen

E.g. every day; more than 5% of volume. (Smallpeice Enterprises Ltd, 2010.)

This is called the occurrence rating and table 2 shows the scale in terms of estimated probability in relation to the process capability and variation control (C_{pk}) from Lean Six Sigma metrics.

TABLE 2. Example of Occurrence Ratings (Smallpeice Enterprises Ltd, 2010)

Probability of Failure	Possible Failure Rates	Cpk	Ranking
Very high: Failure is almost inevitable	≤ 1 in 2	$\leq 0,33$	10
	1 in 3	$\leq 0,33$	9
High: Generally associated with processes similar to previous processes that have often failed	1 in 8	$\leq 0,51$	8
	1 in 20	$\leq 0,67$	7
Moderate: Generally associated with processes which have experienced occasional failures, but not in major proportions	1 in 80	$\leq 0,83$	6
	1 in 400	$\leq 1,00$	5
	1 in 2000	$\leq 1,17$	4
Low: Isolated failures associated with similar processes	1 in 15000	$\leq 1,33$	3
Very Low: Only isolated failures associated with almost identical processes	1 in 150000	$\leq 1,50$	2
Remote: Failure is unlikely. No failures ever associated with almost identical processes	≤ 1 in 1500000	$\leq 1,67$	1

9.5.5 Determining Current Controls

Final step of the measure phase is to determine current controls. Finally, considering all possible failure modes and their associated causes it should be examined what controls are currently in place which would detect or prevent the problem.

There are many methods that can be used to mitigate process risk, some maybe more aiming to control processes whereas others are aimed at finding defective products. Some examples of current controls can be divided into four categories which are audits: sample products and process parameters; inspections: patrols, in-process, final; checking: operator, manual/visual, mistake proofing; and others: engineering specifications tests, set-up verification, limit switches/warning devices. (Smallpeice Enterprises Ltd, 2010.)

Existing controls should be rated on a scale of 1 to 10 as per below:

1 = Will detect the problem immediately (or prevent it from occurring)

E.g. automatic prevention of defect, such as not able to access computer files if case typing in a wrong password.

5 = Will detect the problem at a later step in the process

E.g. some form of manual checking in place.

10 = Problem won't be detected until the customer and/or business have been affected

E.g. can't pick up the problem until customer complains. (Smallpeice Enterprises Ltd, 2010.)

This is called the detection rating and table 3 will provide some insight into detection rating criteria.

TABLE 3. Example of Detection Ratings. (Smallpeice Enterprises Ltd, 2010).

Detection	Criteria: Likelihood the Existence of a Defect will be Detected by Process Controls Before Next or Subsequent Process, or Before Part or Component Leaves the Manufacturing or Assembly Location	Ranking
Almost Uncertain	No known control(s) available to detect failure mode	10
Very Remote	Very remote likelihood current control(s) will detect failure mode	9
Remote	Remote likelihood current control(s) will detect failure mode	8
Very Low	Very low likelihood current control(s) will detect failure mode	7
Low	Low likelihood current control(s) will detect failure mode	6
Moderate	Moderate likelihood current control(s) will detect failure mode	5
Moderately High	Moderately high likelihood current control(s) will detect failure mode	4
High	High likelihood current control(s) will detect failure mode	3
Very High	Very high likelihood current control(s) will detect failure mode	2
Almost Certain	Process control(s) almost certain to detect failure mode. Reliable detection controls are known with similar processes	1

9.5.6 Calculating the Risk Priority Number (RPN)

Third phase in the FMEA technique is called analyse. The purpose of this section is to produce comparable indexes for each failure mode and its priority in terms of effect,

cause and detection. The retrieved information is to act as a basis for business management or process owners to base their judgement on.

For each failure mode a risk priority number is calculated and it will act as a useful tool in identifying the risks with high priority. The RPN represents the overall risk associated with each cause of failure. The risks can then be assessed and an action plan can be issued in order to eliminate them. (Smallpeice Enterprises Ltd, 2010.)

As explained in the previous chapters there can be several effects of one failure mode and several current controls in place. In the calculation the highest severity rating should be taken whereas out of the detection rating the lowest score should be chosen (Smallpeice Enterprises Ltd, 2010.) as per exemplified by figure 6.

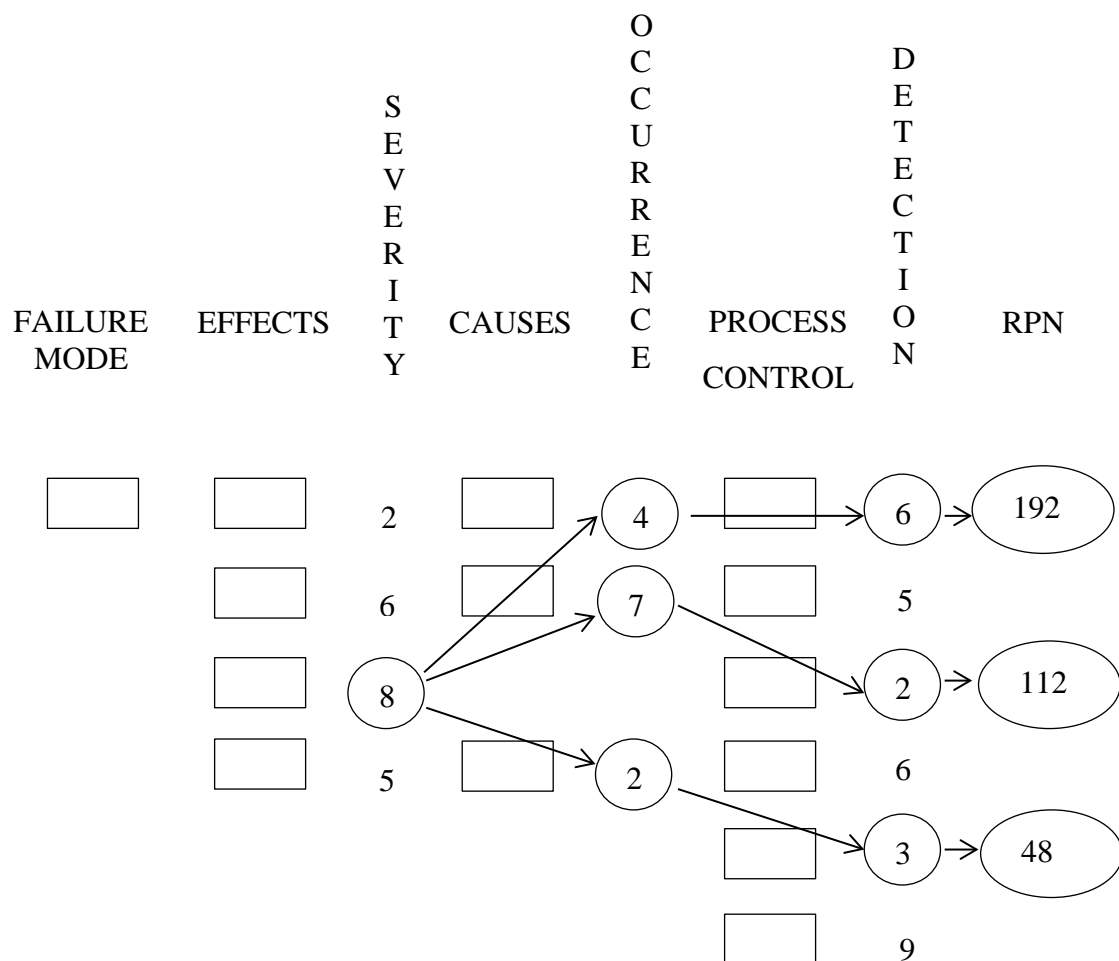


FIGURE 6. RPN calculation example (Smallpeice Enterprises Ltd, 2010, modified)

9.5.7 Assessing Risks and Developing Action Plan

Fourth face in the analysis is named improve. This stage together with the analyse section is the core of FMEA. After having analysed the root causes behind different failure modes the technique is vital in risk assessment of proposed improvement actions.

RPN magnitude will run on a scale from 1 – 1000. There are no specific regulations as to when a risk becomes high but using RPN to sort the risks should allow identifying the highest risks within the chain. It is also good practice to review any severity assessments with a score of 9 or 10 against any individual rating even if the overall RPN would be low (Smallpeice Enterprises Ltd, 2010). This is to ensure the current controls are sufficient and in line with the severity of the potential failure.

Figure 7 (Smallpeice Enterprises Ltd, 2010) is a process flow chart for improvement action planning and indicates the correlation between various steps in the improving face of the analysis. It also provides insight as to the order in which any further decisions should be made.

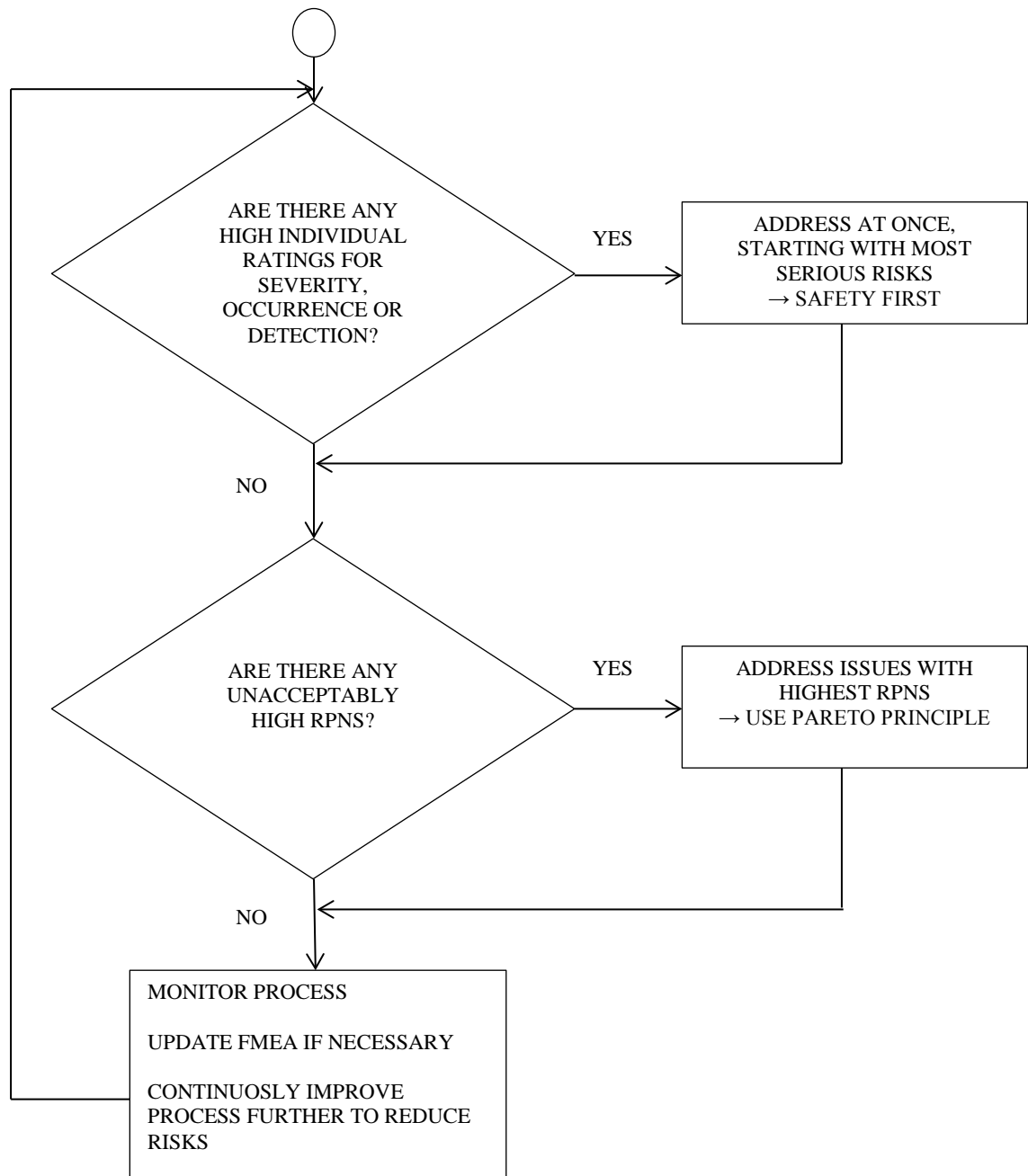


FIGURE 7. Improvement Action Flowchart (Smallpeice Enterprises Ltd, 2010)

It is advised to first tackle any single ratings that have received high values in any of the three ranking steps (Smallpeice Enterprises Ltd, 2010): severity, occurrence or detection especially if any of these are related to work safety. For instance any repeating risk at some part of the manufacturing process or poorly organized current controls regarding safety regulations at a warehouse should be undertaken first.

9.5.8 Assess Action Result

The final phase in the entire analysis is called control. In this section the improvement actions have been implemented and it should be returned back to FMEA ratings and revise the risk rating to verify the reduction in risk made.

To illustrate percent decrease in the RPN can be presented according to equation

$$\% \text{ Reduction in RPN} = \frac{RPN_i - RPN_r}{RPN_i}$$

RPN_i is the initial risk priority number and RPN_r is the revised risk priority number
(Examining Risk Priority Numbers in FMEA, 2003)

10 FAILURE MODE AND EFFECTS ANALYSIS FOR THE CASE COMPANY

This chapter will first distinguish all of the case company's processes in the supply chain related to manufacturing of a new product beginning in the summer of 2014. Research and development of this new product i.e. its recipe as well as production procedures have both already been developed and tested in pilot scale in 2013. Both have been proven to work and the customer has accepted the product as such. Therefore these aspects of the process mapping are excluded and the analysis will focus on the chain from sourcing raw materials all the way down to the final delivery to the customer.

In order to perform an effective and in-depth analysis the scope of the evaluated process must be carefully set to ensure it will not be too wide. Preferably, the target of the analysis should be a defined and significant portion out of a larger complex. By limiting the scope it will be possible to trace those failure modes that carry the biggest impact in the process flow as a whole. Therefore, it is to be noted that the Failure Mode and Effects Analysis will only cover the supply chain processes of one particular product which will be introduced to the market in 2014.

10.1 Business Process Model

The completed FMEA is filled on a Smallpeice Enterprises Ltd.'s spreadsheet which can be found in the appendices. The entire analysis is explained in more detail in the coming chapters.

Before it is possible to analyse the supply chain risks related to the new item to be launched it is necessary to create a business process model which indicates all the process steps. Figure 8 is the business process model for the case company.

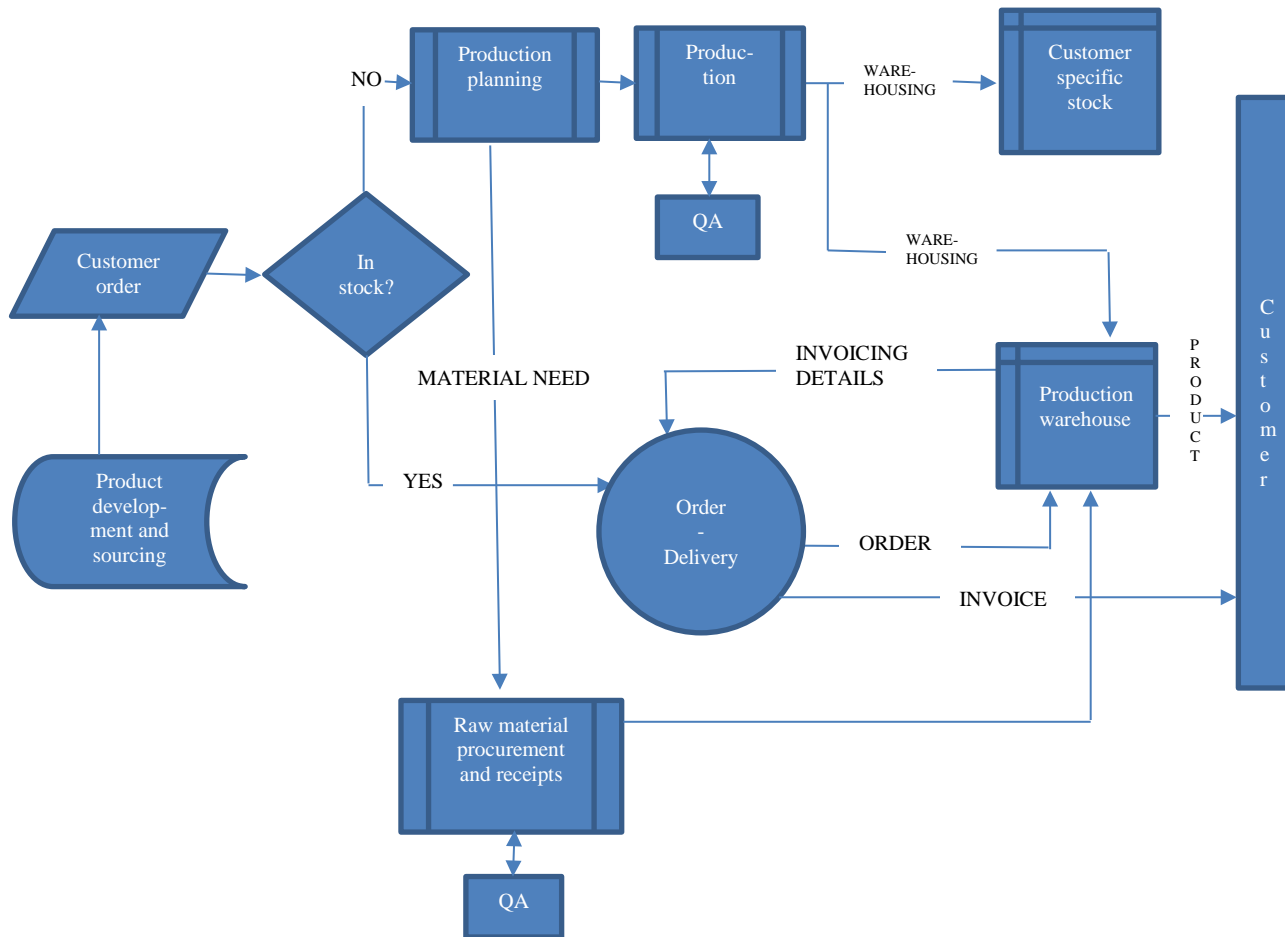


FIGURE 8. Business process model

Figure 9 is a process chart demonstrating the overall picture of the supply chain of the new material production. Each process will be detailed further and related risks will be identified and categorized to be either hardware or activity related, each risk is then assessed and analysed.

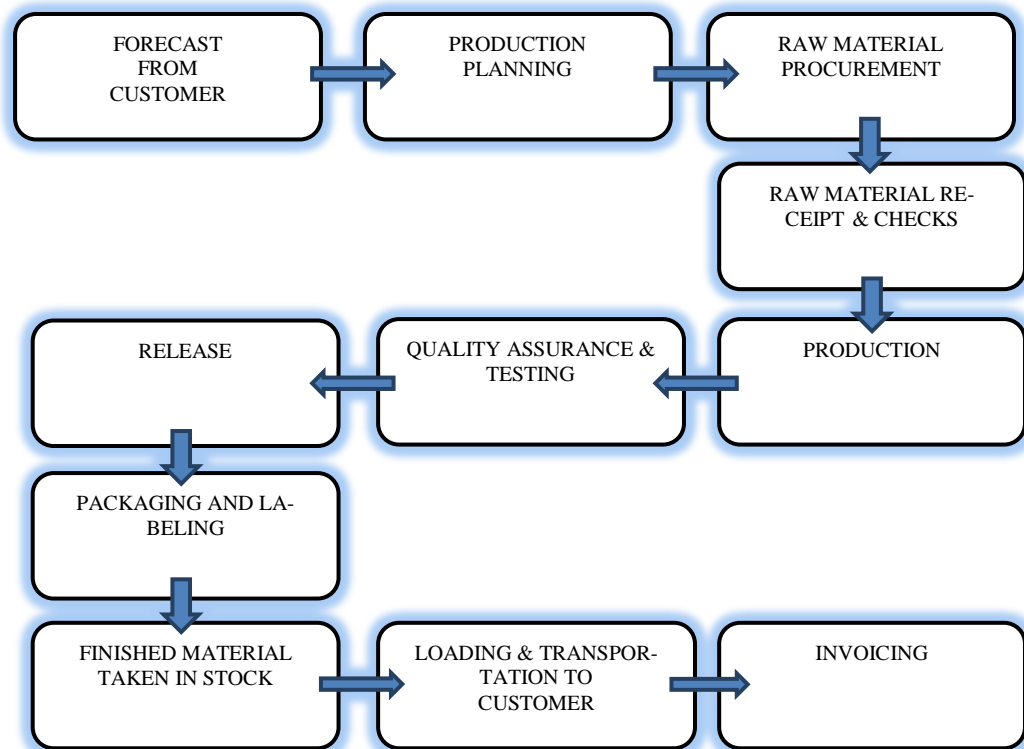


FIGURE 9. Process Flow Chart.

10.2 Process Step: Forecasting

The end use of the new product will be done outside and time period will be limited to the summer months of 2014 thus making the manufacturing process highly seasonal. The case company will receive a binding forecast from the customer for the total needed volume for this year. Binding in this case means that the customer will buy the complete quantity he has forecasted i.e. the overall volume has been agreed upon. Based on these quantities it has been agreed for the case company to hold stocks for the customer: at all times there will be one full truck load (which equals to six containers) available in stock. That is to say the case company is practicing make to stock (MTS) manufacturing – as opposed to make to order (MTO) where goods are produced only after receipt of order (Parry & Graves 2007, 3.) An accurate forecast from the customer will prevent excess stocks whilst avoiding a stock out situation.

10.2.1 Potential Failure Modes

This process poses a risk of inaccuracy in the customer forecast. On one hand the forecast submitted could be too low but it could also potentially be too high. However, as

the volumes have already been negotiated the probability of any changes in the quantities would be rather low in this case.

Another possible risk is reducing customer demand in general. Currently the selling price has been negotiated based on the key component purchasing price with bulk deliveries so the order intake figure is clearly linked to added value i.e. profit.

10.2.2 Potential Effects

Should the customer have provided too low a forecast this would lead to an immediate lack of available material and most likely – due to the high seasonality of the product – production plans should be reviewed to allocate extra capacity to fill the sudden increase in demand. For the customer this would mean un-optimized resources and re-scheduling of his own production in case they would run out of material over a certain period of time.

A forecast too high would result in obsolete stocks and less free capacity at the case company's warehouse. Consequently this would also have an impact on production planning by reallocating capacity. Moreover, inventory management would have to be altered as a decreased outbound flow of finished material would affect the stock rotation figures.

Should the customer demand reduce from the original estimations that would, in terms of risks to the business, lead to lowered batch sizes i.e. decreased production efficiency and consequently a financial impact on the case company. The financial effect would also reflect in terms of lower added value per unit, in other words the profit made by the case company would decrease. Furthermore, raw material prices would most likely increase as order quantities would decrease. Such effects, however, in this particular case study are quite improbable because the overall volume has been optimized and agreed with the customer.

For the customer the financial effect of decreased volumes would most probably be reflected as increases in the selling price. Possible scenarios, in case volumes would decrease, are that both raw material and production batches are decreased which will lead to price increases via loss of efficiency or on the other hand by keeping raw material

intake and production batch size on the current level the inventory costs will be greater. Again, it is to be mentioned that any changes in demand are not likely to occur but should be analysed regardless.

10.2.3 Severity Rating

The severity ratings for each individual potential failure mode are described in appendix 2.

The highest individual severity ratings will derive from decreased customer demand resulting in a severity ranking of 8 as well as customer suffering a lack of material with severity ranking at value 7. On the other hand, the least impact would be caused by production planning of the case company having to reallocate capacity in case the forecast would be too high.

10.2.4 Potential Causes

Potential causes for any issue with the forecast would most likely derive from communication either inside the customer's own organization or then from the end user not being able to plan his own schedules.

As forecasts are not very scientific in nature and are really only perceived as an estimation of the future it is quite possible that someone has made a mistake in their calculations – this can also be traced down to the customer himself or all the way to the end user.

10.2.5 Occurrence Rating

Each potential cause is given a separate occurrence rating based on how often it estimated to take place. The figures are based on both pure assessment but also historical data on similar or almost identical processes and will be detailed in appendix 2. Regarding the process of forecasting the likelihood of anything going wrong is extremely low simply because the volumes have been negotiated beforehand. Although, the possibility of customer needing more material than agreed due to unforeseen demand from the end user did receive a rating slightly higher (2) than the rest of the potential causes. Simul-

taneously, as in the modern business world it would be very well possible that the customer would lose some part of his business during the contract period, the risk of such an occurrence is evaluated still to be very remote due to the binding agreement stating that the customer will buy at least the initial quantity mentioned in the contract regardless of any unpredicted changes.

10.2.6 Current Controls

There are no precise and standardized controls regarding any inconsistencies in the forecast figures. However, communication is not only very open but also proactive and the prevalent relationship between the customer and the case company could be described more a partnership rather than only a business relationship.

10.2.7 Detection Rating

Individual detection ratings are listed in appendix 2. As there are no specified current controls in place – due to the very safe positioning of the case company and the customer as a consequence of the pre-negotiated volumes – the detection rates are on the higher middle class of the scale (either 6 or 7). The differentiating factor as to why some causes were evaluated to be slightly easier caught is the element of the failure mode itself. Since current controls are only based on sufficient information flow it is more likely to gather information more quickly of incidents where there is either a shortage of material at the customer's end or that are larger in scale – for this reasoning the causes initiating from a too high forecast were rated with a bit worse score.

10.2.8 Risk Priority Number Calculation

Risk priority numbers calculated based on the formula: $SEV \times OCC \times DET = RPN$. As assumed the overall scores of the final risk priority numbers relating to forecasting are low due to the nature of the process for the new product. Appendix 2 will indicate all of the RPNs.

10.2.9 Risk Assessment and Action Plan Development

The only cause of failure in theoretical need of further actions is the one proposing unforeseen needs from the end user. This might be due to incorrectly calculated consumption referring to a scenario where more material than initially requested would be consumed to cover a certain area of application. Another possible root cause might be simply enough gained market share in the middle of the contract term.

As the business is new there is no historical data available but it might be worthwhile to record data of the forecasted figure and cross-reference this to actual sales data after the season i.e. in late October. The data should be easily retrievable from the system and would a) indicate results of this year's actual accuracy of the figures and b) begin the database of historical data for the future in case the business was to continue.

10.2.10 Action Result Assessment

Suggested actions should be reviewed as per the schedule in the FMEA analysis spreadsheet in appendix 2.

10.3 Process Step: Production Planning

The following step in the supply chain is production planning which is made against the forecast received from the customer and the delivery date agreed with the customer. Production planner is responsible for optimizing the production volumes according to efficiency principles of the machinery and raw material intake volumes. It is the responsibility of the production planner to confirm that there are six containers of finished product available in stock at all times. In cases where the agreed stock for one reason or another cannot be confirmed it is up to the production planner to collectively with the customer to reschedule coming availability date. If the customer's need was urgent then the matter would be revalued in terms of available capacity and, if needed, escalated internally to prioritize orders.

10.3.1 Potential Failure Modes

A critical failure mode regarding production planning is an error in the plan: wrong material in production at a wrong time or in an incorrect quantity.

The requested delivery date comes from the customer but it is possible that this request changes either for earlier or for later than originally. As mentioned earlier the new material will be highly seasonal thus making it more volatile within a short time frame.

Furthermore, there is a possibility that the safety stock of six containers will not be managed to be respect at all times. This could be derived from an abundance of sources but falls into production planning failure category according to the responsibilities assigned internally.

10.3.2 Potential Effects

Any mistakes in the production plan can escalate in to various different impact scenarios. Ultimately, the production campaigns can be planned for an incorrect time frame as changes to existing plans have been forgotten to be informed onwards. The impact would be a wrong quantity in stock at the wrong time – potentially disastrous for the customer. It is also possible that due to a planning mistake there will be too much material in stock which can create issues in warehouse management or product life cycle in terms of shelf life.

Whereas if it is the customer who needs to modify the agreed delivery date for any possible internal or external reason (sick leaves resulting in lack of manpower, process equipment malfunction or inability for the transportation company to serve as ordered, etc.) it will be production planning having to modify production schedules to meet the customer's requests either by advancing availability date or delaying if needed.

Impact of the third potential failure mode as per production planning in a case where the agreed safety stock would not be present at all times is simply enough a stock out for the customer.

10.3.3 Severity Rating

Severity ratings will be found in the spreadsheet in appendix 3 in a complete form. The most severe effects – with severity rating index of 8 - would be a stock out for the customer. According to the analysis this could derive from two sources which are to be detailed in the separate section below. The smallest impact would be presented from having to reschedule production for a later time as per request by the customer. The severity ranking in such a scenario would be only 2 representing a minor impact.

10.3.4 Potential Causes

Communication flow disruptions during for example holiday season or a sick leave pose a potential cause for an important failure mode which needs to be considered. The most reasonable scenarios of miscommunication with key people being absent include that actions and plans have not been properly recorded thus making it difficult for the substituting staff to catch up on what has been agreed leaving plenty of room for misunderstandings. This could easily lead to either too low stocks or too high respectively. It is to be considered that producing incorrect grades at a given time equals automatically to resources misused and capacity removed from items with possible urgency.

A further possible cause behind an error in the production plan is a human error. The aspect of human error can never be fully removed as long as there are people running the computerized planning systems (which - as a side note – will hopefully be the case in the future as well). There are procedures to minimize both the occurrence and severity of such failures, though.

Concerning the potential failure mode of customer having to alter the requested delivery date, this type of risk can originate from any issues at the end user: maybe final application is not performing as planned due to quality problems or – as it is a new product start-up phase – there are some internal issues in the process. It is also possible that there has been a planning mistake in intake figures at the customer.

Finally, analysis on the causes for the safety stock to not be in place at all times indicates two types of causes: inadequate information flow internally or insufficient capacity on the machine.

10.3.5 Occurrence Rating

Assessment of the probability of such failures to take place will be completed in the appendix 3. For production planning failure modes the occurrence ratings vary from remote to moderate, communication flow disruptions taking the lead with a ranking index 6 whereas lack of capacity positioning on the other end of the scale with occurrence rate 1.

10.3.6 Current Controls

The current controls are based on information exchange between production planning only working during office hours and work supervisor as well as production staff working in two shifts. Every day at the time of the shift change there is a meeting between the production planner and the work supervisor reporting for duty on what has been planned to come out of production on the given day. These discussions should leave a mark in the system and thus be visible and accessible to all parties. Should there be a mistake in the production plan it would be noticed when several people are reviewing the plan from their own roles and responsibilities.

In eliminating the possibility of the end user facing any problems with his final application of the new product the current control is the proactive communication channel between the customer, end user and the case company. The same method is applied for cases where the customer might have planned his schedules in a way which would not be the most efficient.

10.3.7 Detection Rating

Individual detection rates are displayed in appendix 3. In general the detection rating showed a fairly positive status quo with rating leaning towards the middle to lower end of the scale.

For instance on the daily briefings among production planning and work supervisor the production plan will be cross-checked for any issues in terms of daily output as well as

production scheduling. This procedure will detect any incorrectly scheduled campaigns with a very high probability resulting in a rate 2.

The worst scores in terms of current controls to detect the cause of failure mode were found with regards to problems at the end user or customer. These causes are external to the organization but still within the supply chain and therefore, difficult to detect.

10.3.8 Risk Priority Number Calculation

Again, per each failure mode it is to be chosen the highest scoring severity rate to be multiplied with each cause of failure to be further multiplied with the lowest detection rating thus providing a priority index RPN. Overall very low priority risks in the production planning category with the highest ranking for internal miscommunication leading to an error in the production plan or safety stock not being in place hence resulting in a stock out situation. The RPN figures for such a cause were 96 and 64.

All calculations will be presented in appendix 3.

10.3.9 Risk Assessment and Action Plan Development

As the RPNs derived are so low there is no need to start implementing any massive improvement processes, a few quick fixes are suggested such as checking and updating (if needed) the training material for new people joining the organization for example for the summer holidays. This will ensure all the instructions are adequate in sections of what information is needed to put together a production plan, with whom at in which stage it should be revised and general check-ups for the production planner.

Another quick fix to help minimize the possibility of gaps in the internal communication chain is for each superior / team leader to highlight the importance of everyday feedback and information sharing. It might be a good idea to make sure all changes to production plan or schedule occurring in the daily briefs and meetings will be recorded in the system and that all relevant people know where to find this info if needed. Initiating these would be ensured by adding them onto the annual personal performance appraisals for the production planning superiors.

10.3.10 Action Result Assessment

Suggested easy fix implementations should be assessed as per the schedule noted in appendix 3.

10.4 Process Step: Raw Material Procurement

In general the first step in the process of acquiring raw materials would be sourcing of potential suppliers, ordering material in trial scale for testing and finally qualifying suppliers that fill certain set criteria including e.g. total cost of material (containing quality and service level), lead time, reliability etc. However, in the particular section of the supply chain examined by this thesis this step has already been taken. All needed raw material types have been identified, supplier(s) sourced and qualified, and terms negotiated. Therefore, the risk of not finding suitable raw materials at all at the right total cost has already been eliminated in the very first step in planning the new product.

Raw material procurement is a process with a goal of receiving correct raw material, of perfect quality, in the needed quantity and at the right time. With this in mind the potential failure modes will be identified.

10.4.1 Potential Failure Modes

In terms of raw materials the possible failure modes include a delay in delivery which is a very common risk with root cause most likely being external to the company and its supply chain as defined by Waters (2007, 98) and impact varying on both scale of the delay as well as overall leanness of the supply chain (i.e. buffer stocks).

Another potential failure mode is single-sourcing which according to Waters (2007, 93) can be defined as having only a single source of supply with no short-term alternative. This method is perceived to be encouraged by external integration. External integration refers to an organization choosing the best supplier for a material and developing a partnership with this supplier and finally working mostly or even exclusively with just this one supplier. (Waters 2007, 60.)

For the case company there is one key component – with the biggest volume - which is currently being purchased from only one supplier. This is not as much a choice as it is a necessity currently. The material in question is not completely unique and is, therefore, available from other sources, too. However, as the case company is dealing with chemicals, the material in question would not be 100% similar if purchased from an alternate supplier and would, therefore, require plenty of testing as well as customer approval before qualification.

A further possible failure mode relates to raw material stocks and therefore the timing of incoming batches. Stock levels for all raw materials are planned to be as efficient as possible within the agreed lead times for new orders and excess stock is to be avoided for not tie up investments in too large inventory and to make sure the physical stock remains in limits of safe handling. One big risk is again with the single-sourced key component which is purchased as bulk, i.e. one full truck of the chemical is received in one go and transferred from the tank truck directly to the silo located on site. The challenge is that there is only this one particular silo which can be used for this type of a product which requires a certain coating inside the silo for safe storage. This means the arrivals of this component must be well planned to make sure there is room in the silo to fit a full tank truck load.

Stock rotation is a relevant factor for other raw material components as well due to the shelf life of each item. Efficient stock rotation is to ensure raw materials are purchased in cycles permitting usage of old stock prior to new material coming in and no product will stand on the warehouse long enough to expire. This is especially true when considering a highly seasonal product.

In terms of quality there is a possibility that the supplier is delivering poor quality material. For multiple-sourced items the risk in terms of finding alternative raw material is not that severe, the overall severity will be then based on the receipt check success. In other words, if faulty raw material would be released into production the results would be far more serious than in case the defect would be detected before accepting material.

A final failure mode for raw material procurement is wrong material delivered. It is possible for the supplier to mistakenly send out incorrect material and this is something that should be noticed at least when receiving the lot as the case company. Preferably, of

course, the supplier would be able to note the mistake in advance and perform corrective actions.

10.4.2 Potential Effects

Considering a delivery not arriving in time the potential effects can be divided in two categories: for a late delivery the impact would be obvious resulting in either an internal lack of raw material or a stock out for the customer whereas in case the delivery would arrive earlier than planned the result could be excess stock.

Single-sourcing risks are better to be considered as a separate failure mode to prevent final data from distorting. Severity for any single-sourcing effect will most likely be considered higher than for multiple-sourced items. Potential failure mode effect arising from single-sourcing are (prolonged) quality problems and availability issues. As there is no alternative component in hand the process of new material acquiring will have to start from testing and hence result in longer production delays in case a risk was to realize.

After analysing a scenario where there was a tank truck in the factory yard waiting to be unloaded only to discover there is no (or at least not enough) space in the silo it is easy to detect that this would cause money for the case company. The supplier would charge for dead freight costs as well as extra storage of material until more space became available.

Ineffective stock rotation is a potential failure mode leading to internal impacts of raw materials ageing due to extended warehousing and ultimately expiring. An alternative effect arising from such a failure mode is the reduced level of work safety in the warehouse. This of course is with regards to majorly excess inventory and would not present a severe effect in case of one or two items not having the most effective turnover.

Finally, there is a case of poor quality material being delivered. Since there is alternative materials available the risk of stock out for the customer is minimal but there might be some kind of a delay period when waiting for standard quality material to arrive either from the same supplier (usually their mistake is enough to speed up the normal lead time) or then from a different supplier altogether.

10.4.3 Severity Rating

Individual severity ratings resulting from raw material procurement are listed in appendix 4. Highest rankings estimated for any single-sourcing related effects as well as customer facing a stock out due to inadequate raw material availability. The effect with a very minor rating is for excess stock resulting from an early delivery.

10.4.4 Potential Causes

Potential causes behind a delivery arriving too early are that either the supplier has despatched the material too early compared to the requested delivery date or then there has been a procurement planning error – either consumption has not been on as high a level as estimated or then a simple miscalculation in dates or volumes.

When considering a delivery to arrive too late the causes can be found from supplier not being able to keep up with the agreed estimated time of arrival (ETA), either due to problems within his own process or because of a transportation delay which, in turn, can be caused by poor planning, poor selection or route, vessel delay etc.

When analysing single-sourcing based failure modes the root causes are supply chain risks as the origins of any issues are supplier based – either there is an issue with availability or quality of the raw material. The solving of such issues is highly relative to the relationship or partnership between the two companies. After all, if the case company was a major client of the key component supplier he would be much more willing to pull all strings to find fast results to either one of the potential failure modes.

Potential causes for single sourcing risks are any problems within the supplier's process that lead to quality defects. Furthermore, it is also possible that the supplier is changing some component in his selection of raw materials without informing the case company. Such causes are without a doubt very difficult to detect as it is certainly not something the supplier will be eager to expose even in case of a customer claim. When assessing availability problems the causes will most likely be found in either a lack of capacity at the supplier or alternatively the supplier is suffering from a lack of raw materials for his own process.

The cause of not having enough space in the silo to store the key component is bound to arise from a procurement calculation error. Whereas in case of the material delivered is completely wrong this is as a result of a supplier error.

Reasons for ineffective stock rotation can arise from procurement miscalculations or then there is a problem with the first in, first out (FIFO) principle in the warehouse.

As with single-sourcing, also for multiple-sourced materials quality problems can arise. The causes would also lie in some problem at the supplier own process or then a blind raw material change has been made.

10.4.5 Occurrence Rating

Appendix 4 will indicate all of the individual occurrence estimations. On a general note the perceived probabilities are on the low end of the scale. Highest occurrence rating was given to supplier error in a delayed delivery scenario.

10.4.6 Current Controls

There aren't many current controls in place due to the fact that the scale of this type of new business is still very small compared to the overall business range of the case company. Current controls are mainly based on quality checks upon receipt of material, communication at an early stage, checking of official order confirmation received from suppliers, inter-departmental cooperation within the organization and in cases of multiple-sourcing alternative suppliers and materials.

10.4.7 Detection Rating

Individual detection ratings will be illustrated in appendix 4. Naturally most difficult – or even virtually impossible – to detect are the blind changes to raw materials as they are based on the fact that the quality measures remain the same. This, however, does not automatically mean that the quality or operability are on a similar level. On the contrary, the controls that are most likely to detect any potential cause of failure are related to incorrect material noted in the quality checks upon receipt.

10.4.8 Risk Priority Number Calculation

By far highest priority rates calculated for supplier / transport caused delays in deliveries. All of the individual risk priority numbers will be noted in appendix 4.

10.4.9 Risk Assessment and Action Plan Development

Based on the high RPNs it was recommended to start implementing regular supplier audits for 2015 if the volumes were to increase. Currently the business is too small for such actions to take place. Furthermore, to start monitoring the suppliers' accuracy to keep confirmed delivery dates it was suggested for the procurement to start collecting data onto a separate performance indicator report (which can include other aspects of the overall supplier performance e.g. invoicing accuracy, level of customer service, technical support availability and ability and so forth) which, based on the extent of the report and number of problems, should be reported back to the supplier. In case of only monitoring delivery accuracy a time frame of one month would be suitable to receive improvements within a reasonable time, taking into consideration the high seasonality of the business.

Also due to high individual severity ratings for single-sourcing related risks were given some extra thought and consequently it should be looked into the possibility of adopting multiple-sourcing for 2015 if the volumes increased. Furthermore, when reviewing suppliers and volumes for 2015 it should be considered if a stock agreement with the supplier would be useful to implement. This would mean that the supplier would keep stocks for the case company during a explicitly defined time period in precisely agreed quantities thus ensuring raw material availability at all times.

10.4.10 Action Result Assessment

Suggested actions should be reviewed as per the schedule in the FMEA analysis spreadsheet in appendix 4.

10.5 Process Step: Raw Material Receipt

For a company operating in the field of chemicals and other hazardous materials it is of crucial importance to become absolutely certain of what exactly the inbound material flow is consisting of. Therefore very thorough acceptance inspections are performed for every single delivery and quality measures are taken on predefined indicators which are based on the material itself. Such measures could include for instance viscosity. The inspection also cross-references delivered quantity to ordered quantity as well as documentation in terms of material safety data sheet (MSDS), cautions and identification of material in question.

10.5.1 Potential Failure Modes

Potential risks concerning raw material receipt consist of accidentally releasing material in a wrong tank or silo. In other areas human error in terms of receipt has been minimized by various cross-checks of documentation before material is accepted. Any deviations in conditions of packaging for example are marked down on the waybill which will be signed by the carrier. The person in charge of the receipt will also sign the waybill and save a copy in the warehouse office.

Another potential failure mode for the process is spillage. There is a risk that a chemical is spilled during receipt – such a risk has been prepared for in the case company's rescue preparation plan.

It could also happen that the received material does come with poor or faulty documentation.

10.5.2 Potential Effects

The effects of accidentally releasing material in a wrong silo are limited to the key component discussed in previous chapter. Due to the exceptional characteristics of the material it can only be stored in one particular silo which has coated inside walls. Potential effects in such a scenario would include removing the material from the incorrect silo and refilling into the correct one after a quality check performed just in case. The worst case scenario would be in the entire batch of raw material would have to be wast-

ed, on the other hand it might be that the case company would only have to pay for extra moving of the chemical between silos.

In case a spillage would occur the effects would be chemical spreading in the surroundings of the factory. This is a severe impact and safety regulations are, therefore, very strongly present.

Regarding a delivery where the documentation is incorrect the material would not be accepted but would be returned with indications on the incorrect sections and a request to return with proper documentation. This could lead to production delays in case the socks were on a low level.

10.5.3 Severity Rating

Each individual severity rating is indicated in appendix 5. The most severe consequences would come from a potential raw material spillage.

10.5.4 Potential Causes

The potential causes for the failure mode of releasing material in a wrong silo can include process instructions to have been ignored or that the people performing the unloading are poorly trained. It is also possible that the documentation is inadequate or incorrect causing a mix-up.

Furthermore, a spillage can be caused by a simple human error of for example not attaching the nozzle of the tank truck properly onto the silo. There are emergency switches on tank trucks delivering material in bulk but there is a risk the switches would be out of order and therefore not usable.

Causes of poor documentation can be supplier or forwarder related. Either starting from the beginning where the supplier has not for example attached the MSDS document with the shipment or then the forwarder is not precisely enough indicating handling instructions for the chemical in question.

10.5.5 Occurrence Rating

Occurrence rating in general proved to be very low simply because chemical transportation is very strictly regulated and controlled. In practice there is little or no possibility for human error in the cross-checked and multiple-confirmed process.

10.5.6 Current Controls

Current controls are extremely efficient and very well in place. There are clearly defined and addressed instructions on the exact process flow and what type of information must be received prior to acceptance. Also, there are directions on what to do if there is something wrong or unclear. Furthermore, standardized acceptance inspections set the grounds for any defect in the product to be immediately picked up.

In addition, there is a specifically trained safety team which is prepared to take over in case of an emergency such as a spillage.

10.5.7 Detection Rating

Due to the fact that the current controls are (and they have to be in this type of an industry) on such a satisfactory level the detection rates were very low – almost certain or very high likelihood for any issues to be detected and prevented. Each individual detection rate will be displayed in appendix 5.

10.5.8 Risk Priority Number Calculation

Consequently, the RPNs will be on the lower end of the scale as well. All of the ratings can be found in appendix 5.

10.5.9 Risk Assessment and Action Plan Development

Due to the high individual severity rate of chemical spreading upon receipt of material (even though the overall RPN will be low due to low ratings in occurrence and detection) it should be checked to see if the possibility of misplacing the tank truck nozzle onto the silo could be eliminated. For example a filter or some kind of a warning device

could be entered to indicate that the nozzle is not correctly attached before the pumping process begins.

10.5.10 Action Result Assessment

Suggested action should be reviewed as per the schedule in the FMEA analysis spreadsheet in appendix 5.

10.6 Process Step: Production

Production of the new material will take place according to the forecast given by the customer and production plan developed respectively. It is the work supervisor's responsibility to make sure there are always trained people on shift on each station. The responsibilities vary per station and not all staff members can perform duties on all the different stations – for example mixing the product or packaging the finished material and driving a forklift and so forth. This is important to make sure the process performs in an efficient level and that there are no issues in terms of work safety due to missing competence on certain machinery. Furthermore, where production planner will create a plan on a daily basis specifying the exact materials and precise quantities which must come out of production within a certain day, it is work supervisor who creates a production schedule defining on a more detailed level the exact order in which materials are produced.



PICTURE 1. Adhesive silos (Photo: Leena Koivu, 2014)



PICTURE 2. Chemical components (Picture: Leena Koivu, 2014)

10.6.1 Potential Failure Modes

There is only one piece of machinery that is suitable for manufacturing this particular product. This undoubtedly presents a possible failure mode as there is no back-up in case the equipment would face a malfunction.

Furthermore it is possible that during production something goes wrong resulting in poor quality end product. The production is, however, highly automated and most of the set up parameters are defaulted and do not need that much manual updating.

Another potential failure mode relates to the shift planning. If a mistake is made in locating a capable person to perform each process step there is a possibility of even a work safety related effect. Therefore, the third failure mode in the process of production is not having each process step proficiently manned.

10.6.2 Potential Effects

Probable effects after a potential breakage of the manufacturing machine include a delay in production schedule and therefore also possible delays in the customer orders. Due to machine down time during the repairs (which also pose an excess expenditure) overtime will be needed to catch up the lack of availability of finished product.

Another aspect of machinery malfunction related effect is a spillage. Such an incident is critical to be minimized due to work safety and environment protective reasons. Considering that the industry is chemical the potential severity is naturally quite high and could have far-reaching consequences.

Potential effects arising from quality problems during production is that, in the worst case, the entire batch would have to be remade. If there was something wrong in the fresh made batch this would be detected by in-line quality controls during production where feedback would come automatically back to production stating that there is something wrong in the measured parameters and the machine set-up and recipe need to be checked. Therefore, the actual risk of having to scrap an entire production batch is rather small but need to be considered nevertheless. In case of a quality problem the work supervisor would have to reschedule production and based on urgency make the call of either prolonging the problematic production campaign or alternatively transferring the current campaign to some later date to be confirmed by the production planner.

Finally, if a mistake in shift planning occurred this would mean that not each station would be occupied with a capable and specifically trained worker. There are a certain number of workers in the case company that have the competencies to perform each process step in the production process of the new material. However, in case the shift happened to be poorly planned it could be very well possible that at least one station was missing adequate experience therefore increasing the risk of mistakes and even creating a potential work safety hazard as the practices would not be fully realized and assimilated.

10.6.3 Severity Rating

Individual severity ratings will be displayed in appendix 6. In the production process in general the severity rating were quite high due to the fact that each potential effect would have a rather big negative impact either internally in terms of excess costs or presented to the customer with availability deviations. The most severe effect would be either a spillage caused by machinery malfunction or a work safety incidence due to some station not being proficiently staffed – the severity ratings for such risks are 9.

10.6.4 Potential Causes

Neglecting calibrations and regular anticipatory maintenance could potentially lead to the machinery equipment finally breaking down. Such a cause, fortunately, is not perceived to be likely to take place at all even because of the corporate culture standing for

punctuality and obeying the commonly agreed rules and regulations. Even in cases where the anticipatory maintenance procedure is well in-line and followed, the fact that the machinery used for manufacturing the new product is old poses a risk of brakeage simply due to the age of the machine alone.

A further possible cause would be a simple human error in setting up the machine parameters.

When analysing the potential causes resulting in quality problems in the finished product it can be deducted that the root causes lay either in poorly trained or otherwise not fully capable staff performing the process steps. On the other hand, there is a possibility that the in-line quality measuring equipment would fail.

As a final point there is the potential failure mode of some station not having staff that might not possess the competence and skills to perform the process a) safely b) correctly c) efficiently. This could be as a result of the shift not being planned well enough to make sure each station is properly equipped in terms of workers. Another potential cause is a human error for some individual not having fully digested the training and instructions therefore presenting a potential cause for a failure mode.

10.6.5 Occurrence Rating

The occurrence ratings for all potential failure mode causes will be mentioned in appendix 6.

10.6.6 Current Controls

Current controls designed to determine and prevent any potential failure modes in terms of machinery malfunction include anticipatory maintenance to the machinery to be performed as per specifically set instructions as well as internal audits to make sure the instructions are being followed. The staff members are also performing visual checks during the production and are obliged to report to work supervisor immediately in case they would notice anything suspicious.

The company policy is all about performing each process step safely and effectively but one additional target is to make sure communication flows freely and this is applied to the performance of the machinery as well. Whenever the workers notice there is an issue with the machine they're working with (and have vast experience on) they are to pass on the information to the work supervisor. This does not necessarily refer only to the possible breakage indications but also to prevent any quality deviation. Based on these proactive notifications the anticipatory maintenance schedule could be advanced.

Furthermore, whenever the workers notice any potential risk for a safe working environment they are urged to fill in a safety incident report in the system. Such an incident could include for example a leaking roof or spilled coffee on the floor – anything that can potentially be a risk either in the offices or on the factory floor and outside. Each safety incident report is saved in the system, checked and assigned corrective actions to. Additionally, on a weekly basis there is a production meeting in which each safety incident report will be shared and openly discussed.

There is also a possibility that a spillage would occur in case of machinery malfunction. The specifically trained safety team would play a key role in such an incident to help minimize the consequences. Also, all staff members – depending on the role – will wear safety gear at all times in the production hall. Such safety equipment includes antistatic suits, safety goggles and safety shoes, all of which are compulsory for everyone. In addition depending on the station earmuffs, respiration filter and safety gloves might be required.

Considering quality problems the current controls consist of regular equipment calibrations in order to make sure the in-line quality controls are trustworthy and provide accurate, up-to-date data. Moreover, there is a specific recipe designed for the new product which together with working instructions guide the process in terms of the order in which raw materials are to be mixed in the processor, in which quantities and how long each new item is to be mixed before adding the following component. The working instructions also include safety guidelines for safe handling of each of the required raw materials.

Lastly the current controls to detect the failure mode of some station to not have a competent worker assigned and the root causes behind of such a risk are in addition to the

safety team and working instructions mentioned earlier include only the fact that there are a limited number of workers that proficient enough to perform well in each station. Additionally, the element of human error is minimized by including both the internal code as well as the market name for each raw material.

10.6.7 Detection Rating

The detection ratings will be displayed in appendix 6. In terms of prevention the area in need of most development is to make sure there will be no mistakes in shift planning.

10.6.8 Risk Priority Number Calculation

Production risks are being prioritized by the same RPN index and the analysis shows that two areas clearly differentiate themselves amongst the comparison group with far higher overall scores: outdated machinery and mistake in shift planning both with an RPN of over 100. All of the RPNs can be found in appendix 6.

10.6.9 Risk Assessment and Action Plan Development

The actions planned for the production process based on risk assessment are a commercial decision for the CEO to make in terms of renewing machinery. The decision will be based on the relation of the extent to which it will be feasible of bearing a risk of malfunction versus investing in a new piece of equipment. The decision will for sure not be straight forward and will need evaluation of multiple aspects one of which being the total manufacturing volumes of 2015.

An additional action point derived from the analysis is to objectively evaluate if the number of key people (i.e. those workers who are able to perform each process in the production chain) is adequate. Increasing the number of fully qualified workers will significantly decrease the overall risk of not having enough know how to be utilized at all times. This is especially important during sudden sick leaves as well as in the holiday season. Such an evaluation is to be made by the CEO and production manager. Unquestionably, the 2015 total volumes will play a role in this decision as well.

10.6.10 Action Result Assessment

Suggested action should be reviewed as per the schedule in the FMEA analysis spreadsheet in appendix 6.

10.7 Process Steps: Quality Assurance and Release

Quality assurance (QA) is the final step in ensuring the finished product is of excellent quality and within the given specification. This is the last phase where the material is monitored in terms of quality. Release will only take place after all measurements have been performed and verified. The exact characteristics that are measured depend on the product but considering the new material those include for example viscosity, dry out and opacity. All measurement areas and values with an effective range have been agreed together with the customer in advance.

10.7.1 Potential Failure Modes

There really only is one potential failure mode with regards to quality assurance and release, namely a scenario where out of specification was released. This is exactly what is aimed to be avoided in the process step and at the same time it is exactly the only thing that could go wrong.

10.7.2 Potential Effects

In theory the potential effects, in turn, for releasing poor quality material can come in two alternatives. Either the faulty material will go all the way to the customer or then somewhere along the way before despatch the quality deviation is noticed. In practice, however, the latter one would not be possible as there is no way to measure the quality of the packaged product either visibly or by any measurement.

10.7.3 Severity Rating

The severity rating indicates, naturally, that should poor quality material reach the customer the issue would be more serious than in noticing a defect while the material is still in-house.

10.7.4 Potential Causes

The potential causes for quality deviations to pass the sieve of QA can be traced be caused either by a human error in feeding the analysis data into the system or an unfortunate measuring equipment malfunction.

10.7.5 Occurrence Rating

When evaluation the probability of either failure mode root cause it was concluded that both options are very rare in nature and furthermore will be detected by the current controls.

10.7.6 Current Controls

Current controls include a system verification that will deny release of a batch that has one or more quality measurement out of specification – either over or under tolerance level. Furthermore, to prevent any data distortion all scales and measuring instruments - such as microscopes or mixers – are calibrated as per a specific control plan.

In addition, out of each batch retain samples are taken to make sure there is proof of good quality measurements as well as reference data in case the material would prove to not be performing as expected.

10.7.7 Detection Rating

Detection ratings were all representing the best possible score: 1. There is little or no risk that the failure mode cause would not be detected by the current controls. All of the detection ratings can be found in appendix 7.

10.7.8 Risk Priority Number Calculation

Consequently, the calculated RPNs were low enough to not generate any further actions.

10.8 Process Steps: Packaging and Storage

Once the QA has completed all testing and approved the quality of the finished product as well as released it, the process to follow is packaging. The material will be canned according to the explicit instructions assigned to this process. First the exact filter is chosen through which the material will be ran into the specified jar to be used for the new product. The packaging recipe will be instructing each task on a detailed level.

Next the filled and sealed jars will move through a conveyer belt to the labelling station. This is a part of the process where the blank labels will be printed and applied directly on the side of each jar. The label itself is an information package to the customer as well as anyone handling and transporting the material.

After labelling it is time to place the jars onto a pallet and with a forklift move the pallets to the warehouse waiting for a customer pick-up.



PICTURE 3. Raw material warehouse (Picture: Leena Koivu, 2014)



Picture 4. Chemical warehouse (Picture: Leena Koivu, 2014)

10.8.1 Potential Failure Modes

The packaging process itself is rather highly automated but does pose certain risks still. The most probable risk scenario would be that the conveyer belt would suffer some defect thus resulting in a standstill in the process.

Considering labelling the potential failure modes lay either in the machinery where there is a risk of malfunction or on the other hand in the actual process of applying an incorrect label onto the jars.

During the process of moving the pallets as well as storing them on the warehouse shelves there is a risk of spillage, in case the movement wouldn't be smooth and steady enough the jars could be dropped.

10.8.2 Potential Effects

The effects of a conveyer belt defect would include a complete stoppage of the process, which would also be the case if the jars ran out.

When analysing labelling it was deducted that any issues with the line would similarly result in a full stop in the process, which would happen also if the labels were to run out. If incorrect labels were applied the effects would include a potential safety risk as the jars are not differentiated from any other jars by appearance and the only source of handling instructions and safety information is the label.

Regarding storage the effects would, in case of a pallet dropping, be spillage. This could occur either while the forklift is moving a pallet either from the labelling line to the warehouse or from warehouse to the loading area and in the truck.

10.8.3 Severity Rating

The potential work safety related failure mode assigned to a spillage increased the severity rate for storing process. Rates for packaging related risks were above the average as well and all ratings can be checked from appendix 8.

10.8.4 Potential Causes

Potential causes for packaging process failure modes include a mechanical problem with the conveyer belt as well as running out of empty jars, both incidents most likely resulting in a standstill on the line. Similar causes can be retrieved from the analysis of labelling process failure modes: a standstill on the line caused by conveyer belt disruption. Additionally, a reason behind a false label application would be human error.

To cause a pallet to drop upon handling would be either negligence or an unintentional human error.

10.8.5 Occurrence Rating

The occurrence ratings were relatively low for these incidents as there is little or no history of such issues in the past. All of the individual ratings are shown in appendix 8.

10.8.6 Current Controls

Current controls for packaging and labelling alike include anticipatory maintenance on the machinery. This is to reduce the risk of sudden malfunction out of which it would be much more difficult to recover due to the unforeseen nature of the event. Also, to help decrease the risk of applying an incorrect label there is a specific packaging recipe which is to be followed at all times to make sure correct steps are taken. However, this practice does not fully eliminate the human error in the chain. Finally, in terms of secur-

ing an adequate quantity of both empty jars and blank labels on hand at all times there are no controls in place currently.

Whereas for the storage and careful material handling there are continuous (and compulsory) safety trainings in place on a regular basis to emphasise the corporate culture of work safety. Each individual whose job description requires driving a forklift must be qualified with a fork lift driving licence. Furthermore to help reduce the impact of a pallet being dropped the jars used are UN approved which means that they are designed for storage of hazardous materials and built to last a drop. Furthermore all of the logistics operators must wear the assigned safety gear such as safety shoes and goggles. And in case the situation would develop into an actual spillage the trained safety team will be on guard to take action if needed.

10.8.7 Detection Rating

Detection ratings in general were rather low as the current controls are for the most part very well in place. Only securing enough jars and labels are the areas where there currently are no controls in place.

10.8.8 Risk Priority Number Calculation

All calculated RPNs are on the lower side of the scale but a few scenarios deserved a little special attention regardless of the fairly low total scores.

10.8.9 Risk Assessment and Action Plan Development

The aspects that based on the analysis should require some modification are to make sure there are enough empty jars and labels available on site at all times. Currently there are no controls in place to make sure there will be no issues – so far everything has worked very well but especially in case the volumes would increase for 2015 the risk of a stock out at some point increases too. In order to avoid a production standstill due to a lack of packaging or labelling material it would be worthwhile to look into a system update where first of all inventories were conducted on a weekly basis instead of monthly basis like currently. Additionally, the system could be updated to automatically prompt the procurement to reorder once a certain stock level is reached. The availability

of packaging material should be checked every week after the inventory and to reduce error there could be an automatic reordering set-up to suggest quantities to reorder. This is an aspect for the production manager to work on with IT and sourcing with a target dead line by the end of this year.

Considering an effort to eliminate the human error aspect in applying an incorrect label a feasibility study should be conducted to see if the label applicator could be equipped with a sensor to detect the size and shape of the jar to be labelled and automatically default the correct label to be used. If this proves to be too big an investment at this point an alternative mistake proofing method should be assessed – for example a suggestive inspection method could be implemented. This is a method where the inspection is done at the next step of the process by the next worker; in this case it would be the warehouse staff member to make sure the label is correct.

10.9 Process Steps: Loading and Invoicing

The delivery term agreed is ex works; therefore the organizing, risk and cost of transportation will be on the customer. Loading is the final step to take place inside the factory and customer will decide on the schedule. It has been agreed for the case company to always hold stock of six containers and to be prepared to load – in general – on one day notice. Naturally, due to the seasonal character of the business some unexpected turns might occur where loading should take place still the same day.

Invoicing will be done by the case company itself – the service has not been outsourced – and the agreed payment term is a very standard net 30 days.

10.9.1 Potential Failure Modes

Potential failure modes in terms of loading really only comes down to a customer error. Since the material in question is hazardous it is therefore very strictly governed as to what kind of a truck is allowed to perform the transport. The driver must also be specifically trained to have a licence to transport hazardous goods and upon arrival he must present certain documents which the case company warehouse crew will inspect and only allow loading once cleared. However, since organizing the delivery is the custom-

er's responsibility it might happen that a wrong kind of truck is ordered or some documents are missing.

Considering invoicing the potential failure mode can be seen in late payments or a complete failure to pay.

10.9.2 Potential Effects

The potential effects for these processes include refusing to load a truck either because the driver is not certified and trained correctly to transport hazardous goods or then the truck is not fully equipped for chemical transportation. This would be an internal effect for the failure mode of sending an incorrect truck to collect the goods. On the other hand the effect for the customer is without a doubt a delay on some level in any case as a new truck will need to be organized.

Whereas the effect for a failure mode in invoicing would be late payments. This would cause extra work for accounting to keep track on the payment dates. Currently the volumes are not that significant to have any real impact.

10.9.3 Severity Rating

The individual severity ratings can be found in appendix 8.

10.9.4 Potential Causes

The causes for ordering a wrong type of a truck are internal to the customer. Most likely a human error would be behind such an incident as the customer is fully aware of the strict rules concerning hazardous materials transportation in Finland – and without a doubt is keen on obeying those rules.

Should the payments arrive late there could be a mistake in the customer's system scheduling payments for example as per a payment term of 60 days instead of 30 days which is agreed. On the other hand it could be a deliberate contract violation but such cases are out of scope for this analysis as there really is no way to prepare for incidents

like these after being careful in the research work of the customer's financial background before accepting any deals. Any contract violations would be settled in court.

10.9.5 Occurrence Rating

Occurrence ratings for both causes are very low as there is no reason to expect either failure mode was to realize.

10.9.6 Current Controls

Current controls include proactive approaches in minimizing both risks in advance via written agreements and continuous, open dialogue with the customer.

10.9.7 Detection Rating

Detection ratings are rather low as well as both parties are very well aware of the standards and agreed commercial terms of the contract.

10.9.8 Risk Priority Number Calculation

Both RPNs for loading and invoicing are low enough to not generate any further development needs.

11 DISCUSSION

As the analysis included the entire supply chain process of the new product to be launched it is worthwhile to put together the main aspects for future development plans as a whole. In the very last chapters there will be conclusions and final remarks of the thesis. The general process flow of an FMEA is easily interpretable and provides a structure which to follow at each stage of the analysis.

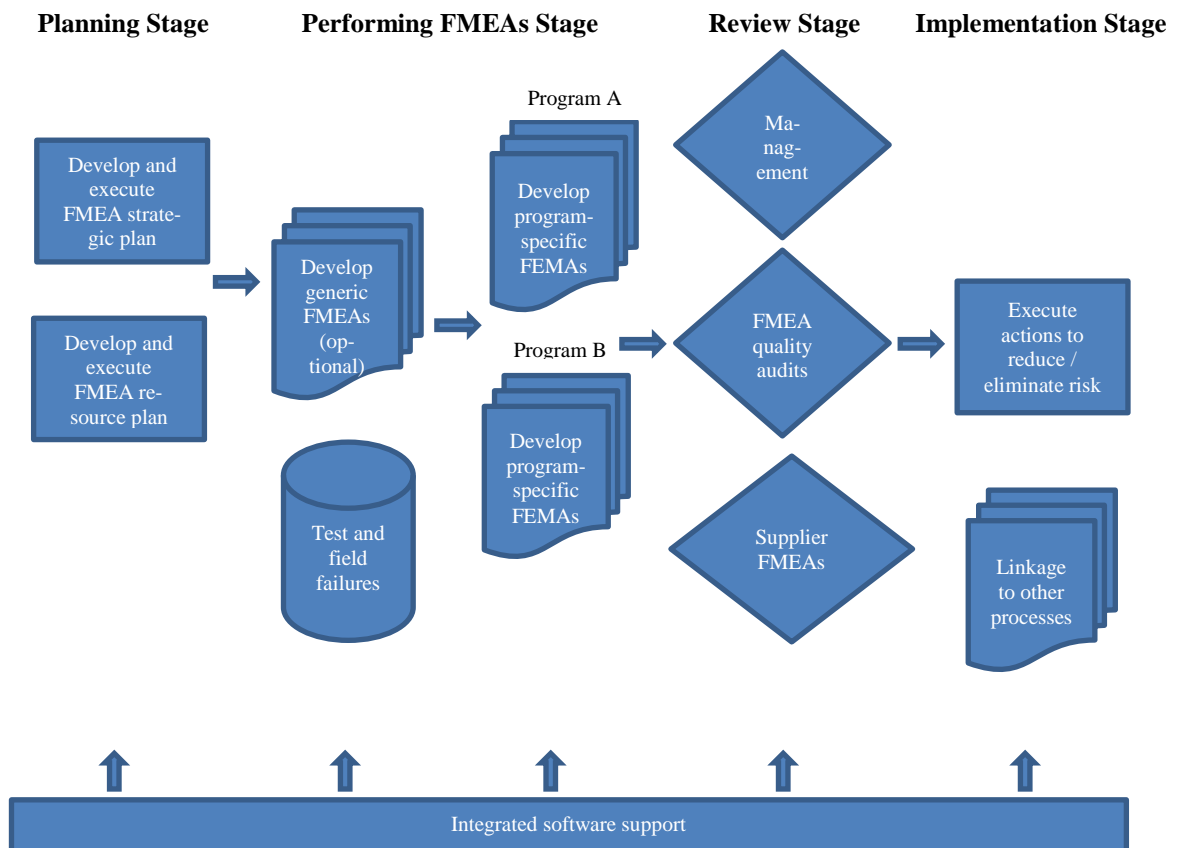


FIGURE 10. Effective FMEA Process Diagram (ReliaSoft 2005, modified)

11.1 Action plan summary

One suggestion based on the analysis regarding forecasting is to start building data on both the forecasted figures as well as the actual sales data, both of which should be rather easily derived from the system. Such a process would support in cases where future demand will be assessed as it would allow some comparison of the accuracy of the previous forecast. This would be important especially in a potential scenario where the customer demand would be higher than the forecast as availability in a highly seasonal product is crucial. Moreover, the binding nature of the customer's forecast will only be

valid during a scale-up and will, in the future, develop into more of a guideline rather than exact and confirmed volume. For this reason it would be reasonable for the case company to begin monitoring the accuracy of the forecast as well as start analysing the market in general.

After completing the analysis on the production planning process it was noticed that there was no evident need to put in place any massive development projects and therefore only a few quick fixes for the case company to implement if evaluated to be necessary. One of the easy fixes includes updating training manuals for new people joining the organization and especially concerning summer workers. This just to make sure all the information is up-to-date and adequate in quantity. Furthermore, it was suggested to look into constantly developing internal communication – in this field no organization can ever be good enough. Such a mini-project would ensure all relevant people would be informed of any changes in the production plan or schedule and can absolutely be applied in other functions and processes as well as the saying “too much information” is not valid here. Potentially, to achieve some concrete improvement in the field of communication this could be added into the annual personal performance appraisals for the production planning superiors to make sure they will communicate down to their own teams how important open dialogue is.

Analysis of the raw material procurement process revealed that closer supplier monitoring could be of use for the following year especially if the current volumes were to increase. The easiest way of completing this is to begin arranging supplier audits and assign a small task to the procurement department. Usually, when considering the performance of a supplier there are no concrete figures to base one’s gut feeling on – the buyer might very well have a perception of how the supplier is performing in general, for example in terms of sticking to the agreed delivery dates. But this is not something that is systematically measured and retrieving information from the system afterwards would at least be difficult if not even impossible. Therefore it was seen that perhaps the procurement could start building data onto a separate performance indicator report, a certain amount of key measures could be included – be it delivery accuracy, invoicing accuracy, technical support availability or general quality of customer service. This data could then be collected in set intervals and reviewed both internally as a supportive tool for sourcing and possibly even shared with the supplier to provide feedback and use as a backup for suggestions.

The biggest concern in terms of RPNs in raw material procurement is single sourcing which is something that the case company might want to move away from in 2015. Single sourcing refers to a scenario where the buyer, for one reason or another, is forced to only work with one supplier to purchase a certain item. For the case company there is currently only one supplier offering the specific, biggest raw material in terms of volume, which is needed in the production process. There are other corresponding raw materials in the market but to qualify usage the case company would have to trial and validate these in the recipe. The first step is to source suppliers, negotiate prices and terms, then trial the raw materials to test performance, have the customer and end user accept usage of substitute product and finally scale-up volumes. This is a project which will take some time and is needed to be put in place soonest to allow multiple sourcing to be an option for the coming peak season in summer 2015. In case multiple sourcing would not be possible then carefully monitored safety stock should be set up in the supplier's premises or in the harbour to help eliminate potential availability and quality risks.

Considering the process of raw material receipt the probable risks are quite well in control, however, there is one thing worthwhile to evaluate and that is if the possibility of misplacing a tank truck nozzle onto the silo could be eliminated. Perhaps a filter or some kind of a warning device could be inserted to indicate that the nozzle is not correctly attached before the pumping process begins. The consequences of such an accident could be large-scale, which is why the case company has already invested a lot of time and effort in controlling and down-sizing the consequences of a leakage. The proposed controls would be more preventative in nature to try to minimize the risk of a leakage in the first place.

The biggest risks in terms of production came down to the age of machinery and number of fully competent workers. There is a commercial decision to be made in terms of the extent to which it will be feasible of bearing a risk of malfunction versus investing in a new piece of equipment. To support this decision a quantitative risk analysis should be conducted to justify if spending on a new piece of equipment was needed and when. Moreover, it should be evaluated if the current number of workers, who have the ability to perform any task within the manufacturing chain, should be increased. Once again it will be a comparison of cost of training and practicing vs. the risk of unexpected absences and mistakes in shift planning.

The last point on the list is packaging and labelling. In these processes the main failure modes could be found from ensuring sufficient stock of blank labels and empty jars as well as eliminating human error in label application. For this process a semi-automated reordering system was suggested where a certain level of stock would be defined based on which the system would automatically prompt to reorder. Certain parameters would need to be set in the system such as order size, lead time for new labels from receipt of order as well as average consumption of the different labels, all of which would be combined with the set safety stock limit to allow the system to automatically place an order for a new batch of labels. Additionally, the risk of applying an incorrect label on the side of the filled jar could be minimized by adopting a mistake proofing aspect. This could be either in the form of a sensor on the conveyer belt to automatically recognize the size of the jar and default a label based on it. Alternatively, a lot smaller of an investment would be for example a suggestive inspection method to be used among workers in the same shift.

11.2 Conclusions

As a final remark it can be stated that supply chain risk management is not yet a fully-developed science as the research is still to grow into new areas and applications. Furthermore, (supply chain) managers are only slowly becoming aware of the risks that lie in the entire chain and that there are ways to identify and measure those risks. In fact, it could be argued that risk management is not to be perceived as a science in the first place according to the general definition, due to the ever present factor of uncertainty and subjectivity of the analysis – be it quantitative or qualitative. The conclusions will never be 100% accurate and there will always be some element of unpredictable events that cannot be assessed nor prepared for. Furthermore, the more complex and multi-layered the supply chain is the more likely it is to be effected of elements totally out of the scope of any analysis.

For sure it is an company-specific decision for each organization how to prepare for risks – or even if to prepare at all. Absolutely, it will not be possible to be prepared to – let alone prevent – all kinds of risks and the organization must always find a balance in the investment of managing a risk versus the cost of such an event to realize. The research, however, rather indisputably suggests that some form of preparation will pay off in the long run in terms of reducing costs related to unforeseen accidents while improv-

ing production efficiency and quality. Furthermore, understanding of potential risky events will enable a company to allocate resources towards controlling the most critical risks thus reducing disturbance and breaks. One important aspect is also the fact that by critically examining current ways of working an organization will gain knowledge on its own operations. Managing risks on a suitable level a company can improve its image and increase customer satisfaction.

When considering measuring supply chain vulnerability there are again several methods to choose from depending on the type of data that is required, the field of industry the organization is operating in and the results that want to be achieved. For the case company in the scope of this thesis it was important to keep in mind the customer point of view at all times – however, not at the expense of neglecting internal effects and related costs, both of which are directly linked to excellent customer service level anyway. Failure Mode and Effects Analysis was perceived to be a powerful tool to give the case company's management support in their decisions on where to lead the company in the future and which development tasks to rank in the top of the priority list keeping in mind the scope of the analysis.

It should be mentioned that FMEA as such will not be any kind of a direct decision-making tool but more of a support and connection-building instrument to provide assistance in the future alignments. The case company has found several new, important and even unexpected potential risks as a result of the analysis and is currently in the implementation phase according to the suggested action plan.

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APPENDICES

Appendix 1. Interview questions

- 1) Please describe your process flow
- 2) What kind of potential risks do you find associated to each process?
 - 2 a) What kind of effect(s) can be derived from such risks?
 - 2 b) How severe would such effect(s) be on a scale of 1 – 10?
- 3) What could be seen as the root cause(s) for each failure mode?
 - 3a) How often could such a failure mode occur on a scale of 1 – 10?
- 4) What types of current controls have you got in place which would detect or prevent the problem?
 - 4a) How likely are those controls to actually detect the problem on a scale of 1 – 10?
- 5) Which are the highest priority risks on the overall process?
 - 5b) What actions are required to minimize them?

Appendix 2. Failure Mode and Effects Analysis for Process Step: Forecast

Failure Mode and Effects Analysis (FMEA)																
Process of Product Name: New Product for summer 2014			Prepared: Leena Koivu													
Team Members: CEO of case company, QHSE manager of case company, Leena Koivu			Date (original): 3.6.2014													
			Date (revised):													
Rating Before Action									Action Plan				Revised Ratings After Improvement			
Process	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Actions Recommended	Responsibility and Target Date	Actions Taken	Implementation / Closure Date	SEV	OCC	DET	RPN
What is the process?	What can go wrong?	What is the impact on the key output? (Customer requirements or internal requirements)	Severity Rating Before Action	What causes the failure to happen?	How often does cause of failure mode occur?	What are the existing controls and procedures that detect or prevent the cause of the failure mode?	How well can you detect cause of failure mode?	SEV x OCC x DET	What are the actions for reducing the occurrence of the cause or improving detection? (Should have actions only on high individual ratings, high RPNs or easy fixes)	Who is responsible for the recommended action?	What are the completed actions taken with the recalculated RPN? (Include completion month/year)	When was the action or implementation completed?	Severity Rating After Action	Occurrence Rating After Action	Detection Rating After Action	RPN Rating After Action
Forecast	Forecast too low	Lack of material (customer)	7	Unforeseen demand from end user	2	Proactive and open communication	6	84	Forecast figures and corresponding sales figures recorded	CEO on 31.10.14						
		Unoptimized resources thus rescheduling (customer)	4	Unprecise planning	1	Proactive and open communication	6	42	No need for further actions							
		Replanning production (internal)	3						No need for further actions							
	Forecast too high	Excess stocks thus ineffective stock rotation (internal)	4	Miscommunication between customer and case company	1	Proactive and open communication	7	28	No need for further actions							
		Production planning to reallocate capacity (internal)	2	Unprecise demand planning by the customer	1	Proactive and open communication	7	28	No need for further actions							
	Reducing demand	Price increases (both customer and internal)	8	Customer lost part of business	1	Proactive and open communication	6	48	No need for further actions							

Appendix 5. Failure Mode and Effect Analysis for Process Step: Raw Material Receipt

Raw material receipt	Material released in a wrong tank or silo	Raw material quality recheck (internal)	2	Process instructions ignored	1	Clearly addressed instructions + continuous training and practicing	1	7	No need for further actions								
		Costs of moving the product between silos (internal)	3	Lack of information	1	Clearly addressed instructions + continuous training and practicing	1	7	No need for further actions								
		Costs of contaminated raw material (internal)	7	Inadequate documentation with the shipment	2	Instructions on what info must be obtained before acceptance + acceptance inspections	1	14	No need for further actions								
	Spillage	Chemical spreading in surroundings of factory (internal + environment)	9	Human mistake	2	Unloading under surveillance	1	18	Check if a warning device could be inserted on the side of silo to notify in case tank truck nozzle misplaced	QHSE manager 31.8.2014							
				Tank truck's emergency switch out of order	1	Specifically trained safety team present on site	2	9	No need for further actions								
	Poor documentation	Material refused	3	Supplier error	2	Instructions on what info must be obtained before acceptance + acceptance inspections	1	6	No need for further actions								
		Availability delay of raw material	3	Forwarder error	2	Clearly addressed instructions + continuous training and practicing	1	6	No need for further actions								

