The need to make decisions with regard to the volume ramp up more rational
the implementation of a structured risk management approach focused on VRU risks at NXP

Moser, A.

Award date:
2013

Disclaimer
This document contains a student thesis (bachelor's or master's), as authored by a student at Eindhoven University of Technology. Student theses are made available in the TU/e repository upon obtaining the required degree. The grade received is not published on the document as presented in the repository. The required complexity or quality of research of student theses may vary by program, and the required minimum study period may vary in duration.

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain.
The need to make decisions with regard to the volume ramp up more rational: The implementation of a structured risk management approach focused on VRU risks at NXP MA

A. Moser

Student identity number 0753350

In partial fulfillment of the requirements for the degree of

Master of Science

in Innovation Management

Supervisors:

dr. J.A. Keizer, TU/e, ITEM

Prof. dr. F. Langerak, TU/e, ITEM

ing. V. Pronk MBA, NXP Mobile Audio
TUE - School of Industrial Engineering.

Series Master Theses Innovation Management

Subject headings: Innovation, Volume Ramp Up, Risk Management
Abstract
The volume ramp up (VRU) phase, also known as the start of mass production, is important for innovation success. However, this phase is associated with risks that may hinder successful introduction of newly developed products. Delayed, unsuccessful or postponed VRUs are expensive, hinder the organization in generating early profits, and in obtaining a market leader position. Subsequently, it is essential to avoid unexpected hiccups and to make rational decisions concerning the VRU phase. The aim of this study is to provide a comprehensive overview of the risks in a high-tech organization, and define a risk management approach that can be useful to gain insights in the time, quality, financial and customer related risks. Ultimately, this approach will contribute to a successful market introduction.
Management summary
The semiconductor industry suffers from fierce competition, which quickly drives down the price of semiconductors after the introduction into the market. A time-to-market focus is critical when introducing innovations, since it supports semiconductor manufacturers to generate early profits. Furthermore, it allows a company to position itself as a market leader, which increases the chance to rapidly deploy differentiated products ahead of competitors. However, excessive focus on time-to-market results in imprudent and irrational management decisions that may lead to low performing products. Therefore, it is plausible to assume that a market leading position can only be achieved when organizations are also able to reach volume and quality targets in time. The moment where time-to-market, time-to-volume and time-to-quality come together is called the volume ramp up (VRU), and is considered as the crucial phase after an NPD project. The VRU corresponds to “[…] the linking phase between the development phase and production phase and has a crucial role for the success of a project” (Thiebus et al., 2006, p. 213). The VRU phase puts major stress on supply chain operations because it necessitates a massive increase of flow of goods to the customer and asks for careful planning, coordination and control of material, parts and finished goods from suppliers to the customer.

Research project
This research project has taken place at NXP Mobile Audio (MA) in Nijmegen. NXP MA deals with difficulties concerning the delivery of a new product to a customer (when and how much). Especially when the product should be ready for the start of the VRU phase, decision makers face enormous pressure from market demands, but still fear risks that could disrupt a flawless supply. Risks are related to quality, time, costs and customer satisfaction and these bring pressure to the planning of the VRU. There are four ways for NXP MA to cope with this situation: start the VRU phase according to the plan, start VRU with stop points at certain production processes, postpone the VRU phase or postpone the VRU phase but decrease the lead time. In this last case, NXP MA has more time to pass the development gates and increases its confidence in the quality of the products and accurateness of the forecasts. However, this last strategy also increases the development costs by 75%. The success of the VRU phase is dependent on making the right estimations related to the VRU risks. Wrong estimations might lead to losses in time and profit, unfulfilled orders, a damaged corporate image, customer dissatisfaction or even worse, customer losses. This master thesis is aimed to define a risk management approach that can be used to make more rational decisions with regard to the VRU.

Theoretical foundation
The high-tech market is considered to be dynamic and turbulent and organizations need to invest in innovation in order to survive (Ogawa and Piller, 2005). Innovation and risks are two related concepts, with the result that if organizations get involved in innovation, they need to take the risks for granted (Keizer et al., 2002).
A market leading position will aid a company in creating early profits, which increases the chance to survive (Terwiesch and Bohn, 2001). To achieve this, a focus on time-to-market is critical. However, reaching volume and quality targets in time are at least as important as the focus on time-to-the-market (Utterback et al., 1992). The VRU phase is considered as the link between these three factors (Chapman et al., 2002). Moreover, this phase connects the flow of goods from the supplier to the customer and is therefore an important issue in the supply chain. However, managing VRU risk need different focus then NPD risks and therefore it should be managed separately. Within the literature, there is consensus about the most appropriate steps to deal with risks involved in NPD projects: risk identification, risk assessment, risk response and a control/monitor. However, there is a lack of research in the area of VRU risk management. Nevertheless, it has been argued that the VRU phase fits the definition of an innovation project. Therefore, it is assumed that the steps are also crucial in managing VRU risks.

Internal analysis
NXP MA faces uncertainties related to the VRU, which makes it difficult for the management team to take rational and appropriate courses of action (when and how much to start). Despite the involvement of risks with regard to time, quality, finance and customer satisfaction, NXP MA does not systematically manage its VRU risks. The internal analysis has shown that the root cause for the business problem NXP MA faces is a lack of a structured risk management approach that is focused on VRU risks.

Design
The risk management approach designed in this study is based on an extensive evaluation of the literature, an all-embracing internal analysis at NXP MA and a benchmark with strategic partners. The approach is based on a tool that needs to be integrated with the NPD processes (see figure 1s and 2s). Actors have a crucial role in this process, although using the tool and introducing it in the NPD process seems simple to accomplish, it will be difficult to achieve successful outcomes without support of the users. The design allows NXP MA to diagnose, assess and control thoroughly and systematically the VRU risks that a project faces and helps managers to make rational decisions based on created scenarios. The decision driven scenarios contain an evaluation of strategic options and should give insights in time, quality, financial and customer satisfaction issues. The potential losses for each generated scenario should be determined.

Figure 1s – VRU risk management approach
**Recommendation and implementation plan**

It is recommended that the design will be implemented in all projects that pass the first development gate (S-gate). The first project that will pass the S-gate is an amplifier called ‘TFA9897’. The implementation plan has figured out what needs to be done before this project will pass the S-gate. These key actions are: 1) ensure management commitment 2) assign a VRU process owner 3) provide training and education and, after implementation 4) celebrate success. Nonetheless, during the implementation, the management should be aware of potential pitfalls. These pitfalls are related to organizational, behavioral, content driven and financial topics.

**Conclusion and reflection**

This study is a first attempt in closing the research gap between VRU and risk management by introducing a structured risk management approach focused on the VRU at NXP MA. An important finding in this study is that critical activities defining the success of the VRU, should take place long before this phase is actually reached. A risk management approach integrated in the NPD process contributes to the ability to increase the volumes according to the plan. Furthermore, it helps decision makers in making rational courses of action regarding the VRU.

![Risk Management Diagram](image)

**Figure 2s – VRU risk management tool**

This study contributes to the existing literature in two ways: 1) It is confirmed that insight in VRU risks helps decision-making. This emphasizes the need for extra attention. 2) A well-known risk management technique (RDM, developed by Keizer et al., 2002) was applied in a new context. However, this study entails certain limitations and therefore the results should be cautiously interpreted. Only qualitative approaches were used to obtain data. Therefore, the quality of the data and the analyses are dependent on the interviewer and interviewees. Furthermore, a case study methodology was used and the insights of this study are therefore related to specific circumstances.
Content
Abstract .......................................................................................................................... I
Management summary ..................................................................................................... II
Content ........................................................................................................................... V
List of figures and tables ................................................................................................. 1
Abbreviations ................................................................................................................ 2
1. Introduction ................................................................................................................ 3
   1.1 Context description: NXP MA ................................................................................ 3
   1.2 Market situation .................................................................................................... 6
   1.3 Problem statement ............................................................................................... 7
   1.4 Methodology ........................................................................................................ 8
   1.5 Research questions ............................................................................................. 9
   1.6 Data collection ..................................................................................................... 9
   1.7 Research structure .............................................................................................. 10
2. Theoretical background .............................................................................................. 12
   2.1 Innovation ........................................................................................................... 12
   2.2 Risk Management ............................................................................................... 13
   2.3 Volume ramp up .................................................................................................. 14
   2.4 Volume ramp up risk management ..................................................................... 16
   2.5 The proposed framework ................................................................................... 18
   2.6 VRU risk management performance ................................................................... 20
3. Internal analysis ........................................................................................................... 22
   3.1 Current situation .................................................................................................. 22
   3.2 VRU related decisions ........................................................................................ 22
   3.3 Risk management procedures ............................................................................ 23
   3.4 VRU risks ........................................................................................................... 24
   3.5 Root cause analysis ............................................................................................ 28
   3.6 Direction for redesign ......................................................................................... 29
4. Redesign .................................................................................................................... 30
   4.1 Design requirements ............................................................................................ 30
   4.2 Benchmark .......................................................................................................... 31
4.3 The final design.................................................................................................................. 34
4.4 Validity of the design ........................................................................................................ 41
5. Implementation plan ........................................................................................................... 44
  5.1 Project selection ............................................................................................................... 44
  5.2 Key actions ..................................................................................................................... 44
  5.3 Implementation pitfalls .................................................................................................... 45
6. Conclusions, recommendations and reflection ................................................................. 47
  6.1 Conclusions ..................................................................................................................... 47
  6.2 Recommendations ........................................................................................................... 48
  6.3 Reflection ........................................................................................................................ 48
Reference list .......................................................................................................................... 50
Appendices .............................................................................................................................. 56
## List of figures and tables

**Figure 1s- VRU risk management approach** ........................................................................... III

**Figure 2s- VRU risk management tool** .................................................................................. IV

**Figure 1 - NXP Stage gates** ........................................................................................................4

**Figure 2 – SAVR gates – normal project execution** .................................................................. 5

**Figure 3 – SAVR gates – VRU risks** ....................................................................................... 5

**Figure 4 – SAVR gates – extreme VRU risks** .......................................................................... 6

**Figure 5 - NXP MA’s production supply chain** ...................................................................... 7

**Figure 6 – Phase execution** ...................................................................................................... 8

**Figure 7 - Structure of report** ................................................................................................ 11

**Figure 8 – Ramp up phase (adapted from Johansson, 2011)** .................................................... 15

**Figure 10 – Proposed framework** .......................................................................................... 18

**Figure 9 – Framework to mitigation implementation (derived from Jüttner et al., 2003)** ........ 20

**Figure 11 – NXP MA’s internal and external supply chain** ..................................................... 22

**Figure 12 – VRU location** ....................................................................................................... 23

**Figure 13 – VRU uncertainties** ............................................................................................... 25

**Figure 14 – Financial risk 1** ................................................................................................... 25

**Figure 15 – Quality risk 3 (derived from Fjällström et al., 2009)** ......................................... 26

**Figure 16 – Customer satisfaction risk 4 (derived from Fjällström et al., 2009)** ............. 28

**Figure 17 – Root cause analysis** ........................................................................................... 29

**Figure 18 – Benchmark steps** ............................................................................................... 31

**Figure 19 – Tools, process and people** .................................................................................. 36

**Figure 20 – Tools, people and processes** ............................................................................ 35

**Figure 21 – VRU risk management tool** ................................................................................ 36

**Figure 22 – Timeline VRU risk management steps** .............................................................. 36

**Figure 23 - Implementation plan** .......................................................................................... 44

**Table 1 - Risk management approaches** .............................................................................. 13

**Table 2 - Elements of risk** ...................................................................................................... 14

**Table 3 - VRU phase vs. NPD projects** .................................................................................. 16

**Table 4 - Similarities and differences between different risk management steps** ............... 17

**Table 5 - Design requirements** .............................................................................................. 30

**Table 6 - Suggestions from benchmark partners** .................................................................. 33

**Table 7 - Scenario proposal** .................................................................................................. 40

**Table 8 - Design validation** .................................................................................................. 42
<table>
<thead>
<tr>
<th>Abbreviations</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-gate:</td>
<td>Available gate (2\textsuperscript{nd} NPD development gate)</td>
</tr>
<tr>
<td>MA:</td>
<td>Mobile Audio</td>
</tr>
<tr>
<td>NPD:</td>
<td>New product development</td>
</tr>
<tr>
<td>NXP:</td>
<td>Next experience</td>
</tr>
<tr>
<td>S-gate:</td>
<td>Specified gate (1\textsuperscript{st} NPD development gate)</td>
</tr>
<tr>
<td>SRP:</td>
<td>Start risk production</td>
</tr>
<tr>
<td>R-gate:</td>
<td>Released gate (4\textsuperscript{th} NPD development gate)</td>
</tr>
<tr>
<td>RDM:</td>
<td>Risk diagnosing methodology</td>
</tr>
<tr>
<td>V-gate:</td>
<td>Validated gate (3\textsuperscript{th} NPD development gate)</td>
</tr>
<tr>
<td>VRU:</td>
<td>Volume ramp up</td>
</tr>
<tr>
<td>WT1:</td>
<td>Wafer test 1</td>
</tr>
<tr>
<td>WT2:</td>
<td>Wafer test 2</td>
</tr>
</tbody>
</table>
1. Introduction
Within the semiconductor industry the gain is superior during periods of growth caused by innovations. However, fierce competition quickly drives down the price of semiconductors after they have been introduced into the market. A time-to-market focus is therefore critical when introducing innovations. It supports organizations in generating early profits and obtaining a market leading position, by rapidly deploying differentiated products ahead of competitors (Li et al., 2004). However, Utterback et al., (1992) argue that a focus on time-to-market results in imprudent management decisions and low performing products. Following Chen et al., (2005), a market leading position can only be achieved when the organization is also able to reach the volume and quality targets in time.

The moment of volume ramp up (VRU) is the last but critical phase of a new product development (NPD) project and links three important factors for project success: time-to-market, time-to-volume and time-to-quality (Wheelwright and Clark, 1992). The VRU corresponds to “[…] the linking phase between the development phase and production phase and has a crucial role for the success of a project” (Thiebus et al., 2006, p. 213). The VRU phase puts major stress on supply chain operations because it necessitates a massive increase of flow of goods to the customer and asks for careful planning, coordination and control of material, parts and finished goods from suppliers to the customer. Besides, in a market where more competition, innovation, short product lifecycles, expanding product variety, globally linked distribution networks and higher demand uncertainty are the norm of the future, semiconductor manufacturers face difficulties with making rational decisions with regard to the planning of the VRU (when and how much products to start). Wrong estimation on potential benefits (revenue, customer satisfaction and market share) and expenses (stock and production), will turn in losses in time and money, unfulfilled orders, a damage of corporate image, customer dissatisfaction or even worse, customer losses.

In general, organizations have poor insight in the VRU risks, and lack the resources, tools and techniques to manage these risks adequately (Winkler et al., 2007). A comprehensive risk discussion focused on this critical phase of a NPD project is therefore essential for every high-tech organization. The next section will present the context in which the master thesis takes place.

1.1 Context description: NXP MA
The research has taken place at NXP semiconductors N.V., an independent company operating in the semiconductor industry and active in more than 25 countries. “NXP semiconductors offers high performance mixed signal and standard product solutions that leverage its leading RF, Analog, Power Management, Interface, Security and Digital Processing expertise. These innovations are used in a wide range of automotive, identification, wireless infrastructure, lighting, industrial, mobile, consumer and computing applications” (NXP.com, 2013). NXP is a European top-three and worldwide top-twenty semiconductor manufacturer with a total revenue of $4,358 million in 2012. Within this organization, three main clusters exist (NXP.com, 2013):
- Businesses (referred to as Business Units (BU)): BUs are divided into business lines (BL) and they are in turn divided into product lines (PL). BUs, BLs and PLs are the responsible entities for achieving business results. For the most parts, each segment has its own customer base and competitors.
- Core processes: The core processes build NXP’s core competencies and leverage the most effective ways of working to achieve the business goals from product creation, demand generation, integral supply chain management to sales realization.
- Support process owners provide leadership in the areas like HR, F&A, Purchasing, IT, Quality, Legal, Communications, etc.

This research project has taken place at the PL NXP MA. NXP MA recently developed “[..] a revolutionary embedded algorithm in a new audio system which boosts the output power of micro speakers by over 5 times, vastly improving the sound quality of mobile devices” (NXP, 2013). This amplifier is perceived as a radical innovation that is promised to open up new markets and destabilize existing markets. The product is recently launched and has already been integrated in five mobile devices. NXP MA also recently developed two other innovations; a platform product and a derivative. These products were planned to enter the market in May 2013 and June 2013 respectively. In general, all NXP’s NPD projects pass 4 gates before mass production starts, according to the BCAM method (NXP, 2012b):

1. S-Gate (specification)
2. A-Gate (available)
3. V-Gate (validated)
4. R-Gate (released)

Figure 1: NXP Stage gates

The completion time of these four phases is somewhere between 1 and 3 years, depending on the degree of innovation. Figure 1 shows the project path. A NPD project starts with the “project execution start” and is a milestone that indicates an approved project idea that has been resourced already. The objective of the specification and planning phase is to define the scope and specifications, set up a project plan and assess the project risks to an acceptable level (by use of FMEA, discussed in chapter 4). At the end of this phase it should be clear “what” and “how” it is to be done. Finally, the S-gate (S stands for specified) examines whether the business case is still valid and if the project and technical documentation is still approved.

After passing the S-gate, the project enters the “Design & Implementation” phase. The objectives of this second phase are to design, implement and test the relevant component parts. Furthermore, the project team should agree on the customer acceptance plan. This plan is designed to not only establish the
design, but also the customer acceptance criteria. At the end of the ‘Design and implementation’ phase, the project enters the A-gate (A stands for availability) at which the semiconductor components are available and ready for integration and testing.

After successfully passing the A-gate, the project enters the “Verification and Validation” phase. This phase is aimed to integrate the components, test and verify the product to make sure that the product is validated against requirements. In this phase, the customer can ask for some selective tests, which should be executed according to their standards (this is called ‘samples for customer qualification’). At the end of the “verification and validation” phase, the project enters the V-gate (V stands for validated).

After successfully passing the V-gate, the project enters the “Release and Preparation” phase. During this phase, the objective is to obtain external approvals. Furthermore, the project team needs to prepare for the product release, by training personnel and preparing manufacturing for high production volumes. The resources for marketing and sales, operation and customer support needs to be ramped up in order to support the product in the ‘field’ after product delivery (after sales service should have been set-up correctly). At the moment that the external approvals are obtained and the supply chain flow is proven to be efficient, the R-gate can be held (R stands for released). After the R-gate, the mass production starts (also known as the ‘VRU’ phase; volume ramp up, see figure 2).

However, it appears that the VRU usually starts after V-gate has been passed to meet (expected market demand) (see figure 3). A durability test, lasting about 1000h taking place between the V and R gate, slows down the introduction to the market. This test is generally considered as non-crucial, since the semiconductor has been tested thoroughly before this test. Therefore, managers decide to start mass production before the R-gate has been passed.
Nevertheless, NXP MA’s forecast often shows that customers want to have the product much earlier than it was initially planned to enter the market, or much earlier than the product is actually finished. The customer is more demanding (market pressure) and this puts stress on the planning of the VRU (see figure 4). To stay competitive, NXP MA should do everything possible to meet the customers’ demand and simultaneously maintain quality. When NXP MA is not able to deliver, NXP MA will lose (potential) customers, which will be at the expense of the profit.

The pressure of the market to start mass production before the product has passed all the development gates is a trend that makes risk management focused on the VRU phase even more important, and requires rational decision-making. NXP MA can apply four strategies to deal with this situation. First, NXP MA decides to start the VRU. Second, NXP MA starts the VRU with stop points at a certain production step (the production will go further when there is more certainty about the quality of the products and accurateness of the forecasts.). Third, NXP MA postpones the VRU. Fourth, NXP MA decreases its lead time with 4 weeks and simultaneously postpones the VRU (increases the development price by approximately 75%). In the last three cases, NXP MA has more time to finish NPD and increases its confidence in the quality of the products and accurateness of the forecasts.

The next section will show how the current market situation puts additional stress on the VRU phase.

1.2 Market situation

In this section, market trends that contribute to the need for risk management related to the VRU phase are discussed. Semiconductors are found in the majority of electronic products ranging from mobile devices to hearing aids and from automobiles to computers. NXP MA is mainly active in the market of mobile devices (smartphones and tablets) and is challenged by the following market trends:

*Short product lifecycles:* The rapid rate of innovation within the market of mobile devices decreases product lifecycles for all parts involved. This means that the window for making profits is getting smaller. Semiconductor companies recognize that they must provide both newly developed products and exceptional service in order to survive.

*Globalization:* Since approximately 30 years, the semiconductor industry has been making significant developments towards globalization. Both the semiconductor production and their usage have become global activities causing a spread of centers of excellence across the world. The supply chains of the recently developed amplifiers in NXP MA are quite the same and the products run through the
production processes represented in figure 5. The products reach the customer by use of disti, warehouse or direct transportation.

Figure 5 - NXP MA’s production supply chain

It is important to notice that the different production processes take place at different locations around the world and that NXP MA’s customers are globally dispersed. This shows that operations are executed on a global level, which makes the internal supply chain vulnerable. The different production steps are described in appendix A. The lead time of the products is approximately 16 weeks (time between order placement and order delivery). As has been described before, the VRU is a driver for supply chain risks and asks for careful planning, coordination and control of material and parts from suppliers to the independent production steps to the customer.

*Increased outsourcing activities:* After standardization of manufacturing techniques, semiconductor companies changed their business model and started to outsource manufacturing activities to merchant foundries. Nowadays, semiconductor companies try to focus on core competence like research and development of new technologies. This trend took place even though semiconductors are complex, hard to design and hard to manufacture.

*Long manufacturing lead-times:* The lead time of a semiconductor generally lies between 12 and 18 weeks. However, this time is much longer than most customers expect when placing an order. This trend forces the industry to strategically manage the forecast and inventory at multiple stages in the production pipeline.

These market trends show that the market is highly volatile. Time has become a competitive weapon and the capability to serve customers with low costs/high quality products in shorter delivery times has become extremely important. These market developments ensure that NXP MA cannot afford problems during the VRU phase. Due to the market pressure and market trends, management of risks during the VRU should receive further attention.

The next section will present the problem statement discussed in this master thesis.

1.3 Problem statement

This section introduces the problem statement that NXP MA encounters. NXP MA deals with difficulties concerning the delivery of a new product to a (new) customer. Especially when the product should be ready for mass production (start of VRU), decision makers face enormous pressure from market demand but still fear risks that could disrupt the supply. Market pressure and market trends are fundamental barriers for NXP MA in making rational decisions about when and how much products to start. The following problem statement can be formulated:
“NXP MA faces uncertainties concerning the VRU phase and has difficulties to make rational decisions”

This recognition has made NXP MA acutely aware of the limited knowledge in this domain and an absence of formal approaches to deal with VRU risks. This thesis is performed to support NXP MA in risk management by providing insights in how risk management may have a positive effect on decision-making during the VRU. Furthermore, this thesis will give NXP MA recommendations on how to implement a risk management approach to manage risks associated with the VRU. The next section will discuss the methodology that will be used to tackle the business problem.

1.4 Methodology

The research will be designed focused because “Design science research intends to add to analysis and explanation, specifications for interventions to transform present practices and improve the effectiveness of organizations” (Denyer et al., 2008: pp. 393).

A design process approach helps to identify the main solution directed to the desired situation and will be used as a guideline to answer the research questions presented in chapter 1.6. Design-activities are nestled in the regulative cycle (see figure 6). This regulative cycle is used as the methodological framework in this thesis and starts with the problem choice. From a scientific point of view this design approach may have some drawbacks. There are researchers that argue that it is difficult to prescribe a certain design when theories about organizational behavior are not developed enough (e.g. van Aken et al., 2007). Therefore, van Aken et al. (2007) developed the reflective cycle. The reasoning behind this reflective cycle is that it links the results with the design. This generates knowledge about the initial design that was used which in turn is useful for designing of solutions for other situations (van Aken et al., 2007). However, due to time limitations this research has only followed the regulative cycle in which problem solving on a specific subject takes place. It was assumed that this research is a primary attempt to reflect the results upon other cases to determine the design knowledge.

![Figure 6 – Phase execution](image)

This thesis on VRU risk management will use a case study methodology to move along the regulative cycle. According to Yin (1994), a case study is “an empirical enquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident”. There is no experimental setup possible which makes it particularly useful to answer ‘how’ and ‘why’ questions. The case that has been selected for this study has been described in chapter 1.1 and 1.2. The unit of analysis for this study is the VRU phase.

1.4.2. Project delineation

VRU activities can take place at two moments of the product lifecycle: First, an increase in volume production after the NPD process has taken place. Second, a VRU taking place after the introduction of a
new production line. However, it is important to notice that this research will only focus on VRU risks during the increase in volume production after a NPD process. The next section will show the research questions that will be addressed in this thesis.

1.5 Research questions
The primary research question of this master thesis is formulated as follows:

“What are the basic characteristics of a specific risk management approach for VRU problems at NXP MA caused by the company’s market situation?”

To answer the main research question eight sub questions are formulated which will guide the drafting of this master thesis:

1. What can be learned from the current literature related to innovation, VRU and risk management? (chapter 2)
2. What are crucial steps in a proper risk management approach focused on VRU risks? (chapter 2)
3. How is NXP MA currently managing risks during NPD processes? (chapter 3)
4. What kinds of risks influence VRU decisions? (chapter 3)
5. What are the root causes and consequences of the business problem? (chapter 3)
6. What can be learned from other organizations/industries that are also dealing with ramp up activities? (chapter 4)
7. How can NXP MA adjust their current way of working to achieve sustainable competitive advantage through a novel, useful and continuous VRU risk management process? (chapter 4)
8. What are the benefits when applying risk management approach within NXP MA? (chapter 4)

The research objectives are distinguished in ‘objective of the research’ and ‘objective in the research’. The objective of the research is defined as follows: “To create knowledge about risk management and VRU risks in order to investigate how VRU related decisions may be improved”.

The objective in the research will help to accomplish the objective of the research. The objective in the research is defined as follows: “To design an approach that will help NXP MA with making rational decisions with regard to the VRU”. The next section will discuss how and which data will be collected.

1.6 Data collection
In order to answer the research questions and to accomplish the research objectives, this research will use multiple sources of evidence, which are discussed in this section. To achieve triangulation of data (construct validity) the following sources will be used; scholarly articles, documents, semi-structured interviews and observation (5 months internship at NXP MA in Nijmegen).

1.6.1 Written resources
The literature study included scientific papers, printed books, and relevant presentations from conferences. Primary sources were found by 1) Google scholar, 2) Emerald, 3) ABI/Inform 4) ScienceDirect and 5) ProQuest. The quality of the studies used was evaluated according to a predefined
inclusion theory, which can be consulted in appendix B. The set of literature was expanded with relevant sources found in the initial literature (snowball effect). Specific NXP documents, which are only available for NXP’s employees, were also used.

1.6.2 Interviews
Cooper and Schindler (2008) consider semi-structured interviews as the primary data-collection technique in qualitative research. Additionally, Yin (1994) argues that this way of data collection is the most valuable and essential source of evidence for a case study method (described in chapter 1.4). Furthermore, it allows creativity and diversity in the answers obtained. Semi-structured interviews are therefore a valuable resource in this study.

Respondents were selected based on their expert knowledge. Furthermore, they needed to have a close relation with NXP MA (with the exception of the VRU experts). All 20 potential interviewees were approached by e-mail to ask them for willingness to participate. It has been promised that the respondents’ identity and referrals are kept confidential and that this report will not disclose any information that is considered proprietary. In the end, 19 participants were willing to participate.

All interviews were recorded after permission was granted. Due to NXP’s global operation, six interviewees were located abroad. These interviews were conducted with the aid of the communication tool Lync. The other interviews were performed face-to-face. The interview lasted around 1 hour. Due to confidentiality agreements, the interviewees will stay anonymous. To give some structure to the answers and conclusions, the respondents were grouped into five categories (see appendix C table 1).

The interviews were carried out in a predetermined sequence, starting with the project manager (included in the product development category), since he is highly involved in all stages of the project. The information gathered from this interview was used to fine-tune following interviews. The interviews were processed by the method of pattern matching and theory building (Yin, 1994).

1.6.3 Observation
Another important source to collect data is by observation. The research project has taken place at NXP MA in Nijmegen for 5 months (February 2013 – June 2013). As a member of the team it was possible to attend VRU meetings to see how proceedings were made. In addition, it was possible to address other team members, when necessary.

1.7 Research structure
This chapter will elaborate the structure of the research (represented in figure 7). The research will follow the
The content of the chapters will be shortly discussed in this section:

- In this chapter, the problem statement was introduced and the research method to address the business problem was presented. In addition, the research (sub) questions and design objectives have been shown. Furthermore, methods for data collection were discussed.
- In chapter 2, the theoretical foundation for this study will be discussed. An overview of the literature related to supply chain risk management, innovation and VRU in high-tech companies will be provided. In addition, a structured risk management approach for the VRU phase will be described.
- In chapter 3, the internal analysis of NXP MA will be presented. The problem statement will be validated and root causes will be examined. This chapter also includes a benchmark to compare and learn from practices of other organizations.
- In chapter 4, a redesign of NXP MA’s risk management approach will be shown. In order to accomplish the aim of this chapter, the requirements for the design will be established first, followed by an overview of the designed solution. Afterwards, the validity of the design will be discussed.
- In chapter 5, a proper implementation plan for the risk management approach in NXP MA will be discussed.
- In the last chapter, the conclusion, practical and theoretical relevance and implications for further research will be presented.
2. Theoretical background

In this chapter, the theoretical foundation for the final design will be discussed by providing an overview of the literature related to innovation, risk management and the VRU phase. This chapter will function as one of the requisites for the final design. The objective is to answer the following sub questions: What can be learned from the current literature related to innovation, risk management and VRU? And what are crucial steps in a proper supply chain risk management approach focused on VRU risks?

2.1 Innovation

The attention for innovation is growing at an increasingly rapid rate (Eveleens, 2010). Both managers and researchers acknowledge the importance of innovation in order to be able to survive. However, despite the attention it receives, a general definition of the concept ‘innovation’ still does not exist. In essence, ‘innovation’ is about change, but this change can take on several forms (Tidd et al., 2005). Eveleens (2010) argues that innovations vary in at least five dimensions: type of novelty, degree of novelty, type of organization in which the innovation takes place, size of the organization that implemented the innovation and the environment in which the innovation was developed. Over the past 80 years, many researchers focused on the innovation process (Tidd et al., 2005). Tidd et al. (2005, p. 87) distilled two key points from this vast source of information:

- “Innovation is a process, not a single event, and needs to be managed as such”
- “The influences on the process can be manipulated to affect the outcome – that is, it can be managed”

Innovation is especially challenging in high-technology markets, which are increasingly characterized by short product lifecycles, globalization, heavy competition and rapid changes in technological possibilities (Bowersox et al., 1999, Mallick and Schroeder, 2005, Wildemann, 2007). These factors make uncertainty and complexity the key contingencies in managing the innovation (Tidd et al., 2005). On the other hand, the potential rewards of NPD in high-tech markets are immense compared to other markets (Ogawa and Piller, 2005). Although researchers argue for NPD in high-technology markets, pioneering new products (or new technologies) is not necessarily a great advantage for all organizations (Tidd et al., 2005). Market leadership in the early stages of product or technology development is characterized as volatile, and pioneers are often displaced by new entrants (Steffens, 1994).

When faced with great uncertainty and risks, many high-tech organizations could decide not to invest in creating innovative products/technologies (even though the rewards of these innovation are more than attractive). However, the high-tech market is dynamic and turbulent so organizations are more or less forced to invest in innovation in order to enhance the organizational outcomes; otherwise their survival chances are seriously threatened (Ogawa and Piller, 2006; Tellis and Golder, 1996). The next section stresses the importance of NPD risk management.
2.2 Risk Management

Innovative companies need to handle risks when launching new products fast and successful (Keizer et al., 2002). The trend towards globalization, short product lifecycles, demanding customers and outsourcing became true and the downside of risk and uncertainty in NPD projects got more interest (Claypool et al., 2010; Colicchia and Strozzi, 2012; Kleindorfer and Saad, 2005; Levy, 1995). There is an appreciable amount of evidence that suggests that failure to manage the NPD risks effectively, has a significant negative impact on the NPD performance (Mitchell, 1995; Mbang, 2012). Building on these statements, a number of authors have sought to develop appropriate approaches to evaluate uncertainty’s effect on NPD (see table 3).

<table>
<thead>
<tr>
<th>Author</th>
<th>Risk management approach</th>
<th>Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edwards and Bowen (2005)</td>
<td>6-step risk management process</td>
<td>Establishing appropriate context, recognizing risk of the project which the stakeholder organization will face, analyzing the identified risk, develop responses, controlling and monitoring the risks, allowing post-project capture of risk knowledge</td>
</tr>
<tr>
<td>Raz and Michael (2001)</td>
<td>4-step risk management process</td>
<td>Identification, assessment, treatment, monitoring</td>
</tr>
<tr>
<td>Tseng, Kyelleberg, and Lu (2003)</td>
<td>4-step risk management process</td>
<td>Risk identification, analysis, response development and control</td>
</tr>
<tr>
<td>Stare (2004)</td>
<td>5-stage risk management process</td>
<td>Risk identification, evaluation and structuring, risk evaluation, risk planning, risk control and corrective actions</td>
</tr>
<tr>
<td>Smitt and Merritt (2002)</td>
<td>5-step risk management process</td>
<td>Identify risks, analyze risks, prioritize and map risks, resolve risks and monitor risks</td>
</tr>
</tbody>
</table>
There are just minor disagreements on the critical steps to manage NPD risks. All researchers include risk identification, risk assessment, risk response and risk control/monitoring. However, it appears that there is no consensus on how to assess the risks in NPD projects. In this master thesis, risk is conceptualized as a three dimensional concept (see table 1).

Table 2 - Elements of risk

<table>
<thead>
<tr>
<th>Risk dimension</th>
<th>Elaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>The expected outcomes are uncertain</td>
<td>Outcome uncertainty is the first consideration when assessing risks in innovative projects (Tatikonda and Rosenthal, 2000). Outcome uncertainty is related to knowledge shortcomings; it is a risk when it’s not known what the outcome will be and the project has more possible outcomes. Vaughan (1997) conceptualized ‘risk’ as a gap between expected and actual outcome: “Risk is a condition in which there is a possibility of an adverse deviation from a desired outcome that is expected or hoped for” (Vaughan, 1997; pp. 8).</td>
</tr>
<tr>
<td>The outcomes are difficult to control and manage</td>
<td>Some project outcomes are uncontrollable and occur purely by chance (Sitkin and Pablo, 1992). According to Tatikonda and Rosenthal (2000, p.10) outcome related risks are difficult to control and manage because “there is a gap between the skills required to perform the task and the skills present in the organization.” Besides, when the ability to influence the project within the time and resources limits is small, the project should be classified as risky (Keizer et al., 2002).</td>
</tr>
<tr>
<td>The potential outcome set includes some extreme consequences</td>
<td>The third reason for a project to become labeled as ‘risky’ is that the potential consequences are severe (Keizer et al., 2002).</td>
</tr>
</tbody>
</table>

Activities that meet these dimensions should be labeled as ‘risky’ and risk management procedures should be applied. This study stresses the importance of critical activities in the final phase of NPD project: the ramp-up phase. The VRU phase is considered to be particularly associated with supply chain risks, and will be discussed in the next section.

2.3 Volume ramp up

Rapidly developing products and moving them efficiently to the market is one of the innovation success factors that will be highlighted in this research, as has been described in other literature (Carillo and Franzia, 2006; Chen et al., 2005; Hamm and Symonds, 2006; Hoek, van and Chapman, 2007; Utterback and Abernathy, 1975). The supply chain has a leading role in this discussion. Over the last few years, the management of supply chains has attracted increasing attention of numerous researchers. This development leads to an increase in definitions and formulations. However, for the scope of this study, it is assumed that a supply chain is a succession of activities concerned with planning, coordinating and controlling material, parts and finished goods from suppliers to the customer (Stevens, 1989). The
connections in a supply chain contribute to the value of the goods, since they carry it through the chain. If one connection does not perform well, it reduces the overall effectiveness of the whole supply chain (Mbang, 2012). Supply chain risks can seriously disrupt or delay material, information and cash flows. These disruptions and delays will damage sales, increase costs or, at worst, both.

The VRU is a critical issue in the supply chain operations. The VRU corresponds to “[...] the linking phase between the development phase and production phase and has a crucial role for the success of a project” (Thiebus et al., 2006, p. 213). The VRU phase puts major stress on supply chain operations, because it necessitates a massive increase of flow of goods from the suppliers to the final assembler (OEM) (Hallikas et al., 2000) (Terwiesch and Bohn, 2001). This massive increase of flow of goods asks for careful planning, coordination and control of material, parts and finished goods. High-tech organizations are known to have complex internal supply chains and when one connection disfunctions, it will reduce the overall effectiveness of the whole supply chain.

According to Bramley et al. (2005), the importance of the VRU is underestimated and deserves more attention. The lifecycle profit of a product is primarily determined in the early phases of product market introduction because innovative high-tech products are known to have high but rapidly falling prices, and the only chance to rush competitive prices is early in the product lifecycle (customers only want to pay premium prices in these early phases) (Terwisch & Bohn, 2001). Certainly for high-tech companies that are focusing on innovation leadership instead of price leadership, it is essential to gain market share and generate cash to guarantee the return on investment (Schuh et al., 2005).

Figure 8–Ramp up phase (adapted from Johansson, 2011)

Figure 8 clearly shows that the ramp up phase addresses three interdependent success factors of NPD (Johansson, 2011). Time to the market is critical for innovations because it allows organizations to achieve early profits and a market leading position by rapidly deploying differentiated products ahead of competitors (Li et al., 2004). However, it has a high financial payoff to achieve high product volume early to serve all customers in the early phases of the product lifecycle (Li et al., 2004). This time-to-volume focus can only be successful when the product has the intended quality. Hence, time-to-market alone does not guarantee NPD success unless it reaches the volume and quality targets in time (Chen et al., 2005). VRU success will not be achieved by focusing on one of the factors without attention for the others (Johansson, 2011).

According to Terwiesch et al. (2001), the most important performance indicators during the VRU are quality, costs and volume time. Nevertheless, pressure from both market and technology, and a high product change rate make it difficult for the management to optimize and fine-tune all product and process related decisions prior to their launch (Terwiesch & Xu, 2004). Therefore, many companies fail to meet the volume, cost or quality targets in time. In the next section it will be explained why organizations should apply risk management focused on the VRU.
2.4 Volume ramp up risk management

A high level of awareness of potential supply chain risks makes the organization a more reliable business partner (Colicchia and Strozzi, 2012), and a well thought-out and structured risk management approach focused on VRU issues could further contribute to successful product introduction. However, within the literature there is no structured risk management approach found focused on VRU risks specifically. There could be three reasons for the lack of research in this field:

1. Risk in the VRU phase is absorbed in the NPD project risk management approach.
2. Firms are not interested in risk management practices focused on VRU phase.
3. VRU Risk management is regarded as a driver of costs (Levy, 1995). Levy (1995) emphasized the hidden value of risk management actions, whereas risk management practices are generally perceived as superfluous constraints imposed by regulations or higher management. Organizations are typically unwilling to invest in mitigation strategies to prevent future disasters that may be quite distant and ambiguous (Levy, 1995).

The VRU is considered as a critical phase within a NPD project and a critical issue for supply chain operations. Besides controlling and monitoring project risks, the VRU phase needs careful planning, coordination and control of material, parts and finished goods from suppliers to the customers. Hence, risks associated with the VRU phase require special attention and expertise. Many researchers have developed approaches to alleviate the effects of risks in NPD projects (as discussed in chapter 2.2). However, none of these researchers discusses the applicability of their tool on VRU risk management. Before concluding whether these approaches are applicable for risk management focused on VRU, similarities and differences between innovation projects and the VRU phase should be discussed (see table 3).

Table 3 - VRU phase vs. NPD projects

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>NPD project</th>
<th>VRU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unique (Gross and Renner, 2010)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Relevant for business success (Schmidt, 2000)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Start and ending (Gross and Renner, 2010)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Involvement of different functions (Gross and Renner, 2010)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Special ‘project’ organization needs to be installed (Schmidt, 2000)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Certain budget has to be approved (Terwiesch and Xu, 2004)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Preparative work of critical tasks before the ‘project’ in order to guarantee smooth execution (Bloodgood and McFareland,</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
Planning is important, use of milestones (Gross and Renner, 2010; Schmidt, 2000)

As can be seen in the table above, well-executed preparative work determines whether the VRU execution runs smoothly (Gross and Renner, 2010). This is preparative work is not necessarily needed for NPD projects. However, it is expected that the moment of critical task execution has no influence on the content of successive steps for risk management. Instead, it is assumed that this difference only influences the moment to start risk management activities. Hence, the similar characteristics of NPD projects with VRU lead to the assumption that, even though the nomenclature differs, the same steps need to be taken (Smitt and Merrit, 2002). Based on this statement, it can be concluded that supply chain risk management focused on VRU risks consists of the following stages: risk identification, risk assessment, risk response strategy and risk control/monitoring.

However, there is still the question why VRU risks management should be an independent process instead of integrated within a NPD project risk management. In table 5, the main similarities of and differences between a risk management approach for NPD projects and a risk management approach for the VRU phase are discussed.

Table 4 - Similarities and differences between different risk management steps

<table>
<thead>
<tr>
<th>NPD project</th>
<th>VRU</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Risk identification</strong></td>
<td><strong>Similarities</strong>: - Cross functional team, each team member should identify knowledge gaps&lt;br&gt;<strong>Differences</strong>: - Project leader is responsible for the execution of the risk approach&lt;br&gt;- Start risk identification at the same time with the start of a project&lt;br&gt;- Focus on all kinds of project risks (broad focus)</td>
</tr>
<tr>
<td><strong>Risk assessment</strong></td>
<td><strong>Similarities</strong>: - Evaluation of each potential risk on its likelihood, consequences, relevance and importance&lt;br&gt;- All actors should score individually on risk statements&lt;br&gt;<strong>Differences</strong>: All actors involved should assess the risk (Keizer et al., 2002)&lt;br&gt;- Assess risk that hamper NPD</td>
</tr>
<tr>
<td><strong>Risk</strong></td>
<td><strong>Similarities</strong>: - Risk response strategies</td>
</tr>
</tbody>
</table>
**Response**
- Include avoidance, mitigation, retention, transfer, sharing and acceptance
- Scenarios can be made based on different response strategies (Harris, 2013)

**Differences:** Decision for a risk response strategy is initially based on the degree of financial input.

**Control / Monitoring**
- **Similarities:** Proactively managing of the risks
  - Frequently sending updates to project members
  - Continually learning

- **Differences:** Frequencies of the meetings stay equal / decreases when project progresses

The differences between the two approaches give reason to why organizations do well to manage VRU issues separately from project risk management. In the next subsections it will be discussed how a framework for VRU risk management should look like. Furthermore, it will be explained what the content of each of these steps is and how this differs from NPD risks management

### 2.5 The proposed framework

In general, unpreparedness for VRU risks can be attributed to a lack of understanding on issues surrounding the risks involved, as well as a lack of resources, tools and techniques to analyze the situation properly (Winkler et al., 2007). No research has yet provided a comprehensive approach to recognize and subsequently manage the VRU risks involved in NPD projects in high-tech organizations. This section discusses a suggestion for such a framework based on the theories described in previous sections (see figure 10).

Applying the proposed framework enables organizations to improve their insight in the ramp up phase. Improved insight in the ramp up phase is defined as the ability to effectively collect data of every aspect on the organization’s operations as well as customers, and at the same time the ability to develop useful insights from the data (Kaipia & Hartiala, 2006). A proper usage of the framework has the potential to help realizing rational and appropriate courses of action during the VRU, and creating a common understanding of the true impacts among all actors involved in NPD processes. It will help the organizations to use their risk appetites as directory when determining their strategy for the ramp up, and it will pay special attention to those risks that might threaten the implementation of that strategy.

**Figure 9 – Proposed framework**
The next subsections will briefly discuss the content of each VRU risk management activity.

2.5.1 VRU risk identification
This first step aims to discover all relevant risks that could disrupt the VRU. The identification of the risks that can hamper the VRU planning should focus on critical product components, processes, suppliers and customers. The environment in which the high-tech organization operates needs to be carefully scanned in order to recognize relevant risks in time (Craighead et al., 2007; Kern et al., 2012). Risk is a social construct and each community, organizations or individual will have clearly different views on what actually constitutes a risk (Renn, 2008). Therefore, all actors involved during the VRU should be able to bring up ‘gaps’ (knowledge, skills, expertise) in the project without feeling impeded to pronounce their worries (Keizer et al., 2002). Individual risk identification makes it possible for the team to consider risk in a more coherent framework (Edwards and Bowen, 2005).

2.5.2 VRU risk assessment
Risk assessment concerns the appraisal of the eventuality of occurrence and an estimation of the possible impacts in the event the risk unfolds (Kern et al., 2012). According to Kern et al. (2012), the outcome of this stage needs to provide a classification of all identified risks in a prioritizing order. During this step it is important to assess not just direct and indirect effects in case the risk unfolds, but also the short- and long-term effects (Raz and Michael, 2001).

Because risk is a social construct it raises important questions regarding the objectivity of the procedure, which makes it important that all actors score individually the risk statements developed in the risk identification phase (Keizer et al., 2002). To stick on the tridimensional concept of risk (see table 2) team member should assess risks on whether the expected outcomes are uncertain, the outcomes are difficult to control and manage and the potential outcome set includes some extreme consequences.

2.5.3 VRU risk response strategy
The objective of defining a response strategy is to achieve consensus on action plans for dealing with the risks assessed in the previous step (Keizer et al., 2002). There are six risk response strategies that have been described frequently in the literature; avoidance, mitigation, retention, transfer, sharing and acceptance (Perry, 1986; Miccoli and Destefano, 2010; Elangovan et al. 2011). During the VRU it is important to take account for the effort that each response strategy takes. Due to the market pressure it is important not only to take financial input in consideration, but also the time exposure (Nau et al., 2012).

Jüttner et al., (2003) distinguished two ways to execute supply chain risk management; reactively and proactively. Reactive supply chain strategies are aimed to control the risks a company faces or are aimed to recover operational activities after a disturbance has occurred (see figure 9). Proactive approaches are aimed to understand and mitigate risks before the risk unfolds, while enhancing the level of preparedness to respond to the risk after it has occurred (Kleindorfer and Saad, 2005). A primary condition for being proactive in identifying risks is that risk management is a natural activity in NPD projects of high-tech organizations.
Because all the risks have been assessed and the pros and cons are carefully weighed, scenarios on the different response possibilities can be made. The use of scenario creation after this phase will assist in making strategic choices in the concerned business environment (Harris, 2013). Developing a couple of scenarios depending on the different response strategies will ease decision-making. Scenario making enables the plans to be adjusted in case the circumstances vary from what was expected (Becker, 1989).

2.5.4 Control/monitoring of VRU risks
The control and monitor process is aimed to learn from the risks involved and to continuously improve the VRU in general (Kern et al., 2012). The proposed model argues that risk management activities needs to be controlled and monitored on a frequently base and increases when the VRU phase is coming.

2.6 VRU risk management performance
Companies should establish key performance indicators (KPIs) to evaluate the success of the VRU phase. KPIs are “[...] quantifiable measurements that reflect the critical success factors of an organization. While KPIs differ depending on the organization, they always define and measure progress toward organizational goals” (Caruso, 2007). Effective KPIs provide a complete measurement of the company’s competitive advantage and present meaningful rollups for decision makers (Ritchie & Brindley, 2007). This could be very useful in changing or improving risk management strategies.

It has been recognized that developing KPIs and choosing the right number of key KPIs is very challenging (Chae, 2009; Lapide, 2006). However, the literature does not provide a coherent framework for defining KPIs for risks management in the VRU phase. According to various researchers, it is imperative to develop appropriate KPIs to evaluate, educate and direct the VRU decisions (Ritchie & Brindley, 2007). According to Caruso (2007), it takes more than a couple of meetings to establish which KPIs to use and how to implement them. Chae (2009) advises organizations to start with a small number of undeniable necessary KPIs, which are manageable.

Chapter summary and conclusion
This chapter gave answer to the following questions: What could be learned from the current literature related to innovation, VRU and supply chain risk management? And what are crucial steps in a proper supply chain risk management approach focused on VRU risks? Organizations operating in dynamic and
turbulent markets need to invest in innovation in order to enhance organizational outcomes. However, innovation goes hand in hand with risks. Getting a market leading position and creating early profits will increase the chance of innovation success. Nevertheless, an organization can only claim a market leading position when it is able to reach volume and quality targets in time. The VRU phase plays an important role in achieving this goal. However, the VRU phase is associated with significant supply chain risks because it concerns a process of a massive increase of flow of goods to the customer. Within the literature there is consensus on the most appropriate steps to manage risks in innovation projects: risk identification stage, risk assessment stage, risk response strategy and a control/monitor stage. However, literature about risk management specifically dedicated to VRU risks is lacking. The VRU phase fits the definition of an innovation project and therefore it is assumed that these steps are also crucial in managing VRU risks. Risk management focused on VRU will help organizations to use their risk appetites as directory when determining strategy about the VRU. Organizations should establish KPIs to evaluate the success of the ramp up.

Before designing a VRU risk management approach in NXP MA, the business problem needs to be validated which will be addressed in the next chapter. Furthermore, root causes will be identified and the direction for redesign will be determined.
3. Internal analysis
This chapter describes NXP MA’s current situation and will validate the business problem as has been described in chapter 1.3. The objective is to answer the following questions: How is NXP MA currently managing risks during NPD projects? What kinds of risks affect decision-making with regard to the VRU? And what are the root causes and consequences of the business problem? Data in this chapter are derived from semi-structured interviews. To complement this data, NXP documents were used as well. The chapter will be closed by a description of the main areas for redesign.

3.1 Current situation
The internal and external supply chain of NXP MA has been outlined in figure 11. The practices of supply chain management are supposed to be a multi-facet concept, including the up and downstream partners of the supply chain. This research focuses specifically on the VRU phase.

![Figure 11 – NXP MA’s internal and external supply chain](image)

The VRU phase is associated with supply chain risks because it involves a massive increase of flow of goods from suppliers to the different customers. If one connection in the external or internal supply chain does not perform well, it reduces the overall effectiveness of the whole supply chain. Therefore, careful planning, coordination and control of the materials involved a requisite.

3.2 VRU related decisions
As explained in chapter 1, the market situation in the semiconductor industry put pressure on the planning of the VRU. During the NPD project, NXP MA’s general management needs to take decisions related to the start of the VRU:
VRU decisions at NXP MA directly affect the variable ‘cost’ (and consequently the profit) and therefore there are good reasons to treat the decisions more rigorously. The next section will discuss the risk management procedures that are currently used.

### 3.3 Risk management procedures

The interviewees were asked questions about the availability of current risk management procedures targeted at securing the supply of a new product, with the right quality, in the right volume and at the right place, i.e. the availability of a VRU risk management procedures. In addition, the respondents were asked whether NXP MA’s current way of working was suitable in realizing this objective. The structure of the interview allowed for discussion about strategies in risk identification, assessment and mitigation, and research possibilities that may aid NXP MA in future VRUs after NPD projects (the interview protocol can be consulted in appendix D).

Figure 12 – VRU location

Figure 12 shows the place of VRU phase within the supply chain. During the interviews, almost all respondents agreed on the statement that a successful VRU is critical for the delivery of a new product to a customer. Three of the respondents neither validated nor reject this statement, due to a lack of knowledge about the VRU phase.

When planning a new project, NXP MA’s project managers make use of the failure mode effect analysis (FMEA) method to address design, system and process related risks. The FMEA starts during the first conceptual stage of product design and continues throughout the development life of a semiconductor. The objective of an FMEA is threefold:
1. Reduction of technical and quality risks, project management risks, organizational risk, external risks and commercial risks
2. Improve risk mitigation strategies
3. Share experience

The input for the FMEA stems from a brainstorm session with the project manager and other important actors present at that time. However, during the interviews, the current FMEA procedure was criticized:

1. The FMEA is only as good as the team
2. FMEA is time consuming
3. It is challenged with unknown unknowns
4. It prioritizes the risks but doesn’t eliminate the failure modes by itself
5. NXP MA fails in updating the FMEA during the project trajectory
6. FMEA is only aimed to identify the risks and the consequences, but it fails to mitigate the risks or seize the opportunities that come along with the risks
7. FMEA in NXP MA is mainly focused on technical risks, while consequences for the remainder of the project trajectory (process and marketing risks) are not taken into account
8. FMEA assessment method is too comprehensive and does not allow for individual risk assessment

It appears that NXP MA does not adequately execute the FMEA. Furthermore, none of the interviewees confirmed that the FMEA method is suitable for to take rational and appropriate courses of action with regard to the VRU. The next section will elaborate the risks associated with the VRU that may influence decision-making.

### 3.4 VRU risks

Due to market pressure and the current market situation, it is expected that the VRU of NXP MA’s products will more often take place earlier in the product development lifecycle. In the literature (chapter 2), it has been argued that the VRU is a risky phase and risk management needs to be applied. In this chapter it will be assessed which VRU risks at NXP MA endanger rational decision-making. Figure 13 summarizes the identified risks that affect VRU related decisions. This identification is needed to figure out where the created scenarios should focus on (see chapter 4). Behind each risk, the percentage of interviewees that has addressed the concerned risk has been reported. None of the risks found during the internal analysis was addressed by 100% of the interviewees. This may be due to the difference in background and interests of the interviewees.
This research did not account for the difference between the different respondents, since all risks were assumed to be complementary. The following subsections will explain each specific risk and clarifies why this affects VRU related decisions.

### 3.4.1 Financial risks
- Chance for obsolescence stock: Obsolescence stock is an amount of products that are unlikely to be used in the future or to be sold for profitable prices. The chance for obsolescence stock is a financial risk, since the products that have been produced have a certain production value but cannot be sold in the market.

- No price alignment with customers: NXP MA usually starts VRU before a soft order has turned into a hard order (as will be discussed under customer satisfaction risks). When the price has not been aligned with the customer before VRU starts, it is uncertain whether the product will be sold and whether profits will be made.

- Low yield: During a VRU the expected production outcomes are in most cases lower than the actual production outcomes (see figure 14). A low yield, which is conceivable during the ramp up phase,
will result in a lower production output than was initially planned. The costs per final product will therefore increase.

- Too many or few products in line: During the ramp up, it is extremely difficult to determine the precise production volume since forecasting in this market is quite tough. Forecast inaccuracy will result in overproduction or unfulfilled orders. When not having enough products to fulfill the orders, the customer may decide to start business with other suppliers. And as stated above, in case of overproduction NXP MA will face the risks of obsolescence stock.

- Strict planning: NXP MA plans strictly; focusing on time-to-the-market increases the chance on early profits, but spending more time and money on the product to increase its reliability will exceed the budget.

3.4.2 Quality risks

- Unknown quality procedures of the customer: There is a discrepancy between the order and lead time and it turns out that at the moment of VRU, it is unknown whether the product meets the quality standards of the (potential) customer. So, there is a possibility that after the moment the products need to be ramped up to meet the demand, the product doesn’t meet the customer’s quality standards. Consequently, the products will not be bought.

- Integrated components are not tested and verified yet: At the moment decisions about the ramp up need to be made, integrated components are not tested and verified completely in order to make sure the product is validated against its predetermined requirements. After the moment the products have been ramped up, it may appear that the product doesn’t work or the quality of the product is substandard.

- Production and product problems: A heavy VRU carry production and product problems (as can be seen in figure 15) (product problems have been discussed above). These events endanger the final product quality. Besides, during the VRU, the globalized production flows have not proven to work properly and efficiently.

![Figure 15 – Quality risk 3 (derived from Fjällström et al., 2009)](image-url)
• Conditionally passing gates: it appears that NXP MA conditionally passes development gates. During the remainder of the project trajectory it is possible that NXP MA faces hiccups that actually may not arise when all gates were carefully checked.

3.4.3 Time risks

• Supply chain complexity: Many actors play a role in the internal supply chain of NXP. This makes the NPD process interdependent and good communication among the actors needs to be secured in order to achieve the desired process performance. Nevertheless, it appears that there are sometimes miscommunications or responsibilities are not well assigned, which will slow down the project.

• Capacity problems in the fab: NXP MA does not owe their own fab which means that it has to ‘buy in’ capacity. If NXP MA ‘books’ too much capacity for their VRU, it has to pay for this unused capacity. However, if NXP MA needs more capacity during the VRU it is possible that the fab is fully ‘booked’ by other users. This results in unfulfilled customer orders due to a lack of production capacity (the products will be finished too late). The management should carefully deliberate the advantages and disadvantages.

• Material shortcomings: The VRU at NXP MA is a global operation. The internal supply chain is complex and close communication about the planning is needed to guarantee the presence of enough material at each production location.

• Transportation risks: During the ramp up, the transportation is not proven to run smoothly which makes the VRU an uncertain process. These risks could result in a delay in lead time. An increased transparency will improve decision making during the ramp up.

• Unexpected hiccups: In case not all risks are identified, assessed and/or proactively managed, it is likely that a delay in market introduction will occur.

• Use of new (unreleased) production processes: Up to now this has not been the case. However, one of the respondents mentioned that it is important to take account for this risk, because the use of a new production processes will result in delay when it works insufficiently.

3.4.4 Customer satisfaction risks

• Late customer change requests: Since the product is not completely approved by the customer, it could happen that NXP MA receives late change requests from the customer while the mass production has already started. This will result in ‘good-for-nothing’ batches (one batch TFA9887 consists of approximately 8000 amplifiers) or in other words: superfluous goods and a waste of money. A risk management strategy should proactively respond to this risk which support timely ramp up related decisions.
• No previous relationship with the customer: Each customer is different and reacts differently on certain situations (like on delay or quality issues). This makes decisions about the ramp up very uncertain.

• Insufficient product alignment: NXP MA’s customer database is growing exponentially but there are limited resources available to support the customer design-in process. This will finally result in products that are not completely aligned with the customer (product does not function well in their devices).

• Forecast inaccuracy: NXP MA deals with the difference between the product lead-time and the time in which the buyer expects to receive the product (order time)(see figure 16). The product lead time is too long for a just-in-time production, which makes it very uncertain when and how much to ramp up. This statement was confirmed by all respondents (lead time is 16 weeks and the customer’s expected delivery time is around 6 weeks). As said before, when NXP MA fails in delivering the right amount of products to the customer, it might lose the order.

![Figure 16 – Customer satisfaction risk 4](derived from Fjällström et al., 2009)

The next chapter discusses the root cause for the inability of NXP MA’s management to take rational decisions related to the VRU phase.

3.5 Root cause analysis

Above, it has been explained what the uncertainties are that NXP MA faces concerning the VRU phase. All these uncertainties affect decision makers in choosing between strategic options. The business problem presented in chapter 1.4 has been validated now. However, every business problem has a cause, which needs to be identified in order to solve the problem. The minor effect that has been selected in order to find the root cause is ‘the lack of certainty for decisions makers to make rational decisions about the VRU’.

Interviewees that were closely involved during the last ramp up (6 in total) were the most valuable in this process. 67% of these interviewees mentioned several times that there was no structured risk management approach focused on VRU issues. Moreover, this risk management approach should provide scenarios to help decision makers with making a choice between strategic options. The
interviewees gave different reasons for why MA is not used to structured integrated risk management approaches. The other 33% of the interviewees only blamed the market situation. The problem mess has been structured in a cause and effect diagram shown in figure 17.

![Cause and effect diagram](image)

**Figure 17 – Root cause analysis**

The causes for the lack of certainty for decision makers on how to take rational decisions about the VRU, have a direct or indirect relation with the lack of structured integrated risk management approach and lack of scenario creation. Since a structured risk management procedures focused on VRU is a requisite for scenario creation is the lack of structured risk management procedures integrated in the business processes is regarded as the root cause for the business problem.

### 3.6 Direction for redesign

The redesign will be guided by relevant theories in the literature and findings from the internal analysis. The next chapter will focus on a redesign that is aimed to objectively evaluate VRU related risks. This design should be integrated within the NPD processes. Furthermore, the redesign should focus on increasing the actual level of visibility in various VRU risks by use of scenario creation.

**Chapter summary and conclusion**

The internal analysis revealed that NXP MA does not make use of a structured risk management approach to focus on risks specifically associated with the VRU. Nevertheless there are a reasonable number of risks related to time, quality, financial and customer satisfaction that influence VRU related decisions. The business problem that has been uncovered at NXP MA, is that the VRU is an uncertain phase of NPD within NXP MA and the management team is not able to take rational VRU related decisions. The root cause for this business problem is a lack of structured risk management procedures integrated in the NPD processes. The next chapter will create a VRU risk management approach that should be integrated in NPD processes, which will help NXP MA to objectively evaluate all potential VRU risks and to make rational decisions.
4. Redesign

The objective of this chapter is to design a structured approach to manage VRU risks, which in turn will help managers to take rational and appropriate courses of action related to the VRU. In order to accomplish this objective, first the requirements of the design are established to which the designed solution must comply. Furthermore, the following sub research questions will be answered: What can be learned from other organizations/industries that are also dealing with ramp up activities? How can NXP MA adjust their current way of working to achieve sustainable competitive advantage through a novel, useful and continuous VRU risk management process? And what are the benefits when applying risk management within NXP MA?

4.1 Design requirements

The designed solution has to fulfill several design requirements. By defining these requirements in advance, it will be easier to involve stakeholders during the creation of the business redesign. Moreover, the design is easier to evaluate. The design requirements are listed in table 6.

Table 5 - Design requirements

<table>
<thead>
<tr>
<th>Functional requirements</th>
<th>The redesign is intended to manage VRU risks that NXP MA faces during the introduction of their products.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The redesign will lead to effective and efficient risk management strategies by use of cross-functional teams.</td>
</tr>
<tr>
<td></td>
<td>The redesign should tell who to involve, when and how.</td>
</tr>
<tr>
<td></td>
<td>The solution should solve the perceived problem and the benefits should outweigh the costs.</td>
</tr>
<tr>
<td>Literature requirements</td>
<td>The redesign should address risk identification, risk assessment, risk response and risk control/monitor.</td>
</tr>
<tr>
<td></td>
<td>The redesign should include the possibility for scenario planning</td>
</tr>
<tr>
<td></td>
<td>The redesign should proactively deal with the risks involved</td>
</tr>
<tr>
<td></td>
<td>The success of the risk management approach should be assessed by KPI(s)</td>
</tr>
<tr>
<td>User requirements</td>
<td>The risk management approach should provide the user flexibility in following the prescribed actions.</td>
</tr>
<tr>
<td></td>
<td>The risk management should provide fundamentals for repeated use</td>
</tr>
<tr>
<td></td>
<td>The risk management approach should be incorporated as a continuous, systematic process within the business operations</td>
</tr>
<tr>
<td></td>
<td>The risk management approach should provide guidelines for a common language among the participants</td>
</tr>
<tr>
<td></td>
<td>The number and the degree of novelty of the tools, techniques and processes that support the design should be kept to a minimum</td>
</tr>
</tbody>
</table>
**Boundary conditions**

The solution must comply with all available regulations and laws in and outside the organization

There must be a fit with NXP MA’s policy, views and ethics

There must be no critical change to already existing strategies

**Design restrictions**

The redesign must have as low costs as possible

The redesign must not take many months to implement

The solution should also provide the possibility of later implementation

Design requirements help to make the solution work. Although defining requirements for a solution seems obvious, Van Aken et al. (2007, pp. 125) mentioned that “…in the heat of the project execution the requirements can be overlooked which can lead to problems for the justification of the solution […] or the realization”.

Functional requirements are performance demands on the risk management approach that will be designed. Requirements have been established after thoroughly analyzing the available literature. The user requirements are mainly based on the data obtained from interviews and are specific requirements from the user’s point of view. Boundary conditions are essential conditions that must be met, to allow the risk management approach to work out. Design restrictions are internal constraints to the intended solution.

The design requirements are not the only input for the final design. Before effort is spent on the creation of the final design, a benchmark is executed in order to find out what has worked well in other organizations, concerning a risk management approach related to VRU (identification of best practices). This benchmark will be discussed in the next section.

**4.2 Benchmark**

This section presents a benchmark and will be used as an additional attempt to design a new (improved) way to respond to VRU risks at NXP MA. Benchmarking is “the search for the best industry practices which will lead to exceptional performance through the implementation of these best practices” (Camp, 1989). There are two types of benchmarks: a benchmark related to products and a benchmark related to processes (Partovi, 1994). Figure 18 represents the successive steps of a benchmark process.

![Figure 18 – Benchmark steps](image)

A benchmark process costs a lot of time, money and other resources, and a certain focus on particular processes prevents inefficient analysis (Partovi, 1994). For the scope of this study, it has been determined to focus on risk management concerning the VRU phase of newly introduced products. According to Holtzman (2011), focusing on tools, processes and people will help to identify activities
with added value for the organizations. Based on this statement, the benchmark will specifically focus on tools, processes and people that are concerned with VRU risk management. Once the focus has been selected, practices which lead to outstanding VRU performance are discussed and compared with NXP MA practices. The next subsections are guided by the steps described in figure 18.

### 4.2.1 Benchmark partners

There are different ways to select strategic benchmark partners. The first way is to benchmark within the organization (Partovi, 1994). Following this advice, the best-performing units within NXP should be selected. Despite NXP is a large organization where PLs work separately in achieving their targets, it is unnecessary to ‘reinvent-the-wheel’. However, due to time constraints, it was not possible to figure out which PLs in NXP were the best-performing units concerning VRU risks management. Therefore, four randomly selected VRU managers from other PLs within NXP have been interviewed to benchmark the situation (these interviews has also been used in supporting the discussion about risks and VRU related decisions in chapter 3).

Another way for selecting a benchmark partner is to benchmark a competitor. However, this is rather difficult since competitors are not likely to agree on sharing information. With the result that key information could be missing (Partovi, 1994). Therefore, a competitor has not been selected for the benchmarking process in this study.

The last potential partner for benchmarking processes can be any organization in any industry engaged in the same type of activities as the focal company (Partovi, 1994). Within this study, there are two types of organizations that are of interest in this study: first an organization that is operating in the FMCG market, second an organization that is operating in the fashion market. Why these organizations have been selected will be discussed in chapter 4.2.2.

#### 4.2.1.1 Data collection

This study uses multiple sources of evidence to obtain data for the benchmark. To be more precise, this research collected data by using presentations, documents, scientific papers and semi-structured interviews. Four semi-structured interviews have been conducted with VRU managers (described in chapter 3 as category ‘VRU experts’). These experts are not involved in activities of NXP MA but are working for another PL within NXP. Due to time limitations, only 1 interview with an operation manager working in the FMCG has been conducted. Unfortunately there was no response from the organizations within the fashion industry that were approached; therefore information from this branch is only based on documentations and scientific papers.

Due to confidentiality reasons, the FMCG organization participating in this study is not called by name; therefore it has been decided to use surrogate names for all benchmark partners (see appendix E table 1).
4.2.2 External and internal situation analysis
The external analysis discusses the corresponding characteristics of the situation of the benchmarked organization and of NXP MA. The situation is described by characteristics that are typical for the relevant market and its products. Appendix E table 2 represents the common characteristics.

The internal analysis examines the strengths and weaknesses of the internal operations of all organizations in the study. As mentioned earlier, the focus of this analysis will be on risk management concerning the VRU phase of newly introduced products. Due to the objective of the benchmark within this study, only the strengths of VRU risk management are treated. The internal analysis will provide additional insights for a structured VRU risk management approach at NXP MA. The results are listed in appendix E table 3.

4.2.3 Comparison analysis and identification best practices
After analyzing the internal and external situation, the interviewees were informed about NXP MA’s situation. Respondents were asked for specific actions that they thought could contribute in rationalizing VRU decisions (see table 7). Some of these actions are supported within the literature as well.

Table 6 - Suggestions from benchmark partners

<table>
<thead>
<tr>
<th>Best practices</th>
<th>Argumentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Create cross-functional teams (Bench5)</td>
<td>Within the fashion industry it has been noticed that cross-functional teams are important when decisions regarding the start of mass production need to be made (Christopher et al., 2004). Process alignment during this NPD phase is critical to increase the transparency in the project and it should be assured that different entities are connected. This can be achieved by creating cross-functional teams that allow geographically and functionally dispersed organizations to operate as if they were one business (Christopher et al., 2004). Cross-functional teams enable a holistic perspective during start mass production and this helps the organization to breach functional ‘silos’ and start a greater degree of cross-functional working. Besides, Tidd et al. (2005) argue that cross-functional teams increase the flexibility and creativity to the solutions developed with respect to individuals.</td>
</tr>
<tr>
<td>Assign a special VRU risk manager/facilitator who is responsible for the execution of the tasks (Bench1, Bench2, Bench3)</td>
<td>The most outstanding difference between PLs with a VRU manager and NXP MA (without a VRU manager) is the task of one person to make the VRU a success. This person is responsible for a smooth communication and coordination of risks. It appears that learning from previous VRU risks helps to identify, assess and response during other VRU situations. The VRU risk facilitator should be assessed by use of KPIs in order to let him/her feel responsible for the achievements. However, there is no agreement within NXP about which KPI suits the assessment of a VRU manager best. Both interviewees of Bench1 suggested to start a discussion together with all PLs who are interested about establishing a business wide accepted KPI for VRU.</td>
</tr>
<tr>
<td>Allow individual risk</td>
<td>To increase the risk awareness and prevent negative effects of group discussions, it is preferred to ask all project team members individually what they consider as risky during</td>
</tr>
</tbody>
</table>
### Assessment (Bench4)

The start of mass production. In Bench 4, more crucial risks were tackled when team members were able to assess the risks individually. This point was also addressed in the literature by Keizer et al. (2002), who stated that people sometimes hesitate to identify/report risky factors within a group discussion when leaders (or higher positioned colleagues) have different views.

### Make Use of Scenario Planning (Bench4)

Scenario planning asks the team to question all possible outcomes, once the risks have been assessed. This contributes to conscious decision-making. These scenarios all contain risk profiles and therefore enable evaluation of strategic options between the scenarios. Scenarios are based on a specific amount of variables. Within this company it appears that scenarios work out well for providing financial planning information.

### Start with Engaging in VRU Activities Just Before the Project Arrives the S-Gate (Bench 1, 2, 3)

To stay aligned with SAVR gates during NPD at NXP (see chapter 1), bench 1, 2 and 3 advice to start engaging in VRU risk management just before the S-gate. The first step of this process will be a VRU quick scan. During this scan, ramp up risks are estimated based on factors like the involvement of one of NXP’s key customers, high diffusion, test or assembly capacity demands and new processes or production flows. This quick scan indicates the need to identify a VRU team that should put more emphasis and support in place, and assists with the coordination and resolution of ramp-up issues. After the S-gate has been successfully passed and the VRU quick scan has shown that a VRU team is needed, the VRU meetings should take place on a regularly basis, in accordance with the stage in which the project is situated.

---

All these five best practices are assumed to be relevant to the final design. The design will fulfill 95% of the design requirements listed in table 6. There is one design requirement that will not be included into the design and that is the literature requirement related to assessing the risk management approach with KPI(s). During the benchmark it appeared that there is no consensus within NXP about which KPI suits the assessment of a VRU manager best and additional meetings are needed to determine suitable KPIs. The next chapter will suggest a design of a new (improved) way to mitigate supply chain risks for NXP MA.

#### 4.3 The Final Design

VRU risk management within NXP MA should no longer clean up after risks have unfolded, but instead it should be integrated with the NPD process. This section proposes a design which helps NXP MA to take rational decisions on VRU related topics. The inputs for the final design are an extensive evaluation of the literature about risk management and VRU, and an extensive internal analysis. To support a redesign, NXP MA will require an efficient and effective tool that is used by its people and is integrated in the NPD process (see figure 19). This chapter will start with the creation of a tool since this is expected to function as a primary attempt to drive processes and motivate people. Besides it is the less difficult part of the redesign to start with. It should be noticed that within the final design the relationship between the tool, process and people is interdependent (see figure 20). The next subsections will describe each design component.
4.3.1 Tool
A VRU risk approach needs the investments of time and other resources and therefore, it is important to first determine the necessity for a project to make use of the VRU risk approach. The project leader of a NPD project should fill-out a VRU Quick Scan just before passing the S-gate. This VRU Quick Scan is a tool available for every PL within NXP. In cases of high risks, the Quick Scan indicates the need to identify a VRU team which puts more emphasis and support in place. Furthermore, this team will assist with the coordination and issue resolution of ramp-up issues.

As discussed in the literature, the successive steps for risk management during VRU are as follows: risk identification, risk assessment, risk response and risk control/monitoring. Continuous learning and improvement is an ongoing effort in this framework and will be part of the process. The Risk Diagnosing Methodology (RDM) (developed by Keizer et al., 2002) has proven to be an effective project risk management tool for any organization to systematically manage its risks. Despite the RDM is initially developed to manage project risks, VRU management resembles project management and therefore it has been assumed that the RDM is also applicable for VRU risks (see chapter 2). The RDM will be used as a fundament for the tool created in this study. The RDM covers all elements that are of importance for the VRU and provides clear steps for a project team to deal with project risks. Moreover, the RDM could function as foundation for scenario planning. However, the content of the steps as described by Keizer et al. (2002) will be, to some extend, deviated from the content described in this section to allow for application in the case context. The steps are shown in figure 21.
### Figure 21 – VRU risk management tool

Figure 22 represents where steps should take place in the development project.

| Step 1: Initial briefing between project leader and risk facilitator (VRU) |
| Step 2: Kick off meeting with project manager, VRU team and risk facilitator |
| Step 3: Individual interviewing of the team by risk facilitator |

### Risk Assessment

| Step 4: Development of risk questionnaire by risk facilitator |
| Step 5: Answering of risk questionnaire by participants |
| Step 6: Constructing of risk profile by risk facilitator |

### Risk Response Strategy

| Step 7: Preparing of risk management session by project manager & risk facilitator |
| Step 8: Risk management session: project manager & team and risk facilitator |
| Step 9: Drawing up & execution of PDCA cycle [CONTROL – MONITOR] |

Step 10: Scenario creation

---

**Figure 22 – Timeline VRU risk management steps**

There was also a possibility to develop an extended version of the FMEA (FMEA which included VRU processes). However, the FMEA fails in providing clear steps for the team to take. Furthermore, it does not allow for individual risk assessment. This study stresses the importance of individual assessment.
because ‘risk’ is considered to be a social construct. Nevertheless, the FMEA will be an important input for the RDM (discussed in step 3). The following subsections will discuss the content of each step.

**Step 1: Initial briefing between project leader and risk facilitator (VRU)**

The risk management approach is directed by a risk facilitator. The risk facilitator acts as an independent, neutral agent and is responsible to independently merge different viewpoints. Because the project leader is highly involved in all development steps, it is unlikely that the project manager takes on this role. The general management team should appoint the activity of the risk facilitator that can be fulfilled by either an internal representative from the BL who is not the project leader, or an external person with state of the art knowledge (Keizer et al., 2002).

In some PLs (BLs) within NXP, this facilitator is called ‘VRU manager’ (function). However, NXP MA does not have a special VRU manager at their disposal. Nevertheless, NXP MA is growing and it might be feasible to hire a special VRU manager in the future; in this case he/she will be the one that is appointed as risk facilitator.

The initial briefing takes place between the risk facilitator and the project leader after the project passed the S-gate. This meeting is meant to make necessary appointments and it should cover both general and project related topics (Keizer et al., 2002). General topics include how information about VRU issues will be made available to the risk facilitator, when and where the VRU meetings take place and how the VRU team is kept informed about the actual status of the process. Project related topics include the current development situation, its stakeholders, and uniqueness (Keizer et al., 2002). The meeting is also meant to determine who should be in the VRU-team. To be effective, the risk assessment method should identify potential risks in the following domains:

- Demand & customer
- Delivery situation
- Semiconductor design data input
- Diffusion process
- WT 1
- Assembly
- WT 2
- Packaging

For each of this domain, the risk facilitator and project manager assign a risk representative. It is possible that one risk representative will be assigned to more domains. Furthermore, it must be noticed that risk representatives for the different production steps (4 – 8) are only needed in case these processes are ‘new’ and have not been released yet. Otherwise the BU capacity planner is responsible for the identifying the risks for these domains.

The project leader has the responsibility to keep close contact with the product development team to ensure smooth and rapid resolution in case of any issue. The project manager has the responsibility to
facilitate the cooperation between the VRU team and development team, since he/she is also responsible for the FMEA. Other experts/specialists will be invited to the team when necessary (based on the FMEA). The output of this step will be as follows: agreements between the project manager and the risk facilitator on activities to be taken, and the final composition of the VRU team (Keizer, et al., 2002). Before proceeding to step 2, the VRU team should receive an invitation for the kick off meeting.

**Step 2: Kick off meeting with project manager, VRU team and risk facilitator**
The risk facilitator leads this meeting and he/she makes sure that the VRU-team knows what to expect during the risk management process. It must be clear for the VRU-team members how much time they could expect to spend on the risk management approach, their level of involvement and the degree of confidentiality of the risk identification and assessment phase (Keizer et al., 2012). After the kick off meeting, the risk facilitator needs to make appointments with all VRU team members for an individual interview.

**Step 3: Individual interviewing of the team by risk facilitator**
Individual interviewing of the team starts when the A-gate is passed (or will be passed within two week). This step is aimed to get a comprehensive overview of potential risks that could hinder a successful VRU. It is prudent to start the interview session with the project leader (Keizer et al., 2002). He has the best overview of the product to be developed and the process of its development.

The input of the project leader during the interview is an executed FMEA analysis. The FMEA is the analytical methodology used in NXP for evaluating and minimizing risk in all areas of NPD (focused on design, test and reliability). However, from the internal analysis it appears that NXP MA does not adequately execute the FMEA and therefore the risk facilitator should put pressure on the project leader to get the FMEA on time. The project leader can make use of a failure mode shopping list in order to identify risks that could hamper the planning of the VRU. This list is provided by NXP and is accessible for all project leaders within NXP. Lessons learnt from different VRU teams are shared via this failure mode shopping list and represents common failure modes that could hinder the VRU.

After the project leader has expressed its concerns in the FMEA, all other VRU team members need to describe what they see as the riskiest aspects of the VRU phase. Interviewing these other members will prevent asymmetry of data and increases the transparency of the risk identification phase. It is important to uncover what is new in this project and determine its impact is on the VRU.

**Step 4: Development of risk questionnaire by risk facilitator**
After the risk facilitator has interviewed all VRU team members, the risk facilitator analyzes the risks and puts together the critical issues grouped under the following dimensions: financial, customer satisfaction, quality and time. Afterwards, the risk facilitator’s task is to design a risk questionnaire in which critical issues are translated into positive statements of “objections to be realized” (Keizer et al., 2002). Positive framing of risk prevents that members accept the risk too easily (Keizer et al., 2002). After the issues have been worked out, the project manager verifies whether all issues are well understood and correctly formulated (Keizer et al., 2002).
Step 5: Answering of risk questionnaire by participants
When all risks have been identified, the VRU team members are asked to individually assess the risk issues developed in step 4 on three five-point-Likert scales (as stated by Keizer et al., 2002):

1. The probability that the risk unfolds. Guidelines for the score are given in appendix F table 1.
2. The ability of the team to reach an appropriate solution using the project’s allotted time and resources. Guidelines for the effects are given in appendix F table 2.
3. The risk impact on the VRU when it unfolds. Guidelines for the effects are given in appendix F table 3.

Respondents are asked only to assess issues on which they have an idea / opinion. An important notice is that this document is different than the FMEA, since the FMEA does not allow for individual assessment of the risks.

Step 6: Constructing of risk profile by risk facilitator
After completion of the questionnaires, the VRU risk facilitator constructs a risk profile from all the scores (Keizer et al., 2002). The risk profile for each specific risk presents to what extent the respondents perceive the statements as risky. In addition, the risk profile should show the distributions of all members’ feelings (Keizer et al., 2002).

The risk statements are classified along the parameters defined by Keizer et al. (2002):

- “*”: at least 50% of the scores are 4 or 5 and there are no scores of 1
- “0”: at least 50% of the scores are 1 or 2 and there are no scores of 5
- “m”: at least 50% of the scores are 3 and there are no scores of 1 or 5
- “?": remaining cases where there is a lack of consensus due to a wide distribution of opinions.

There are in total 64 possible combinations of risk scores on each risk statement (e.g. “0,0,0” or “m,?,m”). The final risk score for a certain risk statement is based on the method developed by Keizer et al. (2002) and can be consulted in their article.

Step 7: Preparing of risk management session
The project leader needs to confirm the risk profile of the upcoming VRU. Furthermore, the project leader agrees with the risk facilitator on the points of discussion during the session with the VRU team.

Step 8: Risk management session
The risk management session aims to efficiently achieve agreements among the VRU team members on action plans for dealing with the VRU risks (Keizer et al., 2002). During this session, the VRU risk profile will be shown. After clarification of the risks and discussion about how to approach these risks, the team decides which actions should be taken and by whom. In the end of this session, the risk facilitator makes clear what is expected of the VRU team. The next VRU meetings will have a fixed agenda that can be conducted in appendix G. A fixed agenda helps the team with a structured way of dealing with the VRU
phase. Keeping members up to date during the VRU meeting avoids suspicion, misunderstandings and inefficient work.

**Step 9: Drawing up & execution of PDCA cycle**
The second last step has one important deliverable: PDCA plans (plan, do, check, and act). In addition to the risk assessment results and the risk management session outcome, the PDCA plan is a recurring action plan to check on the main risks, the contingencies and the progress on actions.

**Step 10 Scenario planning**
The last step, scenario planning, enables the management to decide upon start of the VRU. Scenario planning will make decision makers aware of all possible outcomes, pros and cons. The VRU is a decision driven platform and designing scenarios is particularly useful since it allows for evaluation of decisions that need to be made in a short term, but have long term consequences (Hilletofth and Eriksson, 2011). Moreover, scenario planning will help to prepare for events in the future.

This step should take place after all potential risks have been assessed and the market pressure to deliver the products is high. The decision driven scenarios should contain an evaluation of strategic options. The VRU decision should be based on the pay-off across the different scenarios. Scenario plann creation can work according to the following method:

- The risk facilitator generates a limited number of scenarios, taking into account the risk assessment results, risk management session outcome and the PDCA plans. Obviously, the VRU risks should be well-documented and validated which makes the situation clear for decision makers. All scenarios should at least give insight in the following points:
  - Time (Do we get the products on time? Do we get the volume?)
  - Quality (Do we get the right products?)
  - Finance (Does the VRU bring extra costs? What is the chance for obsolescence stock?)
  - Customer satisfaction (Can we serve the customer as expected?)

- For each generated scenario, the potential financial losses should be determined to allow quantitative analysis for decision-making (Ellis, 1966). Table 8 presents a proposal for scenario creation related to the start of the VRU phase.

<table>
<thead>
<tr>
<th>Kind of risk:</th>
<th>Quality</th>
<th>Customer satisfaction</th>
<th>Financial</th>
<th>Time</th>
<th>Potential financial losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start VRU</td>
<td></td>
<td>“Scenario option”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postpone VRU</td>
<td></td>
<td>“Scenario option”</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4.3.3 Process
The tool that has been designed in chapter 4.3.1 will only lead to VRU performance improvement when it is systematically integrated in the current product development system (as has been shown in figure 22). Systematic VRU meetings improve the input for the scenarios and decision-making. Furthermore, it identifies risks early in the NPD process, which allows for a timely response strategy. With regard to market pressure, decision makers may be led to greater use of intuitive decision-making, which diminishes the quality of decision-making. A systematic approach executed well before the VRU phase actually starts, prevents this situation.

The frequency of explicit VRU meetings will increase when the project proceeds. When the project has passed V-gate and step 1-8 has been fulfilled, the frequency of the VRU meeting will increase to once a week. This increase in frequency will ensure that the risk facilitator keeps up with the risk owners to plan actions (step 9). With the exception of the risk management session as described in step 8, each VRU meeting will have a standard agenda which makes it clear for the team members to follow the VRU progress. An agenda proposal for VRU meetings is represented in appendix G.

Another important process is to gain risk knowledge at the end of each VRU. The evaluation of effectiveness of the applied risk response strategy and the appropriateness of the scenarios should be stored in order to learn in future innovation projects. Furthermore, the project leader should take the responsibility to update the risk shopping list (used in step 3 after each VRU).

4.3.4 People
The most difficult part of implementing the redesign is probably convincing the people that are involved to actually make use of the tool and comply with the tasks that need to be executed. While the tool and the related processes are critical for the VRU risk management, the involved actors are the building blocks for successfully executing VRU risk management. Using the tool and introducing it in the NPD process seems simple to accomplish, however without support of the actors involved it is difficult to achieve. The implementation plan (discussed in chapter 5) summarizes points of attention to secure user acceptance. However, before putting effort on such an implementation plan, the design must be validated first. The next section has the objective to discuss the validity of the design.

4.4 Validity of the design
This section will discuss the validity of the introduced VRU risk management approach and the objective is to figure out whether the design enhances the VRU performance, and helps decision makers to take appropriate courses of action regarding the VRU. The validation of the design has been split up into two parts. First, the design requirements have been evaluated against the content of the final design. In
appendix H it is demonstrated whether and where in the design the relevant requirements are fulfilled. As can be seen, only the design requirement related to assessing KPIs are not covered in the design. Second, users of the approach were asked whether the design meets several dimensions of user satisfaction adopted from Muylle et al. (2004); (relevancy, comprehensibility, comprehensiveness and ease of use). Unfortunately, these ways of validating the design does not involve the performance of the model. However, it gives at least insight in the appropriateness of the model.

4.3.2 Benefits of the VRU risk management approach
The benefits of using this approach are diverse. First of all, by use of a cross-functional VRU team, diverse disciplines are bridged which increases the visibility on the potential risks. Moreover, it improves the creation of innovative solutions within NXP MA. Second, the approach allows for the creation of an aligned plan to pro-actively mitigate VRU risks before they become reality and damage the relation with the customer. It enables NXP MA to anticipate on risks and prevent issues during ramp-up. Third, it creates increased insight in the strategic options that NXP MA has regarding the VRU. Fourth, when making someone responsible for the VRU risk approach, the management indirectly puts pressure the execution of the FMEA. This could also benefit the overall project risks. Last, it supports decision makers to make rational decisions by use of quantitative comparison between different scenarios.

4.6.2 User satisfaction
The design has been validated by the several dimensions of user satisfaction adopted from Muylle et al. (2004). Potential users were asked whether the design is relevant, comprehensible, comprehensive and easy to use. Comments of these potential users will contribute to the validation of the design and can be consulted in table 8.

Table 8 - Design validation

<table>
<thead>
<tr>
<th>Dimension of user satisfaction</th>
<th>Explanation</th>
<th>Findings</th>
</tr>
</thead>
</table>
| Relevancy                     | The design meets the need of the users and could be used to solve the initial problem (Muylle et al., 2004). | -Design will give structure to the VRU process in NXP MA which will enhance the rationalization of VRU decisions.  
-Responsibility of the VRU risk facilitator to create scenarios will increase the transparancy of the VRU and thus enhances rational decision-making. |
| Comprehensibility             | Comprehensibility means that the design should be easy to understand for everyone that would use it (Muylle et al., 2004). | -A methodical approach to structure the VRU risk management makes it easy to understand which different steps need to be taken.  
The approach describes where in the NPD process one should execute the different steps. This is important to assure the information to complete the steps is available. |
Comprehensiveness  The design is complete and no crucial information/steps have been left out (Muylle et al., 2004).

- The design has not been implemented yet and therefore, potential users gave advice to execute an extensive evaluation of the tool after it has been used.

Ease of use  The design is perceived as user friendly (Muylle et al., 2004).

- The design clearly explains when and which steps need to be taken.
- The explanation of the different steps increases the understandability of the design which will benefit the use.

Chapter summary and conclusion
The final business design has been created after an extensive evaluation of the literature, an all-embracing internal analysis at NXP MA and a benchmark with strategic partners. Design requirements were established to which the designed solution must comply. When NXP MA wants to make rational decisions related to VRU issues, they would do well when they implement a special risk management tool focused on the VRU. The tool is based on the RDM developed by Keizer et al. (2002) and will only lead to VRU risk performance improvement when it is integrated by NXP MA’s current NPD processes. People have a crucial role in this process since using the tool and introducing it in the NPD process seems simple to accomplish but without support of the users it is difficult to achieve successful outcomes.

The design has been validated in two ways. First, the design requirements have been evaluated against the content of the final design. Second, potential users were asked whether the design meets several dimensions of user satisfaction; relevancy, comprehensibility, comprehensiveness and ease of use. Both methods are not intended to evaluate the performance of the model, still it gives insights in the appropriateness of the model.

Now the design has been created and validated, the next chapter will present a plan for the implementation of the redesign at NXP MA.
5. Implementation plan

In this chapter, a proper implementation plan for the design described in the previous chapter is discussed. Unfortunately, time pressure on the master thesis execution prohibited an actual implementation of the design. Therefore, the implementation plan will focus on what has to be done when time for implementation has come. First, it will be established in which project the approach will be implemented. Second, key actions for implementation will be discussed. The chapter will finish with the identification of potential implementation pitfalls.

5.1 Project selection

The redesign is integrated within the NPD processes of NXP MA. This NPD process is guided by the SAVR gates and therefore it is plausible to select a project that needs to pass the S-gate. The first implementation of the redesign is a NPD project, TFA9897, which will pass the S-gate within four weeks (week 29, 2013).

As the design in chapter 4 prescribes, the first attempt of the VRU risk management implementation is the execution of the VRU quick scans. The timeline of the remaining steps can be consulted in figure 22.

5.2 Key actions

Employees need to realize that the VRU risk management approach adds value to the business operations and that it’s not just another way of reporting. Figure 23 displays what needs to be done in order to successfully implement and execute the VRU risk management approach. The insights are obtained from discussion with potential users and supported by scholarly articles.

![Figure 23 - Implementation plan](image)

Below, each step will be briefly discussed.

- First, ensure management commitment (Jackson, 2001). The resources that NXP MA needs to invest when putting VRU risk management practices into action are clear and immediate, however the potential revenues are perceived as unclear and hard to quantify. Management commitment is an essential element in implementing the tool, because users have the responsibility to justify their tasks. Management commitment should be visible for users in order to commit users to the use of the tool. Jackson (2001) argues that management commitment is a first requisite when implementing a new management approach. A first attempt to management commitment is the integration of the tool within the NPD business operations.
Second, it must be clear who owns the VRU process. The management should decide who is responsible for the final VRU results (this person will be the risk facilitator). The risk facilitator will be assessed by use of a KPI, which prevents a lack of accountability of the risks they take on behalf of their organization. However, a suitable KPI has not been found yet. Before the management decides to implement the tool, they should, together with the VRU risk facilitator, plan a meeting to agree on which KPI fits best. Everyone involved in the newly introduced VRU risk approach should have the same idea about what is expected and what their role is (Ahuja and Khamba, 2008).

Third, provide training and education. Users may believe that an early integration of VRU activities in the NPD process unnecessarily slows down the process or unnecessarily spends resources, because it increases the amount of effort required to move along the NPD phases. Education will help to show that the tool is meant to ultimately reach the customer faster with higher quality levels. Furthermore, the management should provide a FMEA-training for all project leaders. The internal analysis showed that the FMEA is not adequately executed, while the benchmark has shown that the FMEA is an important input for the management of VRU risks. Training could help to overcome problems with the FMEA.

Fourth, celebrate success. During the execution of the business redesign, it is important that participants are kept informed when the team has achieved success. Publicizing successes on a consistent basis keeps people motivated (Jackson, 2001). An example for success is following the timetable successfully.

5.3 Implementation pitfalls
The implementation of such a tool requires effort, and various obstacles must be overcome (Al-Mashari and Zairi, 1999). The diverse pitfalls that could hamper a successful implementation have been classified as organizational, behavioral, content driven and financial:

Organizational pitfalls
- Inability of management to implement the VRU risk approach
- Inability of management to convince employees about the added value of the approach
- Lack of awareness of VRU risk management approach among NXP MA’s employees
- Inability of management to assess the VRU success by use of KPIs
- Inadequate effort to stimulate employees to educate and learn about the new approach

Behavioral pitfalls
- Stubborn attitudes from employees regarding a newly introduced approach
- Employee’s resistance to adapt the new approach
- Low motivation and effort input towards the methodological approach

Content driven pitfalls
- Inefficiencies found in using the tool leading to poor execution
- Incorrect execution of risk facilitator tasks which endanger desired outcomes

Financial pitfalls
- Absence of financial reward for employees when using the risk management approach
- Requirement of extra resources during the implementation of the approach

*Chapter summary and conclusion*

The design will be first implemented in the NPD project called 'TFA9897'. The implementation plan has figured out what has to be done before this project will pass the S-gate. These key actions are: 1) ensure management commitment 2) it must be clear who owns the VRU process 3) provide training and education and 4) celebrate success. During the implementation, the management should be aware of four potential pitfalls: organizational, behavioral, content driven and financial.

The next chapter will present the conclusion, recommendations and reflection of this master thesis.
6. Conclusions, recommendations and reflection
The conclusion of the master thesis and the recommendations for NXP MA will be presented in this chapter. A reflection on the content and execution of the project will be given at the end.

6.1 Conclusions
The VRU phase at NXP MA faces uncertainties and this recognition has made NXP MA acutely aware of the absence of formal approaches to deal with this situation. The objectives of this study were “To create knowledge about risk management and VRU risks in order to improve VRU related decisions” and “To design an approach that will help NXP MA with making rational decisions with regard to the VRU.” The research question that has been answered in this master thesis was:

“What are the basic characteristics of a specific risk management approach for VRU problems at NXP MA caused by the company’s market situation?”

The VRU phase is a decision driven platform and the internal analysis addressed the need for an organizational design that allows NXP MA’s management to take more rational decisions with regard to the VRU (when and how much to start production). An important finding in this study is that critical activities defining the success of the VRU should take place long before this phase is actually reached. Therefore, it is essential that NXP MA VRU risk management approach is integrated in the NPD process. This will allow NXP MA to diagnose thoroughly and systematically all VRU risks a project faces, and how to respond pro-actively to those risks. The VRU risk management approach designed in this project focuses on VRU risk identification, VRU risk assessment and VRU risk response. A cross-functional team should take account for these steps. When decisions with regard to the VRU need to be made, the general management can ask the team to create scenarios based on quality, customer, financial and time related risks. Team members have a crucial role in achieving success; using the approach and introducing it in the NPD process seems simple to accomplish but without support of the team members it is difficult to achieve the objective.

The benefits of the VRU risk management approach are diverse. First of all, a cross-functional VRU team bridges different disciplines, which increases insight in potential risks. Second, using the approach allows for creating an aligned plan to pro-actively respond to VRU risks before they become reality and damage the relation with the customer. Third, the approach allows NXP MA to anticipate on risks and prevent issues during ramp-up. Fourth, attention for VRU risks put pressure on the execution of the FMEA. This benefits the risk management procedures during the execution of the project. Last, the approach supports decision makers to take appropriate courses of action by the use of scenario planning.

Unfortunately, implementing the risk management approach and redesigning the business operations has an important limitation; it is clear that NXP MA needs to invest when putting VRU risk management practices into action, but the potential revenues after implementation are unclear and hard to quantify. This makes it difficult to evaluate the success of the risk management approach based on the relation between cost input and gain output.
6.2 Recommendations
First, NXP MA is recommended to take the following actions in order encourage a successful implementation of the VRU risk management approach; First, ensure management commitment. NXP MA is recommended to implement the structured VRU risk management approach for every NPD project of NXP MA that will pass the S-gate. The first project (TFA9897) will pass the S-gate within 4 weeks (week 29, 2013). This is the first project in which the approach can be applied. Second, assign a VRU risk process owner. NXP MA is a growing PL within NXP it is likely that the amount of VRUs will increase. The VRU needs specific expertise and it is advisable to hire a special VRU manager that has the time and responsibility to lead all risky VRUs. The learning effect to lead a VRU risk approach will be stronger. Moreover, the exchange of knowledge between the different VRU teams will be more efficient. Third, provide training and education on both the FMEA (to control project risks) and the designed VRU risk approach. Fourth, after the implementation of the approach it’s important to celebrate success. Publicizing successes related to VRU on a consistent basis keeps people motivated. Last, NXP MA is recommended to review the approach after each individual VRU. It is possible that market of company circumstances changes which causes the need for a different or adjusted approach to VRU risks.

During the implementation, the management should be aware of four potential pitfalls: organizational, behavioral, content driven and financial.

6.3 Reflection
This part will reflect on the results, scientific relevance, way the project has been executed, limitations of the project and will finally deliver suggestions for further research.

6.3.1 Results
The objective of this master thesis was to provide a comprehensive overview of VRU risks and supply chain risk management, in order to improve VRU related decision-making. This objective was achieved by designing an approach that helps NXP MA with taking rational and appropriate courses of action during the VRU. Unfortunately, the design has not yet been implemented in the period in which this research was conducted. This made it impossible to evaluate the performance of the model and to assess the implementation plan. However, the model has been validated by two qualitative approaches which represents the appropriateness of the model: 1) the design requirements have been evaluated against the content of the final design 2) potential users were asked whether the design meets several dimensions of user satisfaction: relevancy, comprehensibility, comprehensiveness and ease of use. After the model has been implemented, NXP MA should evaluate whether the design solves the business problem.

6.3.2 Scientific relevance
There is a lack of research with regard to VRU risk management. Many organizations are involved in VRU risks and research in this phase of a NPD project should become more elaborated. This master thesis is a first attempt in closing the gap by introducing a structured risk management approach during the VRU at NXP MA. Two types of contribution can be distinguished:
The first type of contribution to the existing literature is the confirmation from the semiconductor industry that identifying, assessing, controlling and monitoring VRU risks affect decision-making in a positive manner. This confirmation has led to the need for a specific VRU risk management approach which increases the attention of VRU risks within the organization. Because VRU risk management requires specific expertise, the VRU risk management approach cannot be covered by project risk management.

The second type of contribution to the existing literature is the application of a well-known risk management technique (RDM) (developed by Keizer et al., 2002) into a new context. The RDM is used as guidance during the development of the VRU risk management approach. RDM provides clear steps that the team should take when dealing with risks. Besides, it has been argued that the RDM could function as a functional foundation for scenario planning.

6.3.3 Project execution
After 1 year preparation time, the master thesis project took 5 full-time months to complete. The research has taken place at NXP MA in Nijmegen. This possibility enlarged the communication with NXP which makes it easier to get insight into the business problem. Besides, NXP MA’s employees were willing to help whenever the research needed input. Therefore, the execution of the project ran smoothly. Unfortunately these five months were too short for the actual implementation of the design.

6.3.4 Limitations
This study entails certain limitations and therefore the results should be interpreted cautiously. First, this study has made use of qualitative approaches to obtain data; more specifically this study encompasses semi-structured interviews. The quality of the interviews is depended, among others, on the skills of the interviewer. Moreover, the analyses of the interviews are involved with the assessment and interpretation of different thoughts and opinions from a variety of stakeholders. Second, the research includes a limited amount of interviewees (19 in total). Some people that could have been of particular interest for this study were not involved due to time limitations or due to lack of importance recognition. Third, the personal nature of the interviews makes it difficult to generalize the results. Fourth, this study has made use of a case study methodology to move along the regulative cycle described by van Strien (1986). The insights of this study are therefore related to specific circumstances.

6.3.4 Suggestions for further research
Suggestions for further research have three directions. First, it is recommended to examine the design proposal in more detail, especially on the scenario planning. Specific quantitative research on the content of the scenario planning phase will improve the quality of decision-making. Second, the model should also be validated in another context. The results should be reflected upon and compared to other cases to create a wider support for the design. This direction requires moving away from the context of NXP MA. Third, further research should focus on whether the model, and especially the combination of risk management with scenario planning, is also appropriate to rationalize other project related decisions. This direction requires moving away from the context of ‘VRU risks’.
Reference list


Yin, R. (1994). *Case study research-design and methods*. Thousand Oaks; CA Sage

**Company documentation**
NXP (2013). VRU Cookbook

NXP (2012a). Foundation of project execution

NXP (2012b). NXP Process map

NXP (2012c). Product document TFA9887

**Company website**
NXP Semiconductors N.V.: [www.nxp.com](http://www.nxp.com), internal website, consulted between 01-02-2013 and 31-06-2013
Appendices

Appendix A

**Diffusion:** At the diffusion process, new thin layers are baked on raw wafers (sliced from crystal silicon ingots) by use of diffusion furnaces, high-pressure oxidation, and rapid thermal processing (NXP, 2013). The total process consists of 300 to 400 steps that take place at the foundries/waferfabs.

**WT1:** The WT1 stands for the first wafer test. Each finished wafer contains several thousand of dies (for the TFA9887 this is 8000). Each die will be tested before the complete wafer is placed into the die bank. This is done by use of probe testers which uses needle-like ‘probes’ to connection points on the die to check its functioning. Dies that fail the test are marked with a dot (meaning rejected). After the WT1 the wafers are ready for retention bake or stored in a die bank (the die bank is a kind of stock location).

**Assembly:** The assembly phase concerns individually packaging of the semiconductors. There are different forms of packaging which prevents the semiconductor from physical damage and corrosion. The package supports the semiconductor to get connected with a circuit board.

**WT2:** The WT2 stands for the second wafer test. Dies that fail the test are marked with a dot (meaning rejected) and the final yield will be determined during this test.

**Packaging:** This final step concerns the packaging of semiconductors in large packaging to transport them to the final customer.

**Disti / warehouse / direct distribution:** After the products are ready, the products are distributed to the customers. There are three different kinds of concepts that NXP MA uses; use of a disti, a warehouse or direct distribution of dies to a customer.
Appendix B
This appendix shows the inclusion strategy used to obtain relevant articles. As mentioned in the introduction, the aim was to search for research methods that have been used in the past concerned with supply chain risk management in NPD projects in high-tech organizations. Theories about the key concepts were found in academic search engines (1) Google scholar, 2) Emerald, 3) ABI/Inform and 4) ScienceDirect 5) ProQuest) in the period of September 2012 and June 2013. The following search strings were used:

- Supply chain
- Supply chain risks
- Supply chain risk management
- New product development (NPD)
- Innovation
- High-tech organizations
- High-tech market
- High-tech industry
- VRU
- Mass production
- Supply chain AND innovation
- Supply chain AND NPD
- Supply chain risks AND innovation
- Supply chain risks AND NPD AND VRU
- Supply chain risk management AND innovation
- Supply chain risk management AND NPD
- NPD AND high-tech organizations
- NPD AND high-tech industry
- Supply chain AND high-tech
- Supply chain risks AND high-tech
- Supply chain risk management AND high-tech
- VRU AND Supply chain
- VRU AND innovation
- VRU AND Risks
- VRU AND NPD

The relevance of articles was estimated by scanning the titles and abstracts. Furthermore, the set of literature was expanded with relevant sources found in the initial literature (snowball effect).
### Appendix C

Table 1 – Participant categorization

<table>
<thead>
<tr>
<th>Role</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product development</td>
<td>4</td>
</tr>
<tr>
<td>Marketing</td>
<td>2</td>
</tr>
<tr>
<td>Account managers</td>
<td>4</td>
</tr>
<tr>
<td>Operations</td>
<td>5</td>
</tr>
<tr>
<td>VRU experts</td>
<td>4</td>
</tr>
</tbody>
</table>
Appendix D

Interview guide - English
Thank you very much for giving me the opportunity to interview you. Today’s discussion is intended to develop my thesis at the University of Technology in Eindhoven to understand the risks that product line NXP Mobile Audio faces during the development, realization and delivery of a new product to a customer which hamper the volume ramp up. Different groups within the enterprise have traditionally focused on specific areas of risk for my research it could be interesting to get insights in risks from the viewpoint of [TO BE FILLED IN, ROLE INTERVIEWEE].

In this research project I am interested in your experiences with these kinds of problems/disruptions and I hope that it could open discussion regarding strategies in risk identification, assessment and response. Hopefully this will lead to solutions that could aid NXP Mobile Audio in future innovation projects. There are no right, or wrong answers. What I want from you is to share your thoughts and opinions with me; it is your experience that I am interested in. You decide what information you want to give me. If you have any questions during the interview, feel free to ask me. The interviews will be taped and I may take some notes. This is to ensure that I will not forget anything. I am the only person who will have access to these, and no one will be able to read your interview except from myself. The interview will take approximately 1 hour.

General Questions
1. Could you describe briefly your position and responsibilities within NXP Mobile Audio? What are your day-to-day tasks?
2. For how many years? And has the position that you hold now changed over the years?
3. Could you briefly describe the process of development, realization and delivery of a new product?
4. Which part of the development process is according to you most vulnerable for disruptions? Why, and what can you do about it?

Project broad situations
1. To what extent does risk and uncertainty play a role during the execution of your tasks? How much time do you spend on managing these risks and uncertainties?
2. Can you describe the existing risk management process for a new project? Do you think all risks are covered?
3. How would you describe the general attitude of NXP and in general of PL Mobile Audio towards supply chain risks?
4. Which risk procedures/tools are available in order to mitigate VRU risks? Which one do you use?
   a. How does the procedure looks like?
   b. Do you think that these procedures fail somewhere?
   c. Do you think there is a difference between the ‘real’ risks and the risks that are prescribed in the procedures?
   d. How periodically do you measure supply chain performance? (use the tool)
a. If not: What do you think is the reason that these risks are not available?
   ▪ Could it be useful?
   ▪ How does such a tool look like?

Specific risk questions
5. Could you give an example of a specific risk which has cause a disruption during the remainder of the product supply trajectory?
   a. What happened?
   b. When did it take place?
   c. How did you learn of this?
   d. Who did you tell first? To whom must you report disruptions?
   e. Where there consequences in other parts of the supply chain, or for the VRU?
   f. Which strategy did you apply in order to mitigate the risk? Who were involved?
   g. What information was needed to solve the problem? Where did it came from, and how quickly?
   h. What do you feel the impact of the disruption was?
   i. When the disruption occurred, what was the main thing you were trying to protect?
6. What historical data do you have about disruptions?
7. Could you give me an example of a recent decision in order to mitigate the VRU risks?
   a. What were the key criteria for the evaluation of this decision?
8. In hindsight? What are the lessons learnt? And what would you do differently?

Specific VRU related questions (in case the interviewee could answer)
1. How would you characterize a successful or ideal VRU?
2. What risks do you think affect VRU related decisions? Why? Why?
3. What are the biggest challenges you have encountered in VRU? Why?
4. What opportunities do you see to improve risk management related to the VRU phase?

In case the interviewee could answer
5. Are you involved in forecasting?
6. How do you forecast demand?
   o And do you think this is accurate?
7. Because of the unreliability of the forecasts, companies are trying to find new methods to make the supply chain more responsive to uncertain demand.
   o Are there opportunities to improve the accuracy for NXP Mobil Audio?

Thanks – Closure
8. Is there anything that we left out and that you think might be important for me to know for my research.
9. Do you have any questions about my research?
10. Thank you for your time, patience and kindness in answering the questions. Would you mind answering more questions in case I find that I left something out?
## Appendix E

### Table 1 - Nicknames benchmark partners

<table>
<thead>
<tr>
<th>Benchmark partner</th>
<th>Nickname</th>
</tr>
</thead>
<tbody>
<tr>
<td>NXP Power &amp; Lighting - (2 interviewees)</td>
<td>Bench1</td>
</tr>
<tr>
<td>NXP Small Signal</td>
<td>Bench2</td>
</tr>
<tr>
<td>NXP RF Power</td>
<td>Bench3</td>
</tr>
<tr>
<td>FMCG</td>
<td>Bench4</td>
</tr>
<tr>
<td>Fashion</td>
<td>Bench5</td>
</tr>
</tbody>
</table>

### Table 2 – Characteristics

<table>
<thead>
<tr>
<th>Benchmark partner</th>
<th>Common characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bench 1</td>
<td>- Complex products</td>
</tr>
<tr>
<td></td>
<td>- Global supply chain activities</td>
</tr>
<tr>
<td></td>
<td>- Risk of obsolescence stock</td>
</tr>
<tr>
<td>Bench 2</td>
<td>- Complex products</td>
</tr>
<tr>
<td></td>
<td>- Global supply chain activities</td>
</tr>
<tr>
<td></td>
<td>- Risk of obsolescence stock</td>
</tr>
<tr>
<td>Bench 3</td>
<td>- Complex products</td>
</tr>
<tr>
<td></td>
<td>- Global supply chain activities</td>
</tr>
<tr>
<td></td>
<td>- Risk of obsolescence stock</td>
</tr>
<tr>
<td>Bench 4</td>
<td>- Products are sold in great quantities (volume)</td>
</tr>
<tr>
<td></td>
<td>- Risk of obsolescence stock</td>
</tr>
<tr>
<td></td>
<td>- Global supply chain activities</td>
</tr>
<tr>
<td></td>
<td>- Expensive carrying costs</td>
</tr>
<tr>
<td></td>
<td>- Low predictability of demand (forecast inaccuracy)</td>
</tr>
<tr>
<td></td>
<td>- Medium innovation rate</td>
</tr>
<tr>
<td>Bench 5</td>
<td>- Short product lifecycles</td>
</tr>
<tr>
<td></td>
<td>- Global supply chain activities</td>
</tr>
<tr>
<td></td>
<td>- Low predictability of demand (forecast inaccuracy)</td>
</tr>
<tr>
<td></td>
<td>- Quick response on stock shortages determines introduction success</td>
</tr>
<tr>
<td></td>
<td>- Global supply chain activities</td>
</tr>
<tr>
<td></td>
<td>- Marketplace demand</td>
</tr>
<tr>
<td></td>
<td>- High profit margin</td>
</tr>
<tr>
<td></td>
<td>- No single design has dominated for any length of time</td>
</tr>
<tr>
<td>BENCHMARK</td>
<td>Tools</td>
</tr>
<tr>
<td>-----------</td>
<td>-------</td>
</tr>
</tbody>
</table>
| **Bench1** | - VRU quick scan  
 | - FMEA as input (*identification*)  
 | - NXP shopping list (*identification*)  
 | - PDCA (mitigation) | - Proactive risk management  
 | | - Update shopping list every year  
 | | - Risk review after each gate A,V,R (monitor & review)  
 | | - KPI (monitor & review) | - Special VRU manager: Risk owner  
 | | | - Special VRU team  
 | | | - KPI: RLIP, BOM readiness |
| **Bench2** | - VRU quick scan  
 | - FMEA as input: active document (*identification*)  
 | - Risk impact score (assessment)  
 | - PDCA (mitigation) | - Proactive risk management  
 | | - Frequent updates, depends on development phase (monitor & review)  
 | | - Fixed agenda points  
 | | - Lessons learnt after project close  
 | | - KPI (monitor & review) | - Special VRU manager, assigns risk owners for diverse supply chain elements  
 | | | - KPI: CLIP, confirmed line items performance |
| **Bench3** | - VRU quick scan  
 | - FMEA as input: active document (*identification*)  
 | - Risk impact score (assessment)  
 | - PDCA (mitigation) | - Proactive risk management  
 | | - Frequent updates, depends on development phase (monitor & review)  
 | | - Fixed agenda points  
 | | - Lessons learnt after project close  
 | | - KPI (monitor & review) | - Special VRU manager, assigns risk owners for diverse supply chain elements  
 | | | - KPI: CLIP, confirmed line items performance |
| **Bench4** | - SWOT analysis to identify (supply chain) constraints and support decision making  
 | - Global risk assessment by use of interviews and questionnaires by project team members  
 | - JTBD (job to be done) during all NPD phases, assign risk/task owners (mitigation)  
 | - Scenario planning (review & control risks) | - Apply learning from previous launch  
 | | - Daily updates of JTBD communicated to all risk owners | - Special introduction team for each country consisting of regional sales and marketing and global R&D |
| **Bench5** | - Project team identifies risks, project leader leads team this team (*identification*)  
 | | - Analytical hierarchy process (assessment)  
 | - (In some cases) Scenario planning | - Biweekly update  
 | | - KPI | - Cross functional teams  
 | | | - Take responsibility by use of KPI: flawed items on sold goods |
### Appendix F

**Table 1**

<table>
<thead>
<tr>
<th>Probability score</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Will not occur</td>
<td>1</td>
</tr>
<tr>
<td>Low probability</td>
<td>2</td>
</tr>
<tr>
<td>Medium probability</td>
<td>3</td>
</tr>
<tr>
<td>High probability</td>
<td>4</td>
</tr>
<tr>
<td>Sure it will occur</td>
<td>5</td>
</tr>
</tbody>
</table>

**Table 2**

<table>
<thead>
<tr>
<th>Solution feasibility</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sure there is a solution</td>
<td>1</td>
</tr>
<tr>
<td>High ability</td>
<td>2</td>
</tr>
<tr>
<td>Medium ability</td>
<td>3</td>
</tr>
<tr>
<td>Low ability</td>
<td>4</td>
</tr>
<tr>
<td>No ability</td>
<td>5</td>
</tr>
</tbody>
</table>

**Table 3**

<table>
<thead>
<tr>
<th>Risk impact</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Product not released on time</td>
<td>2</td>
</tr>
<tr>
<td>Project slip</td>
<td></td>
</tr>
<tr>
<td>Delay in changeover to lower cost version</td>
<td>3</td>
</tr>
<tr>
<td>No design-in</td>
<td>5</td>
</tr>
<tr>
<td>Hold Lots</td>
<td>2</td>
</tr>
<tr>
<td>Depletion of Safety stock</td>
<td>2</td>
</tr>
<tr>
<td>RLIP impacted</td>
<td>2</td>
</tr>
<tr>
<td>Missed sales</td>
<td>3</td>
</tr>
<tr>
<td>CLIP impacted</td>
<td>4</td>
</tr>
<tr>
<td>Missed market share</td>
<td>4</td>
</tr>
<tr>
<td>High costs during ramp-up</td>
<td>4</td>
</tr>
<tr>
<td>Customer relation endangered</td>
<td>5</td>
</tr>
</tbody>
</table>
# Appendix G

## Agenda proposal for VRU meetings

<table>
<thead>
<tr>
<th>Topic</th>
<th>Input</th>
<th>What to discuss / Actions</th>
<th>Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Status product / issues</strong></td>
<td>Risk facilitator</td>
<td>Update Status product</td>
<td>Important to notice: it’s a VRU meeting NOT a product development meeting</td>
</tr>
<tr>
<td><strong>Customer demands</strong></td>
<td>Demand manager, marketing</td>
<td>1. Check with marketing on sample requests</td>
<td></td>
</tr>
<tr>
<td><strong>Order book</strong></td>
<td></td>
<td>2. Existing orders: Check on timely fulfillment of customer request</td>
<td></td>
</tr>
<tr>
<td><strong>Sample requests</strong></td>
<td></td>
<td>3. New orders: Make plan for timely fulfillment</td>
<td></td>
</tr>
<tr>
<td><strong>Data</strong></td>
<td>VRU team</td>
<td>Assure that manufacturing works with the data in Enovia, and review whether correct planning yields, test times, test flows, are in the system</td>
<td>Initiate actions whether yield is too low</td>
</tr>
<tr>
<td><strong>Yield review</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Capacity situation</strong></td>
<td>Risk owners. See step 1 of redesign:</td>
<td>1. Check whether demand has been confirmed for the different production steps.</td>
<td>2. Check whether there is an allocation</td>
</tr>
<tr>
<td></td>
<td>– Diffusion process</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>– WT 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>– Assembly</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>– WT 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>– Packaging</td>
<td>In case these processes are not ‘new’ and have been released way before the current ramp up, the BU</td>
<td></td>
</tr>
<tr>
<td><strong>Activity</strong></td>
<td><strong>Responsibility</strong></td>
<td><strong>Steps</strong></td>
<td></td>
</tr>
<tr>
<td>---------------------------</td>
<td>------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Capacity planner</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Availability</strong></td>
<td>Risk facilitator (VRU manager)</td>
<td>- Diffusion process</td>
<td></td>
</tr>
<tr>
<td><strong>production steps</strong></td>
<td></td>
<td>- WT 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Assembly</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- WT 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Packaging</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Check for each production step whether production steps are available and required materials are present (enough)</td>
<td></td>
</tr>
<tr>
<td><strong>Risk Review</strong></td>
<td>VRU team</td>
<td>Discuss the main risks</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Discuss whether there are new risks visible / upcoming</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Risk facilitator + General manager</td>
<td>Decide whether team should make scenarios</td>
<td></td>
</tr>
<tr>
<td><strong>Action plan</strong></td>
<td>VRU team</td>
<td>Discuss follow up on actions due for today (clearly define what, who and when)</td>
<td></td>
</tr>
<tr>
<td><strong>Learning review</strong></td>
<td></td>
<td>Check if other teams could help with risks that the project face</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Check if there were learnings that other teams could help as well</td>
<td></td>
</tr>
</tbody>
</table>
### Appendix H

**Validation**

<table>
<thead>
<tr>
<th></th>
<th>Step 1</th>
<th>Step 2</th>
<th>Step 3</th>
<th>Step 4</th>
<th>Step 5</th>
<th>Step 6</th>
<th>Step 7</th>
<th>Step 8</th>
<th>Step 9</th>
<th>Step 10</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Functional</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>requirements</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Literature</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>requirements</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>User</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>requirements</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>