Management of Product Reliability and Reverse (Information) Flows at KPN

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Management of Product Reliability and Reverse (Information) Flows at KPN

"Towards improved use of reverse information flows and pro-active management of the installed base of KPN products"

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The final step in accomplishing the MSc title for the master Industrial Engineering & Management from the University of Twente is the completion of the graduation project. With the completion of the graduation project, I end a great time being a student.

In the last 7+ years I have had the opportunity to do many things besides my study. In particular, I have enjoyed being in the student board of AIESEC Twente, enjoying the time I've spend with my housemates at Villa Doorzon and the international internships in India and Ghana. I look back at these experiences with great pleasure and am thankful that these experiences have brought me to the place I'm at now.

The last hurdle on the way, however, turned out to be a challenging one. The graduation project has proven itself to be far more than writing a thesis; it brought together motivation, discipline, intelligence and the use of social skills to gain the required knowledge and be accepted within the professional environment. Much like the rollercoaster curve which is studied during in this thesis, my own motivation has had its ups and downs too. Looking back, I can say that I've learned from this experience and am now looking forward to the next phase.

I would like to use this opportunity to thank the people that have been very important to me in finishing this thesis. In the first place I would like to thank Rob van der Meij and Rutger van der Leeuw for supporting and enabling me to complete this thesis within KPN. Rob offered help where possible and helped me quickly get acquainted within KPN. Next, I would like to thank Leo and Peter for their constructive help and useful assistance throughout the duration of this research. I feel lucky about having had Leo as a first supervisor, and I'm thankful for the time and personal interest Leo has shown.

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The Hague, 20th of October 2011,

Joep ter Avest

Summary

This report is dedicated to the results of a research performed at KPN in the field of reverse (information) flows and product reliability management. The services KPN offers the consumer market require technical products, in particular Set-Top-Boxes or Residential Gateways for the support of Interactive Television, Digitenne and Internet. In 2010 KPN introduced a logistics improvement program, that ensured that products that are due to be returned because a service is ended or because the product supposedly is defect, are either collected or swapped. This resulted in an increase in the reverse flow which offers opportunities for better use of the information in the return flow. This is formalized by the following problem statement: "What **insights** can be **gained from the information collected** from **reverse flows** with respect to **product failure behaviour** and which adaptations are required in these reverse processes to enable and embed the **structural monitoring of product failure behaviour** in order for KPN to **timely pro-actively act**?"

In the first chapter we introduce the research structure and the research questions that are used to answer the main problem statement. This structure consists of a study of the current situation, a literature study, a comparison of literature and KPN and a case study.

In the second chapter we analyse the current situation of reverse (information) flows at KPN. From the analysis of the current situation it is concluded that there is no structural method of monitoring returns information and product reliability. Furthermore, analysis of the current situation indicated the complexity of the return flow, and more particularly the wide range of differences in products, product characteristics and product propositions that form the reverse flow. Primary determinants that are hardly registered in the reverse process are (1) the type of order (collection or swap), (2) rental or bought STB (3) pre-announced or non-pre-announced order.

The third chapter is related to a literature study. We chose to use the Maturity Index on Reliability (Brombacher, 1999) as a framework for the literature study and the remainder of the research. The MIR model can be used for monitoring the maturity of an organisation on reliability management, and thereby is appropriate for indicating the improvement areas in organisational processes to perform and improve product reliability analysis. The MIR model consists of 5 levels; (0) uncontrolled; (1) measured; (2) analysed; (3) controlled and (4) improving.
From the literature study it is concluded that MIR 1, MIR 3 and MIR 4 need to be analysed. On MIR 4 we find that both about the range of pro-active actions that could be undertaken as well as about the conditions for which these actions would be appropriate little literature is available. However, on MIR 4 an overview of costs to be taken into account in a pro-active action is provided. On MIR 3 we find that Failure Mode and Effect Analysis is the most common method to perform root-cause analysis. On MIR 1, the Quality & Reliability Reference model was used to make a distinction can be made between hard (product breakdown) and soft (performance error) reliability problems. This research is limited to hard reliability problems. Furthermore, the four phases suggested by the four-phase rollercoaster model (hidden zero-hour, early wear-out, random failure and systematic wear-out) are accepted as a phenomena for reliability analysis.

The fourth chapter is dedicated to the application of the relevant literature to KPN. It is concluded that in order for KPN to pro-actively control the installed base, KPN should observe the following two phenomena: 1) early product wear-out (production models/series that are particularly prone to failure) and 2) systematic wear-out (development of the installed base of products and products reaching their technical end-of-life).
Based upon irregularities in the observed phenomena, the following categories of pro-active actions are identified within KPN: 1) The decision not to act, 2) Stop distribution of the product or series, 3) Pro-actively stimulate customers to use other products/services and 4) Pro-active preventive replacement of (a part of) the installed base. These categories may exist of various strategies. The relationship between the observed phenomenon and the pro-active decision to be taken is supported by a tool that incorporates safety, customer base affected (impact), costs, Netto Promotor Score (customer satisfaction), strategic interests/planning and time line (that describes how the problem increases over time). The tool weights these arguments against: time line/feasibility (time required for implementing the solution) and costs. The tool enables KPN to weigh these measures of benefits to customers with arguments the costs and feasibility (or time line for implementing the solution) of the pro-active action. The outcome of the tool is a category of pro-active action.
At each MIR level, gaps between literature and the current situation at KPN are identified. For these problems, combined with other problems that had not been covered by previous MIR levels, solutions are introduced. The solutions are prioritized, and the following 3 solutions are determined to be most important for improving quality information flows:

1 The determination of the customers appreciation of pro-active actions, within the NPS program.
2 Including multiple deployments in the product hardware strategy by productmanagers within the Producthouse department.
3 Improving the overview of reverse logistics and product reliability (including the registration of distributed products), driven by Teleplan.

In the fifth chapter a case study is performed for Digitenne tuners. The primary role of this case study is to provide insight into the product reliability of Digitenne products based on the information currently available. In order enable the analysis of the data from the test center, we created an excel tool. The excel tool supports retrieving the production months of a large quantity of Digitenne tuners as well as to ensure that no errors are made when interpreting the various formats. By using this tool, we find that there is a tuner of inferior quality, and that series from the period December 2008 – December 2009 are even less reliable than older production series. Furthermore, it is found that the root-cause of this reliability problem, contrary to how the supplier had informed KPN, is likely to reside within the use of inferior quality PCBs. Subsequently, the tool that was created in chapter 4 to support pro-active decision making was used, but it was found that the level of information that is currently available is inadequate to use the tool in a profound manner. The problem that stands out is the level of detail available regarding the installed base of products.

It is concluded that KPN is on a low level of structural product reliability management. By implementing the suggested solutions KPN will be able to improve its insight and will be able to make grounded decisions regarding pro-active actions, and thereby set a step towards being the best service provider of the Netherlands.

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Chapter 1: **Introduction**

1 Introduction to the management of Reverse Flows at KPN

In the context of completing the master's degree in Industrial Engineering & Management, the author was given the opportunity to perform a research within KPN. In a period that should last about 6 months, the author was up to the challenge to perform a research on academic level related to the specialization in Production & Logistics Management. The final result of this research is presented in this report.

This chapter introduces the research setting of the research performed at KPN. The first section is dedicate the introduction and motivation of this research. Subsequently, the company KPN and its structure and pro portfolio are introduced. Then, the problem description, research objective and problem statement are clarified. The first chapter concludes with the research model that is adopted in this report and the related research questions.

1.1 Introduction

Product flows in today's supply chains do not end once they have reached the customer. Many products lead a second and even third or fourth life after having accomplished their original task at their first customer (Fleischmann et al., 2004). To create an environmental and economic win-win situation, companies have to master reverse logistics (Janse et al., 2009). The increasing competition in the market of consumer electronics forces industry to simultaneously improve the functionability, reliability and costs of their products. Due to the strong dynamics of this field an important measure in improving product quality is the feedback of information on actual field behaviour of a product which is extremely relevant for product development (Molenaar et al., 2002). There has been a growing interest in monitoring the ongoing "health" of products and systems in order to predict failures and provide warning to avoid catastrophic failure (Vichare and Pecht, 2006).

Fuelled by cost-saving motives, increasing legislation and CSR aspects, KPN implemented the SRET[1] (Service & Returns process) project in 2010 to emphasize improvements in its reverse logistics processes for its products in its consumer market *fixed* segment. KPN managed to increase the collection rate of supposedly defective articles and other returns from 25% to about 80%. Since the services that KPN offers this consumer segment mostly consist of propositions where consumers rent equipment from KPN, KPN can significantly save costs if it finds ways to cost-effectively collect and re-deploy its consumer products.

In the past months, several reliability issues amongst the entire product portfolio have manifested itself. As a result, the need to monitor returned products to analyse product reliability has appeared at KPN. For various reasons, later to be elaborated upon, KPN wants to study the information from returns to improve its processes. In particular, it is interested in learning about product reliability from product returns, in order to pro-active handle reliability issues in the future. However, due to the high costs of collection and refurbishment[2] (whilst a refurbished product is not technically equal to a new product) it is argued that the decision to re-deployable and technically good products is in the long run not cost-efficient. KPN can now use this information to improve its reverse logistics decisions, extending to for example pro-active decision making regarding return flows, better argued decisions regarding which products to take back, which take-back option to use and which products to re-deploy.

This research aims to explore the improvement possibilities in product reliability resulting from data gathered in the reverse logistics processes. It builds upon the achievements realized the past year to refine the decision making process. It is thereby strongly in line with the CSR targets that KPN values highly whilst maintaining economic sense. Before continuing to the problem description, a description of the research setting at KPN is provided.

[1] SRET process encompasses the collection of consumer products in case a service is ended or the replacement of a product by a substitute product in case of a defect.
[2] Refurbishment in this report is used to describe the renovating of a technically flawless product into cosmetically new-state.

1.2 KPN & KPN Consumer Market segment

KPN is the leading telecommunications and ICT service provider in The Netherlands, offering wireline and wireless telephony, internet and TV to consumers, end-to-end telecommunications and ICT services to business customers. KPN's subsidiary Getronics operates a global ICT services company with a market-leading position in the Benelux, offering end-to-end solutions in infrastructure and network-related IT. In Germany and Belgium, KPN pursues a multi-brand strategy in its mobile operations and holds number three market positions through E-Plus and BASE. KPN provides wholesale network services to third parties and operates an efficient IP-based infrastructure with global scale in international wholesale through iBasis (KPN, 2011).

At December 31, 2010, the KPN group served 34.7 million customers in wireless services, 4.4 million in wireline voice, 2.6 million in broadband Internet and 1.2 million in TV. With 23,991 FTEs in the Netherlands (30,599 FTEs for the whole group), KPN reported revenues of EUR 13.4 billion and an EBITDA of EUR 5.5 billion in 2010. The KPN group revenues are distributed as displayed in Figure 1. In the KPN NL market, the consumer market makes the largest share of the total revenues.

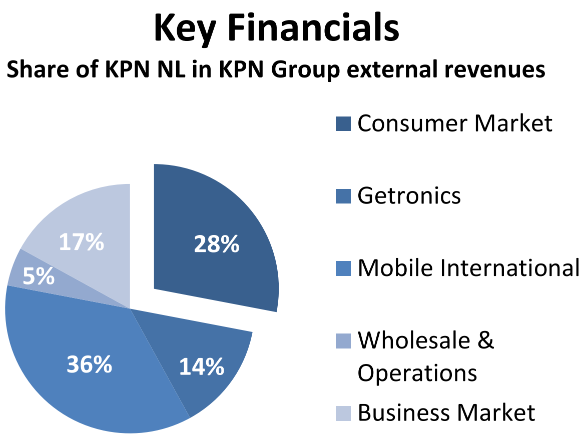

Figure 1: KPN group key financials composition over market segments (KPN, 2011)

Structure of KPN NL

KPN is structured according to its main business segmentation differentiating between the Dutch and the mobile international market. As Figure 2 displays KPN NL has five divisions, being:

1) Consumer Market (CM): By providing fixed and mobile telephony, internet and TV, KPN offers retail customers a broad package of services in the areas of communications, information, entertainment and commercial services (KPN, 2011). This is the business segment in which the research takes place.
   The consumer market segment exists of various departments as displayed in Figure 3. The research is performed in a sub-department of the department of Customer Processes & Products.
2) Business Market (ZM): KPN offers its business customers a complete portfolio of services from voice and internet to a range of data network services.
3) Getronics: KPN's subsidiary Getronics operates a global ICT services company with a market-leading position in the Benelux, offering end-to-end solutions in infrastructure and network-related IT to KPN's largest customers.
4) Wholesale & Operations: Wholesale & Operations (W&O) is responsible for KPN's operational activities, for the Dutch networks (both fixed and mobile) and for KPN's wholesale customers and portfolio in the Netherlands.
5) Corporate Center: Corporate Center conceives other activities such as IT support for the other four departments. The major component of this is IT NL, which supports the IT for KPN NL.

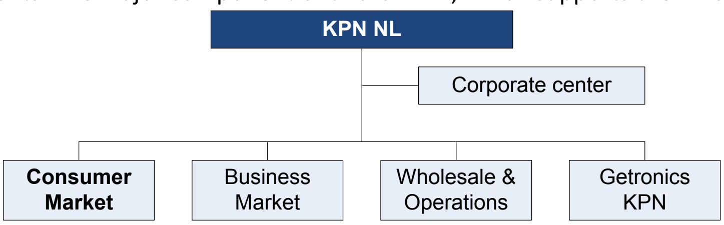

Figure 2: Organisation of KPN NL (KPN, 2011)

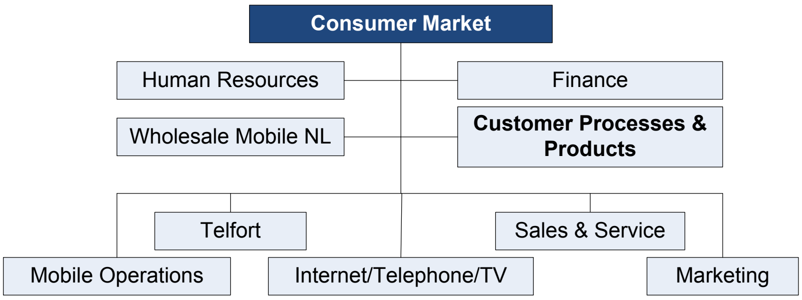

Figure 3: Organisation of KPN Consumer Market (KPN, 2011)

1.3 KPN CM KP&P Producthouse *(fixed)* department

The research will be performed within the Producthouse department, which falls under the staff department Customer Processes & Products or KP&P (see Figure 4). The Producthouse department is responsible for: fixed consumer hardware, supplier selection and distribution policies and also KPN NL wide logistic policies.

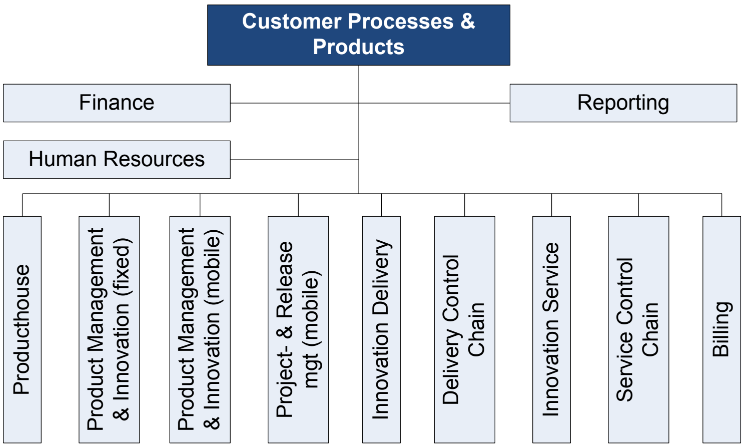

Figure 4: Organisation of KPN Customer Processes & Products (KPN, 2011)

The activities of Producthouse (fixed) are centred around 3 service offerings.

1 Internet, calling and Internet Plus Calling (IPB) or Multiplay
KPN offers broadband internet service via the traditional copper network and via the fiber network it is currently installing in the Netherlands. The fixed internet connection can be combined with wireline telephone service.

2 ITV Interactive Television
KPN offers high-end, high quality, interactive television via the KPN fixed copper or fiber network.

3 Digitenne Television
KPN's low-end service proposition is digital television via *Digital Video Broadcasting - Terrestrial* techonology, i.e. wireless signals that can be decoded using Digitenne television tuners.

The Producthouse department consists of a team of 13 people who are involved in three key activities:

1. Managing the Consumer Market product hardware portfolio

The Producthouse department selects the consumer-end of the hardware that is used for the consumer market. This incorporates not only the composition of technical product requirements, but also the selection and the subsequent management of suppliers. For this purpose Producthouse closely cooperates with the Corporate Procurement Office. Once the hardware has been selected, and production has started at a supplier, Producthouse is engaged in the management of operational issues in the forward and reverse flow of products. This includes handling of for example late deliveries and quality problems.

2. Managing logistics for the Dutch market

Producthouse is responsible for the outbound logistical processes for consumer market (*fixed)* products. Currently, forward logistic services are outsourced to the logistics service provider (LSP) Ceva Logistics, and reverse logistics are performed by Teleplan. The Producthouse department supports Ceva, and Ceva in turn manages the coordination of its sub-contractors. Producthouse is also responsible for strategic and long-term improvements in the logistics process, such as those included in the long-term contract with Ceva logistics.

3. Ensuring a high quality customer experience

Producthouse is responsible for ensuring a high quality customer experience, i.e. how KPN is perceived by the customer from delivery of the product onward (however, excluding contact with the helpdesk of KPN). This encompasses the steering of external parties that design and fabricate contents of package delivered at consumers, ranging from the physical box and remote control layout to the product manual and user interface.

Producthouse *(fixed)* context

This research is performed within the Producthouse department. In the consumer market in general a distinction is made between fixed and mobile services. The mobile market covers services for mobile telephony and mobile internet, whereas fixed services refer to those services that require the KPN fixed grid (copper or fiber) or Digitenne. The Producthouse department is only concerned with *fixed* services.

Figure 5 depicts the context of the Producthouse department. The Producthouse department operates amidst the Corporate Procurement Office, the Supply Chain Service Center and the Marketing department on the one hand and Ceva Logistics, Teleplan, Drake & Farrell, subcontracting distributors and suppliers on the other hand. Their roles and responsibilities are clarified in the following:

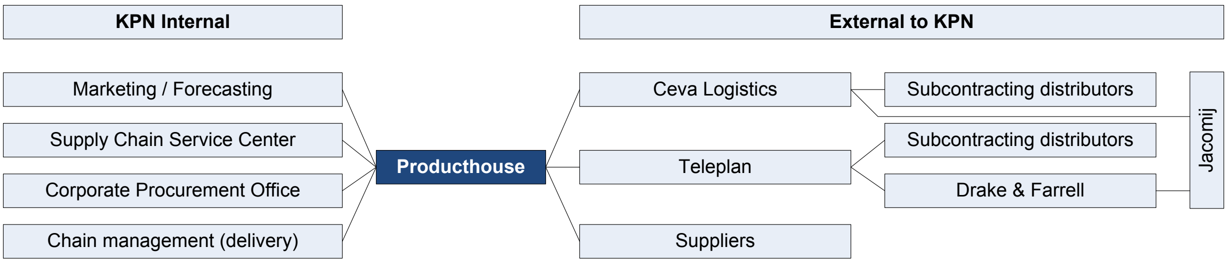

Figure 5: Context of the Producthouse department

<u>Internal parties</u>

- Marketing/Forecasting: Producthouse communicates with the Marketing department about sales Drake & Farell forecasts per month. Marketing provides an overview of their expected sales, and Producthouse confirms with the product suppliers if they are able to meet the production quantities required by the marketing department.
- Supply Chain Support Center (SCSC): works for all KPN NL parts and purchasing categories. The department provides (almost) all planning and procurement activities for the segments CM, IT NL and the Corporate Centre. For the segment W&O the SCSC provides purchasing activities and part of the planning. For the ZM segment a part of the sales activities are performed.
- CPO Corporate Procurement Office: The Corporate Procurement Office offers professional support in the area of purchasing to all business areas of KPN.
- Chain management (delivery). Chain management positions aim at coordinating various steps over the supply chain. Chain management delivery specifically focus on product delivery for customers.

<u>External parties</u>

- Ceva logistics: is the Logistic Services Provider (LSP) for KPN. Ceva's operations include:
  - Management of the central warehouse in Leidschendam
  - Import/export support service
  - Performing quality tests and checks
  - Bundling of products into kits
  - Handling the distribution from the central warehouse to KPN shops and retailers.
- Teleplan: Contractor that handles reverse flow of goods for KPN (also for mobile phones and ZM).
  - Manages the subcontracted services for the reverse flow of KPN CM (*fixed*).
- Drake & Farrell: Subcontractor for Teleplan, handles the return flow including refurbishment for KPN.
  - Quality and functionality check of good inflow of retour products
  - Shredding of unusable products
- Subcontracting distributors: The distributors are managed and coordinated by Ceva and Drake & Farrell. The relation between KPN and the distributors stems from the choices regarding the delivery services upon which KPN decides.

- Suppliers: The product managers at the Producthouse department manage relationships with the product hardware suppliers. They align the requirements of new products with suppliers and manage relationships with suppliers concerning product quality improvements.

1.4 Problem Description

The problem studied in this research involves the product returns from KPN's customers. Product returns can originate from customers who face a problem in one or more services from KPN. If a customer faces such a problem he/she can contact KPN's helpdesk (KPN contact) to assist them in solving the problem. Figure 6 indicates the information flows that are triggered by the customer (this figure will be treated in more detail in chapter 2).

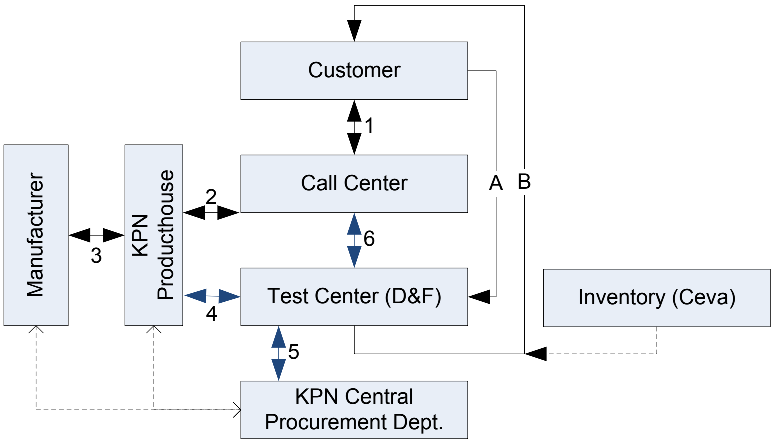

Figure 6: Information flow front-end and back-end

Arrow 1 indicates the customer contacting the KPN call center with a question, complaint, problem or request for cancellation of the subscription. In case the call center agent assesses the problem to reside in the consumer hardware, the call center agent can order a replacing consumer product for that customer (indicated by arrows A & B). The replacement of these consumer products has changed significantly since the implementation of the SRET[3] program in 2010. By means of the implementation of the SRET program, the number of product swaps[4] has greatly risen and thereby the fraction of the actual product returns out of the total number of products scheduled for return from about 25% to 80% (less consumer products that should have been returned to KPN remained at the houses of consumers). The increase in product returns handled has caused KPN to rethink in which ways the information collected from the reverse flow can be used.

The extent to which call center agents are able to conclude with certainty that an error actually resides in a failing consumer product is limited. The test results from the test center contrarily, are performed in a controlled environment, and the test results are binding. However, the data flows (depicted by arrows 4, 5 and 6 in Figure 6) are not embedded into the current processes at KPN. This research explores the potential ways in which the information gathered from returns can complement the information flows from KPN contact.

The various different roles within the organization each have their own perspective of the usability of information from returns. Some of these perspectives are:

- What can KPN learn from defects in returns to coordinate call center agents at KPN contact?
- In what way can the information from returns be used to create insight into pro-active replacement of the installed base?
- How can KPN incorporate the age of returned products in determining a product state for which it is unadvisable to redeploy the product?
- How can we minimize the number of unnecessary reverse movements be minimized?
- Can the number of returned products and product defects be forecasted?
- Can KPN use the information from returns to improve the warranty agreements with suppliers?
- Can KPN use the information from returns to improve the performance of the Logistics Service Providers?

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[3] SRET process encompasses the collection of consumer products in case a service is ended or the replacement of a product by a substitute product in case of a defect.

[4] During a swap a courier offers a replacement product to a customer and collects the supposedly defect article.

As is clear, the different perspectives each have their own interests and purposes for the potential information gathered from reverse flows. However, it is outside the scope of this report to explore all of these perspectives. Appendix A provides an even more elaborate view on the wide range of questions that have originated within KPN. It is important to note that the different perspectives require different information.

This research focuses on a subsection of the issues identified in the above. In particular, this research focuses on quality and product reliability aspects that follow from the analysis of the returns information. Several reasons for studying reliability are:

- Ideas exist about the preventive replacement of consumer products, but these thoughts have not been quantitatively supported.
- The product reliability, and related expected product lifetime are key indicators for the expected return flows, which in turn is an important element for the other questions.
- Thorough analysis of the returns data in general is new to KPN. Hence the research provides new insights and possibilities for KPN.

The reliability analysis is centred primarily around 2 phenomena:

1) Early wear-out:	Production models/series that are particularly prone to failure.
2) Systematic wear-out:	Development of the installed base of products and products reaching their technical end-of-life.

In Section 4.1 these phenomena, and why these in particular are studied, is explained.

This thesis focuses on the information flows indicated by arrows 4, 5 and 6. It thereby uses the data that is available from test results of returned product. Analysing trends in the returns will allow KPN to increase its control over the consumer hardware that is used by customers and act pro-actively. Pro-active action here refers to various ways in which can influence the hardware that customers are using, and the state they are in (e.g. new or used).

1.5 Research Objective

Verschuren and Doorewaard (1998) have proposed guidelines for setting up an adequate research objective for a research in a practical setting. A research objective should be: useful, attainable within the set time window, unambiguous and it should be rich of information. These guidelines have been incorporated when setting up the research objective. The research objective is the following:

*To contribute to the **insight into products' reliability** and provide **recommendations for adaptations** in reverse logistics processes in order **to support control of the installed base** by **pro-active action***

Based on the data currently available, an assessment into product reliability will take place for Digitenne products. The choice for Digitenne is mostly due to the information availability for Digitenne. In order to be able to perform better and structural performance of product reliability, recommendations for adaptations in processes are given. The higher level objective is the enabling of control over the consumer products used by customers. The research objective formulated above offers a high-level objective for this research. In the following section the more concise problem statement is formulated taking into account the limited time window of this research.

1.5.1 Deliverable

The deliverable is twofold; an analysis (in the form of a report) of improvement requirements for product reliability management and a tool (mostly in excel 2010) for operational implementation of product reliability management (with interpretation of Digitenne case studies in the report).
Firstly, this report should provide a thorough overview of the current state of the organization regarding reliability management and the required changes that foster product reliability management. For this purpose a study of theory is combined with the current situation at KPN. This section of the report uncovers the shortcomings in the current processes regarding product reliability management and provides starting points for improvement based on an analysis of the organizational maturity in reliability management and product life cycle theory. This part of the deliverable can be found in Chapters 2 and 3 of this report.
Secondly, the deliverable consists of a model that uses the test results of the Service and Returns Process (SRET) as an input. Output of this model for operational use are statistics and diagrams that provide insight into product reliability indicators. Amongst the variables included are indicators of failure sensitive series, the percentage of

the distributed products that is returned defect, forecasted returns and trends in returns. The calculations in this model are made in excel 2010[5]. The model is aimed to be used as starting point of what reliability analysis tools should incorporate. However, the intention is that the calculations will be embedded in software and/or other performance dashboards of the logistics service provider Teleplan, such that the reliability analysis becomes an integrated part of their tasks. This ensures that product reliability management is performed for IPB, ITV and ITV whereas the excel model is only applicable to Digitenne due to data limitations. Due to time restrictions the actual implementation into the IT systems at KPN and/or its logistical partners or suppliers will not be within the scope of this research.
The purpose of this tool is to provide regularly provide performance on key characteristics of reliability such that KPN can act accordingly. Exactly which way of acting (think of pro-active replacement, accelerated introduction of a new model, migration of customers to a different technology) is chosen by KPN is, aside from the factors that should be taken into account, outside the scope of this thesis.

1.5.2 Project risks

To successfully reach the research objective, a number of risks are identified and mitigated. They are the following:

- Time and scope

Driven by the potential success of the implementation of reverse logistics, employees are increasingly getting involved in reverse logistics projects. The inherent increasing number of viewpoints creates new business needs and requirements. Sufficing these needs dangers the ability to finish the project within a 6 months' timeframe. This risk will be mitigated by narrowing down the problem statement and frequent re-alignment of project progress with the research objective.

- Availability and correctness of information

Last year significant steps in the collection process of returns were made. This has resulted in better insight into the ratio of supposedly defect returns out of all returns. Furthermore, new quality control tools have been implemented to improve the reliability and speed of tests. As a result data regarding products and processes (especially) older than previous year is unreliable or unavailable.
The risk is mitigated by using the latest data for which employees at KPN and its partners are most likely to remember if any irregularities in the products or supplies have occurred. This way, the possible effects of a change in the testing procedure will be taken into account during analysis of the data.

- Support by employees

Because reverse logistics are relatively new to KPN, employees might not be aware of the processes and potential benefits yet. This jeopardizes the extent to which employees that are not directly involved in reverse logistics projects are willing to cooperate and themselves come up with solutions to problems.
To mitigate this risk, assistance is provided by supporters of reverse logistics projects in convincing others to participate.

- IT-impact of suggested solution

The solutions to the problem of this thesis should be acceptable with respect to the required IT changes. Due to the abundance and heritage of IT systems, solutions suggested by this thesis should not require extensive additional IT packages. It may be expected that recommendations will not be implemented if the IT-impact is too large.

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[5] Versions of Microsoft Excel earlier than excel 2007 do not support the number of records required for this analysis.

1.6 Problem Statement

Based on the problem description and the research objective this section introduces the problem statement that is central to this research. The problem statement is consequently clarified in the section below. The problem statement is formulated as follows:

Which **insights** can be **gained from the information collected** from **reverse flows** with respect to **product failure behaviour** and which adaptations are required in these reverse processes to enable and embed the **structural monitoring of product failure behaviour** in order for KPN to **timely pro-actively act?**

This thesis is centred around the insights that can be gained regarding consumer product failure behaviour from the information collected during reverse logistics processes. The topics: 1) consumer product failure behaviour[6] and 2) Information extraction in the reverse flow are key to this research. Starting point for a large share of this research is the field information collected (i.e. the data of defective product returns)at the test centre of returned consumer products. This leads to insights following from the data *currently* available, such as the average age of defective tuners, the age at which the proneness to failure increases and series that are extra prone to failure.

Findings from literature are combined with the reality at KPN, to determine the subsequent indicators that KPN should monitor. Next, the required changes in processes and administration for KPN to be able to structurally monitor product failure behaviour are elaborated upon, as part of its everyday operations.

As a result of process changes and the subsequent monitoring of indicators in the reverse flow, KPN will be enabled to timely pro-actively act. Timely acting pro-actively encompasses the range of actions to be taken in anticipation of a trigger (i.e. an observation from monitoring the returns). These pro-active actions comprise a wide range of actions, ranging from accelerated product introduction to migration of customers to another service, claims towards suppliers, blocking of outflow, et cetera.

Since KPN is neither in control of the production process of products nor has decisive influence on the product design, feedback loops with the purpose of improving the product design are not the primary focus of this research.

Problem owner

The problem owner is a person or a group of persons that have the responsibility to resolve the problem (Heerkens, 2003). Identifying the problem owner enhances the probability of solving the problem. In this research setting the Producthouse department is the problem owner. The Producthouse department is responsible for the logistics in the Netherlands. Its performance indicators are related to the delivery speed and reliability and the costs of these operations. Furthermore, product managers at the Producthouse department are responsible for the inventory levels of the products. The Producthouse department thus has the ability to influence the factors that contribute to the core problem and hence is devoted to solve 'their' problem.

Stakeholders

- KPN Productmanagers & Marketeers

KPN has designed its product return collection process such that product managers are offered various choices for the collection of product returns. Product managers may decide which stream is used for the collection of their product portfolio. Also, product managers together with marketeers are responsible for new service and new hardware introduction. Hence they are key players in the design of the reverse flow and in deciding which products are included and excluded in the refurbishment process.
Marketeers together with the Productmanagers decide which products are refurbished and which are shredded upon receival as a return. They are thus involved in the decision making process of products that qualify the refurbishment conditions.

[6] Product failure behaviour and product reliability are used interchangeably

- Teleplan & Ceva Logistics

KPN contracts two Logistics Service Providers for its logistics operations. As a starting point Ceva Logistics is contracted for the forward stream in the supply chain, whereas Teleplan is responsible for the reverse flow of products (In terms of annual spent by KPN both are about equally sized). Teleplan in turn contracts parties to execute sub-processes for Teleplan, where Teleplan coordinates these sub-processes.
Ceva Logistics is an important source regarding the data analysis of the installed base of KPN (Ceva holds records of the products that have been distributed over the past years). Furthermore, in order to acquire adequately and reliable information concerning the products that are distributed in the future, Ceva is likely to have to implement additional steps or registration steps in its processes. Its ability and the time window within which it is able to do so are decisive for the size and timing of savings for KPN.

- Drake & Farrell

Drake & Farrell is contracted by Teleplan for testing and refurbishment of products for CM fixed. Drake & Farrell will thereby inevitably be involved in (process) changes related to the reverse flow. Furthermore, decision making at Drake & Farrell is influenced by decisions following from this research. Its capacity utilization, reporting standards and processes are impacted by decisions following from this research.

- Consumers

Currently, the services that KPN offers consumers mostly consist of propositions where consumers rent equipment that is required to use KPN's services. Consumers are thereby bound to use the hardware KPN offers them. As with new hardware, the refurbished hardware needs to satisfy the needs of consumers. Furthermore, history has proven that consumers do not accept each form of returns collection. Since consumers are more and more environmentally conscious they urge suppliers such as KPN to be more socially and environmentally responsible with their goods. Hence, the consumer satisfaction level needs to be taken into account, at least, as a constraint.

- KPN Corporate Procurement Office (CPO)

The Central Procurement Office is the body within KPN that is concerned with the strategic and tactical selection and contracting of suppliers as well as the operational fulfilment of these contracts. The CPO is influenced as changes in the reverse flows influence the stream of refurbishments and therefore the employable products of KPN changes, as does the purchasing function. Furthermore, direct feedback about the effectiveness of the agreements regarding Defective-On-Arrival[7] products (DOA's), results advice regarding the DOA agreements used by the procurement department.

- Suppliers

Suppliers are involved in the following ways. The feedback-loop about the failure rate of their products provides them valuable information about their product/component quality. It thereby provides them insight into the quality of their suppliers' supplies. Furthermore, suppliers are involved as they could be forced to provide tools for improved traceability of their products. There is however a dualism here, since the re-use of products implies that the supplier will sell less products to KPN.

- Distributors

The channels used for the collection of returns are reviewed in this research. Improvements are expected to be found by matching the products to reverse channels. This implies that the quantities of the return flows per channel are subject to change. As a result, distributors are affected by the choices KPN makes.

[7] DOA is a situation in which the product is not working directly after the customer purchases it (Baskoro, 2006)

1.7 Research Scope

The following aspects limit the scope of the research in order for it to be attainable within the set time window.

- Product portfolio limitations

This research will limit itself to the product portfolio of the KPN Consumer Market fixed segment, thereby incorporating the services Internet, Internet Plus Calling, Interactive Television and Digitenne. The service offerings to the business market, mobile telephone services, and other services are thereby excluded from this research. Restricting to the consumer market fixed segment implies that nearly all products considered are offered as a rental proposition towards customers, hence they remain the property of KPN.

- Producthouse context

The research is conducted within the Producthouse department. In line with the activities performed within the Producthouse department logistics and supplier relationships/agreements will be incorporated within this research. Customer experience however, is not relevant to this research and is therefore excluded.

- Consequences for forecasting and inventory control

A large part of the returns are either new or used but technically OK. These returns can either be directly enter the distribution stream or can be refurbished (in the future possibly repaired). The products thus enter the forward logistics stream and are added to the inventory of new products. How these streams of returning products influence the forecasting process will not be taken into account in this research.

- Focus on main components

Consumer products are offered to consumers as a package that includes for example cables, instruction manuals, plugs and remote controls. Although the products cannot be delivered if one of these subcomponents is missing, this research is limited to (the reverse flow of) main components. These components represent by far the largest share of the total monetary value of a package, and these are the components that can be refurbished and redeployed (as opposed to manuals or remote controls that are not suitable for redeployment).

- Product design improvement not a primary goal

Though the SRET test results are the primary quantitative source, the primary source of qualitative data regarding returns is from the call center KPN Contact. Product design improvement initiatives primarily result from the qualitative signals picked up at KPN Contact. These design improvement steps are not a primary goal of this report.

- Limited to 'normal' reliability/failure behaviour

This study focusses on the normal failure behaviour of products, and not on extra-ordinary hardware defects, such as safety issues with products in which case the question of whether the products need to be replaced is beyond doubt.

1.8 Framework for analysis: Maturity Index on Reliability (MIR)

This section introduces the Maturity Index on Reliability (MIR). Brombacher (1999) introduced the Maturity Index on Reliability (see Figure 7) to measure the maturity of an organisation on reliability management. We chose to use the MIR framework because of several reasons. Firstly, the MIR model was originally developed for assessing the (maturity of) reliability management in the business processes of organisations developing high-volume consumer products {Brombacher, 1999 #65} which matches the KPN market. Secondly, the MIR model has been applied various times; in the literature there are quite a few papers about the MIR-concept as a tool to analyse product quality related information flows. The MIR-concept has been used over thirty times when assessing the information flow structure in industry, in Europe as well as in South-East Asia {Petkova, 2005 #92}. Furthermore, no other model was found that allows for incorporation of both product reliability analysis as well as the wider view on the quality of the reverse information flows.

The Maturity Index on Reliability contributes to the analysis of reliability by not only analysing the technical aspects of a product, but also analysing the (quality of the) reliability control loop of the organisations developing and operating a product. This scale of five levels reflects the increasing capability of an organisation to analyse, predict and improve the reliability of current and future products.

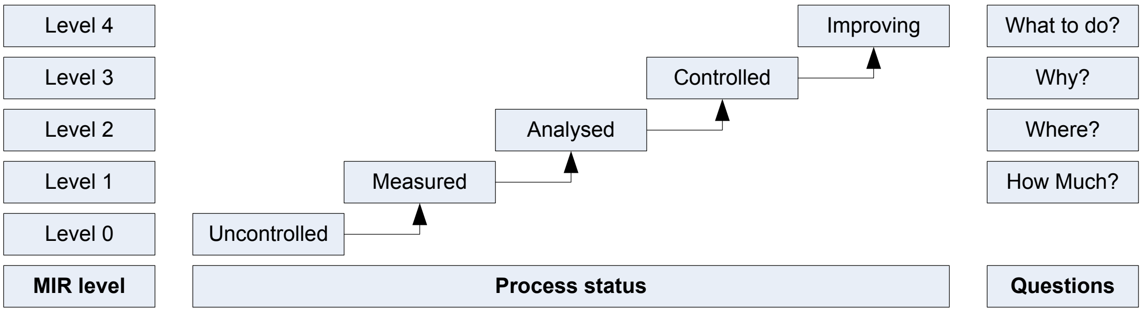

Figure 7: Maturity Index on Reliability model (Brombacher, 1999)

The MIR model will be elaborated upon in Chapter 0 and onwards. In short, its levels are the following:
An organization in MIR level 0 either does or does not predict reliability, but these predictions are not validated; there is no control loop in place. A MIR level 1 does have a control loop in place; this control loop allows for measurement of performance. In a MIR level 2 organization the reliability is not only analysed, the results are also translated back into business processes. A MIR level 3 organization is not only able to allocate reliability problems to the various activities in their business processes, but is also able to identify the root cause of the problem. The knowledge of these root causes enables the organisation to modify the existing products.
MIR Level 4 is the highest level in the MIR model. It corresponds to an organization that has fulfilled the requirements of all lower levels. The difference between a level 3 and a level 4 organization is the difference between a reactive and a proactive organization.

The organizational capabilities regarding product reliability management of MIR level 4 corresponds to the vision that KPN has regarding product reliability management. The long term goal is to be able to pro-actively control the installed base. By pro-active control KPN means that is able to act, such as accelerated introduction of a new model or replacement of the installed base of a particular model by a new model. These options, as well as the requirements/characteristics of the other stages are elaborated upon in Chapter 4.
The MIR model clearly depicts the discrepancy between the KPN objective of being able to structurally control reliability for its installed base, and the current state; a level 0 organization with no structural control loop in place. This report will use the MIR model in a top-down manner. In order to achieve the level 4 goals, the requirements of a MIR level 3 state organization will have to be satisfied. These requirements depend on the objectives on the higher levels. In a similar fashion the required changes and measurements to move towards a level 1 and a 2 organization.

Recall that the MIR is aimed specifically around control loops related to product reliability control. Product improvement changes, which by many authors have been described as primary goals of using information from product returns are not the primary purpose for KPN; as described in Section 1.4 the front-end information from KPN Contact are used for this purpose.

This thesis focuses on the information flows indicated by arrows 4 and 5 in Figure 6. It thereby uses the data that is available from test results of SRET product returns. The lack of arrows 4, 5 and 6 leads to a low level 0, classification within the MIR model. I.e. KPN has not ensured sufficient measurement techniques to structurally measure product reliability. Current actions are always a reply to a trigger from KPN Contact, and thereby always re-active.
Although KPN envisions the MIR level 4 to be a long term goal, this thesis will focus on the requirements on lower levels (i.e. MIR 1, MIR 2) since all lower lying MIR levels will need to be satisfied before MIR level 4 can be reached.

1.9 Research Model

Figure 8 visualizes the research model of this research. The numbers in the upper-right corner of the boxes indicate the chapters in which the respective topics are dealt with. This research model is used for the creation of research questions in Section 1.10.

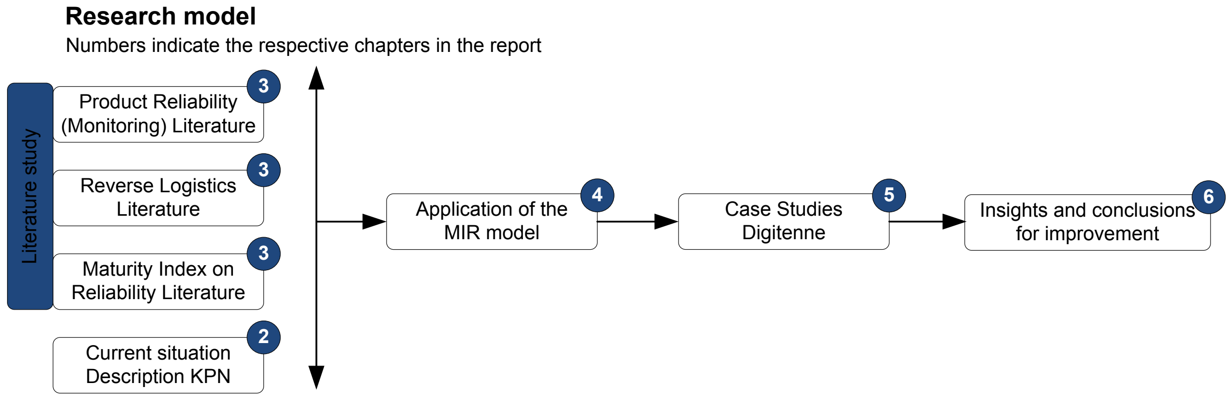

Figure 8: Research Model

Following the first introductory chapter, chapter 2 describes the current reverse flows and product reliability for the CM fixed market portfolio. It provides an extensive overview of both the complexities and imperfections in the reverse logistics operations as well as prime indicators for product reliability, such as the quantities of products in the installed base and the characteristics of returned (defect) products. This information is required for product reliability analysis in subsequent sections.

Chapter 3 is devoted to a study of relevant literature. This chapter is divided into 4 sections, thereby following the structure of the MIR model. The MIR model is treated in a 'backwards' order; i.e. four to one. In this way, the first section deals with MIR 4 and the long term pro-active actions, that form the starting point for the analysis and underlying variables that are used. In chapter 4 the MIR model is applied to KPN to serve two purposes: the gap between the current and the insights from literature are identified and the steps to be taken to meet the requirements for the MIR levels are elaborated upon. In chapter 5, a case study of Digitenne products identifies reliability issues and shows the possibilities and shortcomings of reliability analysis in the current situation for Digitenne. Chapter 6 concludes by answering the problem statement presented in section 1.6.

1.10 Research Questions

This section will guide the reader through the research questions that are created in order to structure this research. The research starts by reviewing the current situation in order to identify in which processes the largest improvements can be gained.

Research Question 1: ***(Chapter 2)***
"What is the current situation regarding product reliability management and reverse logistics information for CM fixed products?"

- Which processes are related to reverse logistics?
- What are the characteristics of the current processes in terms of size and growth development?
- What is the installed base and age distribution of the product returns?
- Which information can be collected from reverse logistics activities?

The purpose of the first research question is to provide an extensive background of the current reliability management related processes and related reverse logistics process at KPN. Chapter 2 will provide the basis for the reliability aspects that will be reviewed in the remainder of the report. The first research question is answered in Chapter 2.

Research Question 2: ***(Chapter 3)***
Which insights does literature provide with respect to reverse logistics information and product reliability monitoring?

- Which findings does literature present regarding pro-active actions on an installed base of products?
- What insights does the (Reverse) Product Life Cycle provide regarding life cycle length?
- What factors of product (un)reliability does literature identify?
- How can different reliability problems be classified?
- Which variables from product returns should be included for monitoring product reliability?
- Which metrics are available to model product reliability?

The purpose of the second research question is to explore the fields related to the various MIR aspects. The MIR aspects are only defined on an abstract level; i.e. the relevant theorem per MIR aspect nor a measure of when sufficient analysis per MIR aspect has been performed is presented by the authors of the MIR model. Research question 2 is answered in chapter 3.

Research Question 3: ***(Chapter 4)***
What can be learned from applying the Maturity Index on Reliability to KPN?
- Which proactive actions can KPN take and which aspects should it take into consideration?
- What is the status regarding the stage and length of the product life cycle ?
- What methods does KPN have in place to identify root causes of problems?
- What are the reliability indicators that KPN should use?
- Which method of product reliability modelling is appropriate?

Research question three combines the findings from literature with input from KPN to explore the goals, methods and variables that are required to be incorporated into business processes within KPN to reach higher MIR goals. The third research question is dealt with in Chapter 4.

Research Question 4: ***(Chapter 5)***
How does modelling failure behaviour currently work out in practise for Digitenne?
- Which cases meet the data requirement level (following the second research question)?
- Are there series that are particularly prone to failure amongst the selected series?
- Which insights can be gained from the failure behaviour unveiled by the metrics?
- Which trends in return flow can be deduced from the case studies?
- Which additional requirements for reliability registration follows from practise?
- Which generic conclusions can be deduced from this reliability analysis?

The fourth research question is focussed on the application of product reliability modelling models (MIR 1) to Digitenne products. It provides insight into the product failure behaviour, trends, and development of returns of Digitenne products. The fourth research question is answered in chapter 5.

Research Question 5: ***(Chapter 6)***
Which insights can be gained from the information collected from reverse flows with respect to product failure behaviour?

- What are the key changes that are required to enable KPN to structurally monitor product reliability?
- Which further research steps are recommended?
- Which opportunities for related research are identified?

This chapter handles research question 5, which provides the answer to the problem statement stated in section 1.6. Next to that, the results of this research and its methodology are discussed and suggestions for further research are given. Research question 5 is answered in chapter 6.

1.11 The product portfolio of KPN fixed

The concluding section of the first chapter introduces the product portfolio of the consumer market fixed market segment to get acquainted with the products and their characteristics in this research .

Telephony and Internet

Telephony and internet service and technology have evolved rapidly over the past years. These developments are twofold: both the functionality of the consumer product (think of the different wireless network standards that have evolved over the past years) as well as in 'underlying' technology in the KPN infrastructure. Over the past ten years the development of the 'underlying' technology has evolved over ISDN, ADSL, VDSL and currently towards large scale the roll out of fiber.

Television

From 2004 onwards KPN added the service Television to its fixed line portfolio, which at that time existed of telephony, internet and the combination of these two: IPB. The opportunity of adding television to the portfolio resulted from technical improvements in the KPN infrastructure and the simultaneous opportunity to extend the KPN service portfolio. The technical improvements on a longer term would enable video broadcasting over the IP-based infrastructure that KPN utilizes (a technology technically different from the technology used by traditional cable-television providers).

KPN has entered the Television market by using two technologies distinctly coupled to the services Digitenne and Interactive Television. Digitenne is a service based on Digital Video Broadcasting-Terrestrial (DVB-T) technology. DVB-T uses masts to wirelessly broadcast signals, and thereby uses a network infrastructure separate to the IP-based infrastructure KPN operates for telephony, internet and Interactive Television.
Compressed video signals make it possible to wirelessly transmit digital quality video. One major drawback of DVB-T technology is its susceptibility to interference by external sources, ranging from noise created by building construction to noise resulting from a passing motorcycle. Hence, the distance to the transmitting mast and the absence of interfering external factors are decisive for the appropriateness of Digitenne. Note that KPN can determine the network coverage for Digitenne, but is not able to determine per customer if the television reception is proper. The Digitenne signal is received and decoded by means of a Digitenne-tuner.
Interactive Television is offered via the IP-based network over which KPN delivers telephony and internet services. Television, and High Definition in particular, require a great bandwidth (about 8 mbit per HD television). To support the ever increasing bandwidth needs, KPN is 'rolling out' fiber throughout the Netherlands. The fiber technology is significantly different from the copper technology, and the fiber network will enable significantly greater amounts of traffic. The investment in the roll-out of fiber is a strategic investment. It will allow KPN to support the latest (multi room HD TV) as well as future 3D, multi-room 3D and Video-On-Demand[8] services.
To use Interactive Television a customer requires both a KPN Residential Gateway[9] for internet connection as well as a Set-Top-Box[10] for video signal conversion.

Competitors in Television and Internet

Amongst the major competitors in the Dutch television market are UPC and Ziggo, who both are cable operators (i.e. they use cable technology as opposed to IP technology as KPN does). Aside from the underlying technology, another key difference is the ownership of the consumer product. At UPC and Ziggo the customer becomes the owner of the consumer product, whereas KPN remains owner of the consumer product in its proposition. The impact is significant, since KPN benefits from receiving well-functioning products, where-as UPC and Ziggo do not benefit as such.

Although KPN offers returns services for their mobile phones, the reverse processes of the fixed and the mobile market portfolio are completely disconnected. Also, KPN has no clear view of a company that is best-in-class in reverse logistics, and has not established ways of cooperating with other companies to benchmark its reverse logistics processes.
The market share of KPN in the television market is estimated to be around 15% (Van der Leeuw, 19-05-2011).

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[8] Video-on-Demand: systems which allow users to select and watch/listen to video or audio content on demand.
[9] Residential Gateway: A residential gateway is a home networking device, used as a gateway to connect devices in the home to the Internet or other Wide Area Network (Erol Baran, 2011).
[10] STB: Set Top Box, the universal term for the box that connects the television with the television signal. A Digitenne tuner is also an STB. Although an STB technically doesn't necessarily contain a tuner, the terms STB and tuner are used interchangeably.

There are more competitors in the Internet market than in the Television market. The main competitors are the same for both markets. The market share in the broadband market is about 41% (KPN, 2011).

Bill of Material (BOM):

The bill of material for Digitenne, IPB and ITV packages delivered to customers are as follows:

Digitenne:	Digitenne tuner (low-end or high-end), antenna, smart card, manual, remote control, scart cable.
ITV[11]:	ITV STB (low-end or high-end), ethernet cable, scart cable, remote control, power cord, manual.
IPB:	Residential gateway, ethernet cables, power cord, converter plug, manual, installation CD.

The ITV kit is often complemented one or more of the following products:

- Wireless connection kit. This connection kit allows for a connection of the ITV tuner with the RG by means of the power grid. In this way the two can be connected without requiring physical proximity.
- Network Terminal. In case of a fiber connection a network terminal is added to the package that is sent to the customer. The network terminal is installed by a KPN service engineer.
- In case the customer orders multiroom ITV which it allows him to use ITV on several TV's, more ITV tuners are added to the package that is sent to the customer.

Long term vision internet and television

-- KPN Classified Information --

[11] Note that in order to be able to use the service ITV two preconditions have to be met: 1) the connection must support the speed required for ITV and 2) The residential gateway must be suitable to support ITV. Hence, the ITV package is often delivered together with a modern residential gateway.

Products in the consumer market fixed portfolio

The product portfolio managed to service the consumer market fixed is depicted by Table 1.

Product	Description
ITV - Set Top Box  Motorola STB – Model 1963	A Set Top Box is required for the service Interactive Television that KPN offers. The various types of Set Top Boxes differ in their ability to record, e.g. whether they have a hard drive installed or not and their age. The older models change channels slower than newer models. A Set Top Box, once installed at a customer is accessible by KPN for software updates. As a result, STB's have the potential for a long lifecycle. In order to be able to acquire interactive television by KPN, the customer must also acquire internet via KPN, and thus have a KPN Residential Gateway.
Digitenne Tuner  Topfield Digitenne tuner – Model TF-6000COK	Digitenne uses the Digital Video Broadcasting – Terrestrial (DVB-T) technology. Basically, there are three technical solutions to use Digitenne. The first, and most common, is the use of a Digitenne tuner as the Topfield model TF-6000COK. The second technical solution is to use a model that has recording functionality. The third option is only applicable with modern televisions. It is the use of a Digitenne CAM-Module, a module that fits into a special slot in the television. In the latter case a separate tuner is not required, though an external KPN-antenna still is.
IPB – Residential Gateway (RG) or Modem  Arcadyan Modem – Model 7519	Residential Gateway: A residential gateway is a home networking device, used as a gateway to connect devices in the home to the Internet or other Wide Area Network (Erol Baran, 2011). A Residential Gateway or modem is required for wireline telephony, internet and interactive television. KPN refers to the Residential Gateway as the "KPN Experia Box". RGs differ in the type of technology (ISDN, ADSL, VDSL, fiber) and the supported speed for which they are used. RGs are generally backwards compatible[12], but 'old' modems that are built for the copper network, are not employable in 'new' fiber networks. In case of a fiber connection (Fiber to the Home) an additional product, a network terminal (NT), is required to connect the glasfiber connection with the residential gateway. The NT converts the light signal into an electrical signal.

Table 1: The product portfolio of KPN fixed

[12] A product or a technology is said to be backward compatible when it is able to fully take the place of an older product, by inter-operating with products that were designed for the older product.

Chapter 2:
Current Situation

2 Current Situation Product Reliability & Reverse Logistics Processes at KPN

In this chapter the current situation of reverse (information) flows and essential information regarding product reliability at KPN are described. As this section will show, product reliability monitoring is currently not well embedded in the processes at KPN. Triggered by anomalies in the call ratio[13] only severe incidents in product (un)reliability are picked up. The information requirements in order to enable product reliability analysis are the subject of this chapter, in the sequence described by research question 1.

Section 2.1 deals with a general reverse flow process overview. This section not only provides insight into the reverse process, it also indicates the range of differences in the products in the reverse flow. These differences complicate the study of product reliability. Subsequently, in Section 2.2 the characteristics of the curre situation are elaborated upon. Section 2.3 describes issues concerning the registration and administration returns. Section 2.4 describes the aspects of the product life cycle of products. Section 2.5 describes warranty agreements relevant for the reverse flow, whilst section 2.6 is dedicated to the Net Promotor Score (a measure of customer loyalty) and Corporate Social Responsibility aspects. Chapter 2 concludes by summarizing the most important findings of this chapter.

2.1 Reverse Flow Process Overview

This section describes which processes the products go through in the reverse flow. The term 'return' is used to describe all products entering the reverse flow, regardless of their age and status. Returns thus include for example new/used working products, products that are returned within the trial period and supposedly defect products. Returns at KPN are handled as described within the Service & Returns (SRET) program. An overview of these stages in the collection and re-employment of returns is given by Figure 9. An extensive description of the activities per stage will be given in the following section.

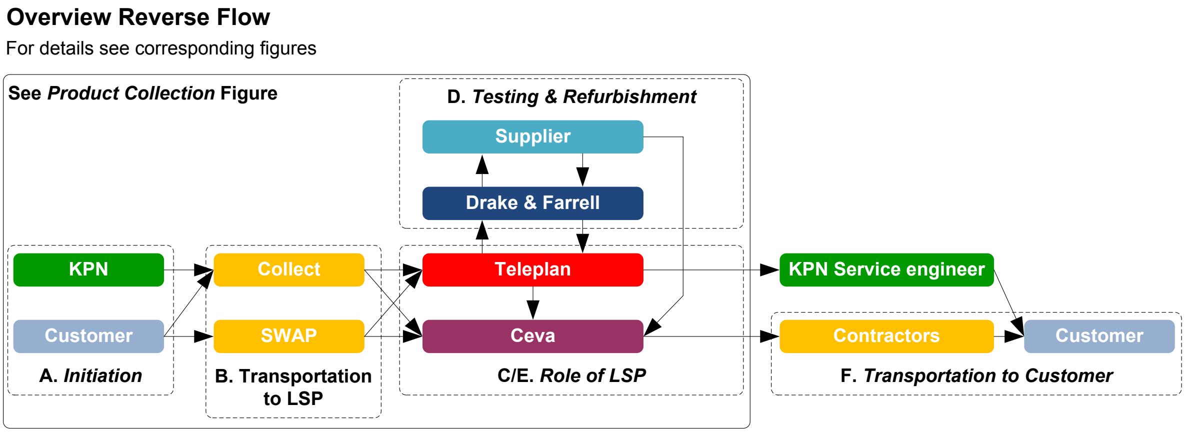

Figure 9: Overview Reverse Flow

A. Initiation

The reverse process can be initiated by KPN or by a consumer. KPN can initiate the reverse process when for example a customer fails to meet its payments. A consumer can initiate the reverse process if he/she wants to report product failure or end its service at KPN. The consumer may do so by contacting *KPN contact*. The steps to be taken in case of a termination of the service are rather straightforward; however in case of a failure-report *KPN contact* has the complex task of assessing what the error is. The extent to which it is able to do so, is product-specific. For example, a problem with Digitenne is harder to analyse for an agent (since there are more factors external to KPN that influence the picture quality) than modern RGs. If the agent is not able to solve the customers' problem by telephonic assistance, the agents' scripts will help the agent to provide an alternative solution for the consumer. For example, if the problem is expected to reside within the network infrastructure at

[13] Call ratio: Fraction of the calls that KPN contact receives that concerns a certain topic. I.e. the call ratio of 'Digitenne cancellations' concerns the fraction of the calls (either total calls or all 'Digitenne' calls) that is dedicated to cancellation to a Digitenne contract.

the customers' house, an appointment can be made for the customer to receive assistance by the KPN service engineer. In case the customer contacts the agent to terminate a service, a collection-order is created for KPN to collect the item. In case the agent suspects the customers' problem resides in the hardware, it can create a swap-order.

Because the analysis that can be performed by agents is by nature not decisive, products that are categorized as supposedly defect. Supposedly defect articles are treated as defects until they have been tested at an Logistics Service Provider (LSP). The analysis at the LSP is binding with regard to the defect analysis.

For consistent use of definitions, Table 2 summarizes the frequently used definitions.

Definitions in reverse logistics		
English	**Dutch**	**Description**
Collect	*"Ophalen"*	Process in which KPN collects working or supposedly defect product(s) at the consumers location without replacement by another article.
Swap	*"Omruilen"*	Replacement of supposedly defect products(s) by new/refurbished articles according to an appointment at the site of the customer. N.B. the courier does not assist with the installation of the new/refurbished equipment.
Hand-in	*"Inleveren"*	Process in which a customer hands in equipment at a certified location such as a postal office.

Table 2: Definitions in reverse logistics

A more refined view of the entity that initiates the reverse flow is by the distinction between the following categories:
1) Return within the trial period
2) Contract cancellation with customer contact
This category contains customers that cancel outside the trial period.
3) Contract cancellation without customer contact + defaulters
This category contains both consumers that are not meeting their payment obligations towards KPN, as well as customers whose contract is cancelled by a third party. The latter occurs for example when an 'internet'-customer changes its subscription to another party, such as Tele2, Online or Ziggo.
4) Swap
A swap occurs when the customer remains a subscriber at KPN, but has a supposedly defect consumer product that needs replacement.
5) Returns by KPN service engineer (car inventory) and inventory returns (both KPN shop as well as external distribution channels)
6) Delivery without collection of old product
For integrality, this option is mentioned here. This flow is relevant for KPN, since it is a result of a KPN decision whether or not to collect the old model. Note however that, contrary to the other options, this option does not result in a product entering the reverse flow.

B. Transportation to LSPs
Retrieving a return from the customer is currently possible by means of 2 processes; collection and swap. Collection takes place if the product at the consumer needs not be replaced by a substitute product. A swap takes place if the consumer maintains the service at KPN and thereby needs a replacing consumer product.
As described in phase A, the reverse flow is initiated by a KPN service engineer or by a customer that contacts KPN contact. If a customer calls with the purpose of ending its subscription (both within as well as outside the trial period) he/she will be routed to the KPN save team[14]. If the save team is unable to convince the customer to stay with KPN, the team will enter an order into the KPN IT system for collection of the customers hardware. The IT system will subsequently guide the order to the appropriate contractor to collect the item at the customers' location. What happens next depends on the product category:

[14] KPN save team: Team within KPN contact that aims to maintain customers that call to cancel their subscription. The team will persuade the customer to stay with KPN by offering him/her custom-tailored promotions.

- Category 1: Products returned within the trial period

Once collected, these products are delivered at Ceva. At Ceva the products undergo a cosmetic and 'simple' technical test. Ceva is equipped with spare parts to execute refurbishment operations in case products fail the cosmetic test. Products that do not meet the technical test are sent to Teleplan for scrapping (executed by Jacomij).

For KPN, the products that are returned within the trial period are differentiated from those that are returned outside the trial period. Those that are returned within the trial period are expected to nearly always be in perfect technical condition. Given the sheer number of returns, and the significantly higher costs of performing an extensive test compared to the simple test performed at Ceva, KPN differentiates those in-trial period products from the outside of trial period products.

- Category 2&4: The product is returned with customer contact (outside the trial period) or is swapped

During a swap a courier offers a replacement product to a customer and picks up the supposedly defect article. Note that contrary to the KPN service engineer, the courier does not assist with connecting the replacement product for the customer, nor does he check if the customer's problem is actually solved by connecting the replacement product.

A pre-condition for the replacing product of a swap is that the replacing product has at least the same functionality as the product that is swapped. For this purpose a differentiation is made between a new model and a service model. A new model can always replace a service model, however a service model can only replace a new model if it is of the same generation as the customer owns.

Irrespective of whether the product is swapped or collected, the product is collected and delivered at Teleplan. At Teleplan the product is subjected to a cosmetic and an extensive technical test. In stage D this testing process is elaborated upon.

- Category 3: Contract cancellation without customer contact + defaulters

For the products in the third category (contract cancellation without customer contact) no suitable arrangements have been made. These products return only if customers themselves send the products themselves.

- Category 5: Returns by KPN service engineer (car inventory) and inventory returns (both KPN shop as well as external distribution channels)

These returns are routed to Ceva. The common characteristic of these returns is that the products are new and unopened, and testing would be superfluous. They are directly added to the forward flow.

C. Role of LSP

Returns can arrive at both Ceva as well as Teleplan. As a starting point Teleplan is the main LSP for the returns. The roles of both parties are as follows:

Ceva is responsible for the forward flow in the supply chain. Products that are returned within the trial period are transported directly to Ceva. Because the technical product test is limited, products that fail the test are routed to Teleplan (i.e. Drake & Farrell) for extensive testing. Suppliers do not certify the test that takes place at Ceva.

The role of Teleplan is to coordinate the subcontractors that carry out the collection from customers (see stage A), coordinate the processes at Drake & Farrell (subcontractor that executes testing and refurbishment on behalf of Teleplan), solve operational issues, provide IT support and a single interface towards KPN and analyze data from Drake & Farrell. Teleplan has licenses for testing and fault analysis of products. This certification ensures that the results that follow from test by, or on behalf of Teleplan, are decisive; they are accepted without further investigation by suppliers.

Whereas Teleplan is responsible for strategic and tactical improvements in the testing and refurbishment, such as the development of a time-saving and quality improving automatic testing procedure, the execution of testing and refurbishment is executed by Drake & Farrell.

D. Testing & Refurbishment

Testing & Refurbishment is executed by Drake & Farrell and is commissioned by Teleplan. Schematically the processes at Teleplan are depicted by Figure 10. Upon entry the products are scanned and the serial number is identified. The products that are suitable for re-deployment consequently undergo a technical quality check. This quality check is certified by vendors, and the results of this check are thereby binding in subsequent stages.

Many of the service offerings by KPN are rental-based as opposed to buy-based. Digitenne is the only service for which customers can buy the tuner. It that case they will still require a smartcard to insert into their Digitenne to receive television signal. The smartcard in turn is coupled to a Digitenne subscription.

Furthermore, the testing process has the following outstanding characteristics. The test results show No-Fault Found percentages is in any case greater than 50% but can range up to 90%. This implies a large share of the returns are not defect, and can be redeployed with mere cosmetic rework. Part of the explanation for the large number of products without defects is the complexity of product testing. I.e. in particular for Digitenne and IPB tracing errors is complex for various reasons. With IPB, an RG that may fail on one day, could be working the next day, without clear reason. For Digitenne, the image quality is dependent on the signal quality, which in turn is dependent on a wide range of factors, including the distance to the 'signal' tower and building activity in the area of usage. Such factors cannot be overseen by KPN and analysis by KPN Contact is thus limited for these products. As a result, a relatively high number of non-defect returns are tested.

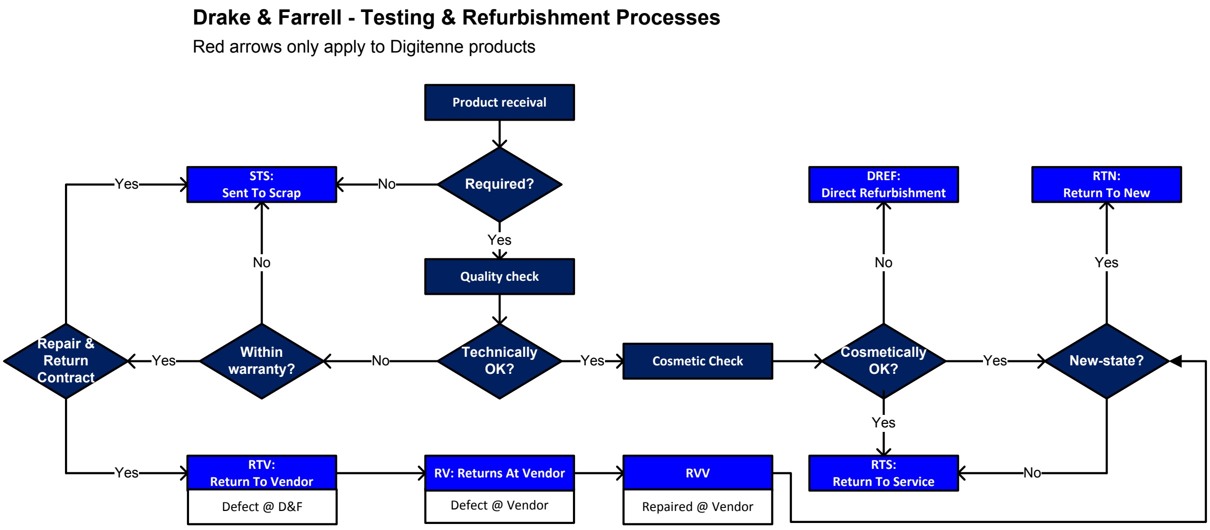

Figure 10: Testing & Refurbishment process at Drake & Farrell

E. Role of LSP

Products that enter stage D are only those products that are suitable for redeployment and that should therefore enter the forward chain. All these products should be routed to Ceva for subsequent distribution, except for the stock of products for KPN service engineer[15] that is distributed from Teleplan. The products that arrive at Ceva are unopened returns, used but re-deployable articles (including refurbished articles), and repairs that are shipped in by vendors.

F. Transportation to Customer

Products on stock at Ceva should be suitable for re-deployment by means of the 'normal' forward flow. The options for customers regarding the picking-up an collection of products are limited and expensive for KPN. Therefore KPN is investigating the implementation of the options outlined in the KPN logistics 'menu' (see Appendix C; not all options on the menu are currently offered). This menu should offer customers more options for picking-up and handing-in products, tailored to the value of products and the preferences of customers.

Note that in the current process products that have a hardware defect are scarcely repaired. Only products that are returned within the warranty period and for which a Repair & Return contract exists (as opposed to discount

[15] In the future, a second stock level will be kept at Drake & Farrell for contingency purposes, allowing for resilience in the event of a disruption at Ceva.

or over-delivery) are repaired at their respective vendors. Another category are Residential Gateways for which a software update can suffice to make a product new-state again. These software updates are performed by KPN's LSPs.

Summarizing, the variety of flows is influenced by the categories depicted in Table 3. Together with KPN employees it has been determined that the topics printed in *italic* are the factors that complicate the reverse flow most, and thus deserve special attention in this report.

	Determinants	Categories
1	Type of return	Multiplay, Digitenne & ITV
2	*Order*	*Collect or Swap*
3	*Replacing model*	*Service or New*
4	LSP	Teleplan or Ceva
5	Initiation	In trial period, Cancellation with customer contact, Cancellation without customer contact, Swap
6	Digitenne	Buy or rent
7	*Contact with customer*	*Yes/no*
8	Within trial period	Yes/no
9	Redeployment	Yes/no
10	ITV	One or more units
11	Packaging	With or without/ complete or incomplete
12	*Pre-announced/non pre-announced returns*	*Pre-announced (order entered by callcenter agent) or non-pre-announced return (their RMA starts with CA)*

Table 3: Summary of determinants in the reverse flow

2.1.1 New / Service Models

KPN aims to have 2 models supporting a service; KPN differentiates between 'new' and 'service' models.
'New' models are those models that are (1) currently ordered as new from suppliers and (2) are the latest models that KPN supports. Their specifications and functionality are at least as good as the models they replace. Service models are models that are still delivered to customers but are not the latest model, not new, or both. Note that service models are cosmetically identical to their new-state, and can (therefore) also be delivered for new contracts.

In case of a swap a customer always receives a model that is at least as good as the model it means to replace.
For new customers this implies that, particularly in case of scarcity of new model stock, they might receive a service model. In practise, several factors complicate having two models per service. KPN has a dual-vendor strategy (though not implemented for all services). For example, there are two suppliers of Digitenne tuners and both can be delivered as new and as service model. Also, since phasing in and out of products can be imperfect and discount on older models can make it sensible to acquire older production models, more than 2 models per service are generally on stock.

Figure 11 indicates the introduction of new models as a function of time for a service. Note that the technical support required for all these models expands dramatically. Particularly for ITV and IPB, which are connected to the KPN network, this implies that the hardware and software management for all these models becomes a complex task. This in turn stimulates the management of the installed base by pro-active replacement of the eldest models (here model A) of the installed base.

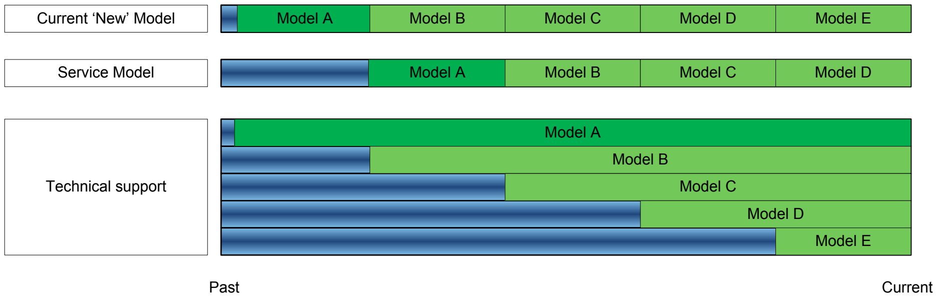

Figure 11: Multi-model support by KPN

2.1.2 Product & Information Flows

Figure 12 depicts the information flows triggered by customer calls (where arrows A & B indicate physical product flows).

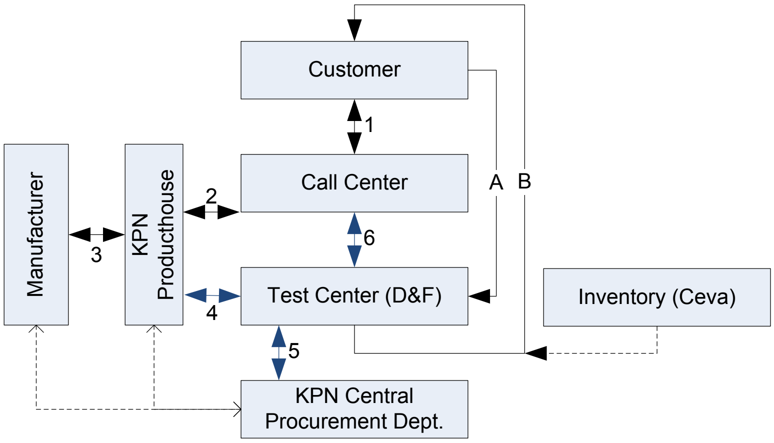

Figure 12: Information flow front-end and back-end

Arrow 1 indicates the customer contacting the KPN call center with a question, compliant or request for cancellation of the subscription. This interface with customers is commonly referred to as front-end communication. The complaint-topics and number of complaints provide valuable information about the products and their shortcomings. However, in general the nature of the information is mostly directed towards KPN processes and billing. Those problems that are hardware related predominantly involve product design changes. Good examples of changes initiated by the front-end are the change of the design of reset-button of RGs, after it turned out that many customers accidentally demolished it. Also, it turned out that customers whose equipment had been struck by lightning were unable to reset their RG. By means of a hardware change (dual memory banks instead of a single memory bank) this issue was resolved. Arrow 2 and 3 refer to communication to ensure these design changes are realized.

The extent to which call center agents are able to conclude with certainty that the error actually resides in a failing consumer product is limited. This is because malfunctioning can occur as a result of a multitude of factors, such as errors resulting from KPN infrastructure, errors resulting from the way the customer connects products, product failures, etc. Product defects, and detailed information about bad build quality production series, are not integrated into this information flow. These results can typically be determined at Drake & Farrell (the Test Center).

Information flow 4 and 5 reflect information flows that are not embedded into the current processes. Note that products that arrive at the test center are either:

- products for which KPN contact assessed they are defect
- products from services that are cancelled by the customer

Analysis of returns, as described in literature, often has the purpose of product quality and design improvement, i.e. learning from defects. However, since KPN is not the manufacturer of the products, it has very limited influence over the design of the consumer products. For the purpose of product design improvement, information is gathered from KPN Contact helpdesk. However, from this information it cannot be determined with certainty if products are defective. Data from the test center Drake & Farrell is used for this purpose.

2.2 Characteristics of the Current Installed Base and Reverse Processes

The characteristics of the current reverse processes are described along the installed base[16], the number of swaps/collection orders and the costs.
The installed base is a crucial indicator of the amount of expected future returns of a product. In short, the expected future returns are expected to depend on 1) the average (technical) lifetime expectancy of a product and 2) the number of products used throughout the country, or the installed base. The installed base contains products of various ages, and therefore, the growth of installed base, which provides insight into the average age, is also relevant.
The analysis of returns with differentiation between swaps and collection orders is particularly interesting from the test result perspective. A high ratio of defective products out of the total number of collection orders potentially indicates that customers are needlessly lost, since it is likely that they end their subscription because they unknowingly have a defective product.

2.2.1 Installed Base

The installed base of the different product portfolio's is as follows:
-- KPN Classified Information --

2.2.2 Number of Swaps and Collection orders

-- KPN Classified Information --

2.2.3 Costs

-- **KPN Classified Information --**

2.3 Registration and Administration of Returns

The registration and administration of returns is a complex process. The related processes are described, by differentiating between the entity that enters data, the data collection point and administration-issues.

2.3.1 KPN Contact and KPN Service engineers initiate return flow

Entry of returns in the return flow results from orders entered by two entities: KPN Contact call center and KPN Service engineer. If a call center agent initiates a return order, a unique product return number (or RMA code) is created upon entry of the order by the agent. The customer is asked to tag the component that enters the reverse flow with this RMA code. Subsequently, upon arrival at the testing station at Drake & Farrell, the product details are entered into the IT system Repairnet.
If a return is initiated by a KPN service engineer, or sent by a customer without RMA code, products arrive at Drake & Farrell in bulk instead of uniquely tagged. A consequence hereof is that it is not possible to match the test results of a unique product to a unique customer problem.

In 2010, out of all returns that arrived at Drake & Farrell, only about 3/8th of all returns has an RMA code attached. This makes tracing back the customer complaint with the product error more difficult.

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16 Installed Base: The total number of, in this case, residential gateways that is working throughout the Netherlands (Baran,2011).

2.3.2 KPN Contact and Test Center (D&F) collect product and customer data

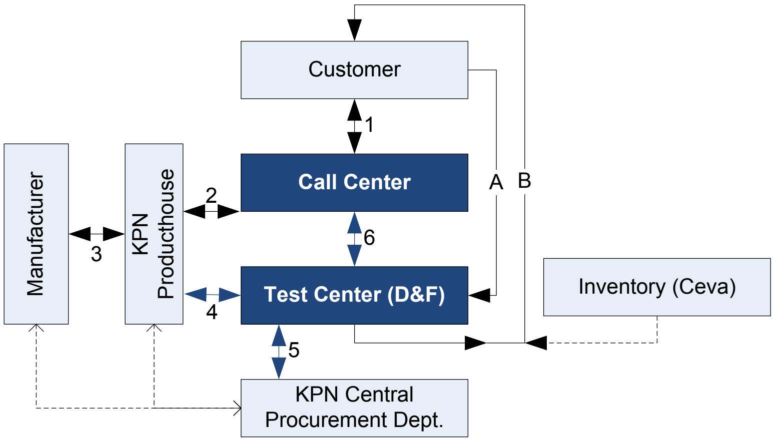

Figure 13: Information flow front-end and back-end (call center and test center highlighted)

Figure 13 highlights the call center (KPN Contact; front-end) and the Test Center Drake & Farrell (back-end). These are the two main places in the process where data is administered.

Returns administration at KPN Contact
When a call center agent enters a return order, it enters various fields of information in the order entry system. Important fields that are entered for the reverse process are the RMA code, the date of collection, the customer details, the smartcard number and in case of Digitenne, it is indicated if the product is bought or rented. In appendix D an extensive overview of the required data entry that is required is provided.

KPN contact in turn exists out of two departments with distinct tasks. The first is the generic service desk, which helps customers with (technical) problems. In case the problems result in an analysis of a defect product, this will generally lead to a swap or collection order to replace the malfunctioning product.
In case a customer calls to end a subscription, the call is forwarded to the save team. The save team's processes are identical to those of the generic service desk, however the save team is able to offer the customer a custom tailored promotion to persuade it to remain a customer of KPN. In case the save team is unsuccessful in doing so this could result in a collection order.

Returns administration at Ceva/Teleplan
Upon receival of the main component at Ceva or Teleplan, the product is identified and the return-order is matched with the outstanding return order in Repairnet. Should the RMA code be missing, Ceva/Teleplan have several search options to see if the returns can still be matched with outstanding RMA's (by KPN contact). Teleplan than updates the record in Repairnet according to the test results found. Important fields that are updated are: the actual date of collection, the serial number, the mac address or smartcard number, the hardware version and the software version, whether the product is inside or outside its warranty period, if the product is defect, if it is restored after a software update and if not, which error code belongs to it (for further defect analysis by suppliers).

Data processing
The processing of returns data is executed by Teleplan, Ceva and KPN. Teleplan and Ceva process data to report if they meet the service level agreements made with KPN. KPN processes data to create a closed control loop. The returns information is matched with the KPN contact information to provide a loop in which not only the customer's complaint is linked to the product test results, but can also be used to coach the agent that had assisted the customer in the first place.

Testing method
The testing method that is applied to ITV tuners and Digitenne tuners is a standardized method that runs through a sequence of tests certified by the suppliers. The steps that are ran through are identical in each test. For Digitenne, the tests provide results on whether the tuner is working or not, and what the antenna power output is. For ITV tuners the testing process is more extensive, and the software returns a code where the tuner stalls.

2.4 Product Life Cycle

To describe the life time of products, three different perspectives are used:

1) Technical lifetime
The technical life time refers to the time the product can be utilized until technically breaking down. The technical lifetime varies per product and usage. The technical product lifetime is agreed upon in contracts by means of agreeing on a MTBF. The technical lifetime is relevant to KPN with respect to the warranty agreements that KPN closes with manufacturers.

2) Financial lifetime
The financial lifetime refers to the depreciation rates used on the financial balance sheet. To account for depreciation/deterioration of products, KPN currently employs a fixed depreciation rate over the entire installed base. Products are depreciated over a lifetime of 3 years.

3) Product life time for KPN
For the product life time, various definitions are used within KPN. The life time, delimited by the introduction and 'phasing out' of the product depends on the perspective of a department. The difficulty is that whilst the introduction date of a product is unambiguous (it equals the first delivery after a pilot), the 'phasing out' date of a product depends on the adopted organizational perspective. Products that have a successor might not be distributed to new customers, but they could still be used for service products (replacement product of existing customers). Also, models might be kept on stock "just-in-case". By all means, the installed base needs support to ensure it keeps working.

In the Producthouse department the product lifetime is defined as the time from introduction of a product until introduction of a successor. The introduction of a new model depends on various factors, out of which from a Producthouse perspective the most decisive are determined to be: Technology, call ratio, NPS, costs , failure rate, quality (Van der Meij, 29-03-2011).

Technology:	Technological development is the main driver of new product introductions.
Call ratio:	The call ratio refers to the amount of calls that concern a specific product model or service as ratio of the total number of calls. In case the call ratio is significantly high, structural drawbacks of the product induce to the need to replace the product.
NPS:	The Net Promotor Score, which indicates the customer loyalty, can cause the need to replace a product. If the NPS of a service or product is consistently declining, the product that delivers a service such as internet is replaced by a successor.
Costs:	Lower costs drive the introduction of new models.
Failure rate:	The failure rates of products provide a legitimate reason for introduction of a succeeding model. The failure rate of models is monitored, though there is no strict definition of which failure rates are unacceptable.
Quality:	Product quality, such as cosmetic quality, influence the new product introduction process.

The decision to introduce a new product is also highly dependent on plans of the marketing department, since the decision to launch a new product is made in accordance with the marketing department.

Currently KPN does not have a pro-active replacement strategy of products in the installed base. The information about the average technical lifetime that is gathered in this research will be used as an input for decision-making regarding the feasibility of such a plan.

Technology was mentioned as a driver of new product introductions. Note that this not only comprise technology changes in the STB's, but also technology changes in the KPN network. Note that for example current STB's are only compatible with NokiaSiemensNetworks-platform, which is based on an ancient technology (Haaze, 2010). Change of platform will also cause depreciation of older STB and a substantial investment for replacement (Haaze, 2010). Figure 14 displays the stage on the PLC for the current KPN services.

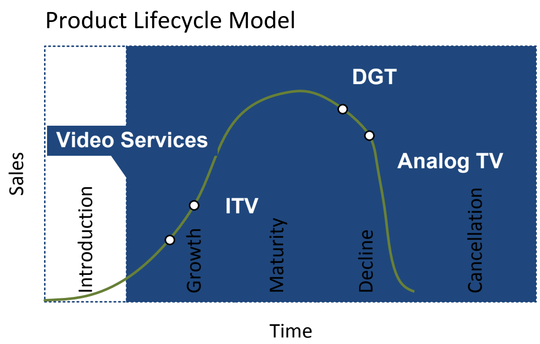

Figure 14: Product Lifecycle KPN Services (Haaze, 2010)

The technology of Digitenne, both for the infrastructural side at KPN as well as for the consumer product located at the consumer, have long lifecycles. This is partly inherent to the technology used: since, contrary to modern ITV tuners and RGs, no software updates can be exchanged with Digitenne tuners once a tuner is used by a consumer. The technology lifecycle of IPB products is shorter. ITV technology lifecycles are the shortest of the three, and this technology is still in the growth phase.

2.5 Warranty Agreements

-- KPN Classified Information --

2.6 Netto Promotor Score (NPS) and Corporate Social Responsibility (CSR)

Customer loyalty and CSR are focus areas for the business execution of KPN. To assess a customer's loyalty towards KPN, KPN uses a system based on the Net Promotor Score. The concept that is central to the NPS philosophy is that the extent to which a customer recommends a service to others is a better predictor of customer loyalty than questions about a customer's satisfaction. The NPS Score is measured at several levels. At the highest level it is established whether a customer is inclined to recommend the brands KPN, Telfort, Hi, etc. to others. One level down, the NPS-score is determined on a product or service level, such as KPN internet.

The Net Promoter Score is obtained by asking customers a single question on a 0 to 10 rating scale, where 10 is "extremely likely" and 0 is "not at all likely": "How likely is it that you would recommend our company to a friend or colleague?" Based on their responses, customers are categorized into one of three groups: Promoters (9-10 rating), Passives (7-8 rating), and Detractors (0-6 rating). The NPS score is calculated on the basis that promoters add +1 to the NPS, a passive response does not change the score, whilst detractors deduct -1 from the NPS score. KPN performs NPS measurements extensively at least on a quarterly basis, but more often if KPN wants to measure the effectiveness of a single process change (think of additional information to inform customers about the delivery status of their order).

Aside from inquiring about the NPS-score that customers would give to KPN, KPN asks customers what KPN can improve in its processes and products to improve that customers satisfaction. Because KPN structurally and consistently measures its NPS score, it is able to test the effectiveness of changes in its customer processes. For example, a structurally increased NPS score with respect to delivery indicates that the SMS-service that is implemented to confirm a customer-appointment is effective.

The NPS measurements are important performance indicators for KPN. Almost any decision that affects customers is analysed thoroughly on the impact it has on customers, and how customers will evaluate KPN's actions. The level of customer satisfaction is also a starting point for this research, since KPN is willing to invest in pro-active actions in order to ensure customers maintain satisfied.

Aside from the NPS score, Corporate Social Responsibility is an increasingly important business aspect for KPN. KPN's Corporate Social Responsibility policy is an inseparable part of KPN's business strategy as it is KPN's ambition to strengthen its position as a leading service provider which infuses trust and loyalty amongst its customers, employees and other stakeholders (KPN, 2011). KPN's efforts were rewarded by inclusion in the Dow Jones Sustainability Index in September 2010. According to independent experts, KPN now belongs amongst the 10% most sustainable telecommunications companies in the world.

As is clear from the above, the NPS and CSR consequences of changes in the reverse logistics policy should be taken into account.

2.7 Chapter 2 Summary & Conclusion

This chapter offered an overview of various aspects of the processes in reverse logistics. This chapter answers the first research question: "*What is the current situation regarding product reliability management and reverse logistics information for CM fixed products?*"

The chapter commenced by indicating that there is no structural method of monitoring returns information and product reliability. The sections in this chapter explore the business areas that required to analyse product reliability and reverse information flows in the remainder of this report.

Section 2.1 indicated the complexity of the return flow, and more particularly the wide range of differences in products, product characteristics and product propositions that form the reverse flow. The aspects that have most impact on data usage from return flows are 1) Type of order: collection or swap, 2) contact with customer or without, and 3) pre-announced or non-pre-announced order. Furthermore the distinction between the front-end information entry and the back-end testing process, and the lack of linkage amongst the two was pointed out.

Section 2.2 dealt with the characteristics of the installed base and the reverse logistics processes. Since this research focuses on determining reliability by analysing returns, the installed base and the characteristics of the reverse processes are essential aspects.

Section 2.3 dealt with the largest problematic issue in current reverse logistics processes: the registration and administration of returns. Although currently a trend of improvement is visible, especially in the returns in the beginning of 2010 often lacked RMA numbers or had missing fields in the return database required for product identification (such as a serial number without an article number; i.e. with no product), due to which it is difficult to 'use' the data from these returns.

Section 2.4 elaborated on the lifecycle stage of the services of KPN fixed and the aspects taken into account when introducing a new product. Notable is that when introducing major market changes not only the consumer product but the network infrastructure at KPN needs to be taken into account as well. Furthermore, ITV is in a growth phase, whereas Digitenne is a mature technology.

Section 2.5 warranty agreements had one important message: different forms of warranty agreements are made with different suppliers of different products, but there is no structural feedback loop to ensure that these warranty agreements suffice/are effective.

Section 2.6 explored the field of Net Promoter Score and the field of Corporate Social Responsibility, an important measure of customer satisfaction handled by KPN. This makes clear that the pro-active handling is influenced highly by expected customer satisfaction.

Chapter 3 will now provide extensive literature and industry related sources to support the views upon the improvements in monitoring of product reliability and improvement in reverse logistics.

Chapter 3:
Literature Study

3 Literature Study

This chapter is dedicated to answering the second research question, by exploring the literature field dedicated to Maturity Index on Reliability, reverse information flows and product reliability management. The literature study follows the structure indicated by the research questions. First, Section 3.1, is dedicated to the introduction of the Maturity Index on Reliability. Section 3.2 is dedicated to MIR 4 literature, which consists of the factors that are to be taken into account when taking a decision to pro-actively act, the implications of the life cycle stage and the relation between economic and technical lifetime. Section 3.3 is dedicated to MIR 3 literature, encompassing factors that determine product reliability and root-cause analysis methods. Section 3.4 is dedicated to an abstract review of MIR 2 literature. Section 3.5 is dedicated to MIR 1. This sect ion introduces the Quality and Reliability Reference model. This model is used to see the difference between various reliability issues that can exist. Once these dimensions upon which reliability problems can occur are identified, Section 3.2.3 deals with quantitative indicators of reliability from using field information. Section 3.5.3 is dedicated to techniques to model product reliability. Aside from the literature related to the MIR model, Section 3.6 provides an overview of barriers and facilitators in managing reverse logistics. This section has been added to the MIR model, because we found that the MIR model did not suffice for describing all improvement areas for KPN. The chapter ends with a summary and the conclusions from the findings in this chapter.

3.1 Introduction

Analysing and managing product reliability has several goals, such as obtaining early identification of failure modes and understanding and removing their root causes and thereby improving reliability (Broek, 2001), estimating the costs of non-quality, and in particular the warranty costs (Juran and Godfrey, 1999) and deciding on the need for recall of a product in the field and perhaps extend it (Juran and Godfrey, 1999). In order to measure the maturity of an organisation on reliability management, the Maturity Index on Reliability can be applied[17].

The Maturity Index on Reliability contributes to the analysis of reliability by not only analysing the technical aspects of a product, but also analysing the (quality of the) reliability control loop of the organisations developing and operating a product. The quality of the reliability control loop can be measured in two aspects:

- the quality of the reliability related information in the loop
- the development of this information into the business processes

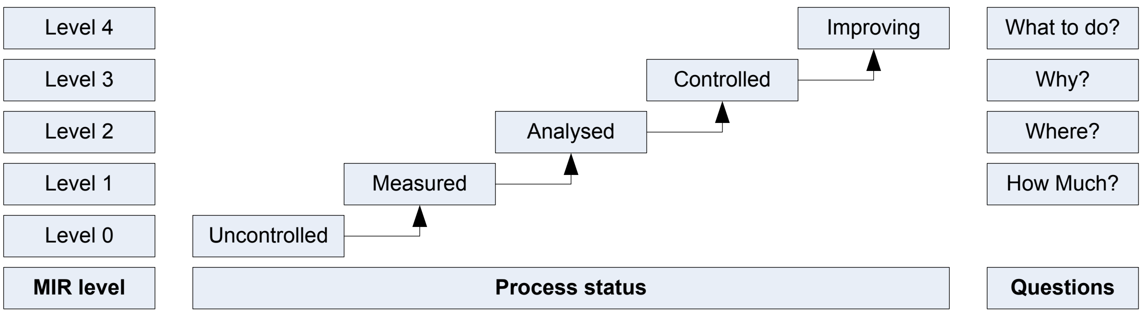

Figure 15: Maturity Index on Reliability model (Brombacher, 1999)

In order to measure these aspects, the MIR concept is used. This scale of five levels reflects the increasing capability of an organisation to analyse, predict and improve the reliability of current and future products. In order to qualify for a maturity level n, the requirements level n-1 and lower have to be fulfilled (Brombacher, 1999). The five MIR levels, depicted in Figure 15, are defined in Table 4.

[17] Reliability is defined as the probability that a system will perform its intended function for a specific period of time under a given set of conditions (Petkova, 2003)
Reliability and quality are often used interchangeably. In this thesis quality refers to the product features and characteristics at the time of sales. As soon as the product behaviour as function of time is discussed, then the word quality should be replaced by reliability.

MIR Level	Stage	Description
MIR Level 0	Uncontrolled	No adequate information available (Boersma et al., 2005)
MIR Level 1	Measured	Adequate metrics are in place (Boersma et al., 2005) Quantitative information is available per product indicating the number of failures in field and production (Petkova et al., 2005)
MIR Level 2	Analysed	Adequate deployment of information is ensured (Boersma et al., 2005) Quantitative information is available on primary/secondary failure location (Petkova et al., 2005): - primary (organisation): Location of the cause of failure within the Development Process; - Secondary (position): Location of the failure within the product (Part NR, Conditions, etc.)
MIR Level 3	Controlled	Adequate knowledge on the cause of a failure is available (Boersma et al., 2005) Detailed information is available for all dominant failures on root-cause level. This can be translated into risks for future products.
MIR Level 4	Improving	Ability to continuously adapt business processes in such a manner that potential problems will be anticipated (Brombacher, 1999) Methods and tools are in place to anticipate on reliability risks for future products and eliminate these risks where needed. (Petkova et al., 2005)

Table 4: Definition of levels in Maturity Index on Reliability

MIR 0: Uncontrolled
There is no relevant quantitative information available of customer complaints about the products. For example, this means that there is no information about the time of repairs, the age of the products or the number of products sold. No control loops are in place from the service department back to the development and production department. In this situation, the process status is uncontrolled and the organisation is in absolute chaos (Boersma, 2001).

MIR 1: Measured
There is a basic feedback system that gives quantitative information, indicating the number of problems during production and the number of field failures. This information is fed back to other relevant departments in the organisation. But still, there is no idea what the causes of the customer complaints are. This level only gives indicators of the performance during the production and the performance in the field. In order to be informative, these numbers must be seen in relation to the quantity produced and quantity sold. In this situation the process status is measured (Boersma, 2001).

MIR 2: Analysed
The company has quantitative information about the origin of the customer complaints and knows what the primary and secondary locations are. At the primary location, the complaints can be either categorised as technical or organisational problems. This location gives insight in the quantity of design, production, material or customer use problems. The secondary location describes where the failures are located within the products, like for example the part number. This level possesses the corresponding information control loops, but there is still a lack in knowledge to define what actually the specific cause is. At this moment the process is analysed (Boersma, 2001).

MIR 3: Controlled
The company has quantitative and detailed information about the root causes of all the dominant failures and of the information about the behaviour of the customers in the field. These root causes can be translated into risks for future products and processes. However, the company is not able to prevent these problems in the future, which means that the process status is controlled (Boersma, 2001).

MIR 4: Improvement
The company has the quantity of complaints available, knows the origin of the problems, what the root causes of the problems are and what to do about it. By using methods and tools, the company is able to anticipate and prevent similar problems in the future. The problems are analysed, predicted and verified against the data from production and service. At this moment all control loops provide the right information to eliminate risks in the future and the feedback is directed to the responsible persons. At this level the company has reached the status of a learning organisation. This means that the organisation is able to react effective and efficiently on external disturbances and creates the ability for continuous improvement (Boersma, 2001).

Use of the MIR model
The ideas behind the MIR model are valuable but the MIR model has various weaknesses. Petkova (2005) argues that the MIR levels are presented as a hierarchical system, but the structure is basically a classification. For example, the MIR concept implies that MIR 3 can only be reached after MIR 1 and MIR 2. However, MIR 1 is about statistical information: how much, while MIR 3 is about root causes: technical information. Petkova (2005) argues that companies should start with root cause analyses immediately after market release. Based on the root cause of the first customer complaint, engineers should try to find out whether the problem is only an incident, or a serious problem.
Of course, one should also start with collecting statistical information immediately after product launch, but root cause analyses should be performed, and the results used, long before the statistical information will be available. Valuable time will pass if companies strictly follow the MIR-procedure and first concentrate on MIR 1. By going for MIR 3 first, one should of course avoid premature decisions that are only based on relatively unimportant incidents.

The MIR levels should be seen as classes, and for this reason it is better to talk about MIR aspects than about MIR levels (even though MIR 4 is not independent from MIR 1 and MIR 3). Bearing the research objective of this thesis in mind, it is decided to focus upon MIR level 1, 3 and 4 in order to make it possible to measure reliability and pro-actively anticipate upon reliability issues.

Whilst bearing in mind the MIR 4 goals, this literature chapter elaborates on the relevant literature per MIR aspect in a sequential order. Notably, the MIR Model does not prescribe which tools/ procedures/ information/et cetera. should be in place per MIR aspect in order to satisfy the requirements per MIR aspect. An exploration of the relevant literature per MIR aspect has resulted in the following sub-topics per MIR stage:

On MIR level 4 literature is used to explore the options regarding pro-active actions based upon observations on lower MIR levels. Literature is also used to retrieve the arguments upon which the decision should be based. Furthermore, theoretical viewpoints upon the product life cycle implications (for insight into the non-technical lifecycle of products) and the economic and technical lifetime of products are reviewed, since this has turned out to be an important factor. The importance is thus less on how to modify products to increase future reliability.

On a MIR level 3 the factors that determine product reliability are reviewed. This entails both literature regarding the known causes of unreliability as well as literature about tracing the root-cause of a problem.

The MIR 2 analysis, which analysis the location of the problem in for example materials used or design of the product, is reviewed to a smaller extent. Due to time limitations we determine that the other MIR levels should receive greater attention.

A MIR level 1 organisation has adequate metrics in place (Boersma et al., 2005). Literature is consulted to identify which phenomena should be measured to be able to analyse product reliability, which methods are appropriate for analysing reliability and which variables need to be measured.

3.2 MIR 4

Ability to continuously adapt business processes in such a manner that potential problems will be anticipated (Brombacher, 1999).

Petkova (2005) defines that organizations of MIR level 4 have methods and tools in place to anticipate on reliability risks for future products and eliminate risks where needed. Exactly which methods and tools should be in place, is not defined.

For MIR 4 analysis it has been determined that literature regarding the range of pro-active actions that can be taken and the factors to be taken into account when making a pro-active action should be reviewed. The literature related to these topics is set forth in Section 3.2.1. Since the decision to pro-actively act includes the possibility to replace products in the installed base, a large capital investment is required which has to be in line with the strategy for that product. Section 3.2.2 elaborates upon these strategic issues by reviewing relevant Product Life Cycle implications. Section 3.2.3 is dedicated to the comparison of economic and technical lifetime. This relates the (technical) failure behaviour to economic lifetime as an input for the strategic factor in pro-active decision making in MIR 4.

3.2.1 Pro-active actions and factors to be taken into account

A MIR level 4 organisation is not only able to learn from previous events in such a manner that possible differences between prediction and actual performance are well controlled, but is also able to continuously adapt its business processes in such a manner that potential problems will be anticipated.

Pro-actively addressing problems in products in the installed base can be achieved by means of product recalls. The effectiveness of such product recalls, and thereby the effectiveness of the pro-active action, is strongly related to: product sale price, average useful life of the product, number of affected units, the time the products have been in the market, percentage of units in consumers' hands, type of recall action, and level of direct consumer notification (CPSC, 2003).

Berman (1999) differentiates between various costs of a recall including those for communication to intermediaries, business customers, and final consumers; physical distribution in recovering and returning the recalled product; product replacement or repair; product disposal; and the loss in profits for the recalled and related products due to diminished sales during and after the recall period.

Kumar and Schmitz (2005) differentiate between the following factors to take into account in case of a product recall: communication costs, loss of sales, cost to maintain business interruption, inventory losses, cost of refund/ compensation, logistic costs and the costs of fines/lawsuits.

3.2.2 Life Cycle level of analysis

This section is an addition to the factors that should be taken into account in making a pro-active decision (Section 3.2.1). Due to investments involved, there is a strong strategic element in the decision to pro-actively act. Note that the KPN-products that a customer has (for example a Digitenne tuner) can be distinguished from the service it uses at KPN (i.e. Digitenne). The life cycle level of analysis assists in relating the developments on model level (i.e. a Digitenne tuner) to the developments of the service (i.e. Digitenne). Before proceeding to the life cycle level of analysis, the standard product life cycle is introduced.

Product Life Cycle

Over the life of a product, a firm does not know exactly how future sales will change from one period to the next but, typically, the sales of any one product will follow the well-known product life cycle curve. From initial concept until its cancellation, a product passes through several distinct phases.

After the product is introduced, sales begin growing slowly, until a critical mass of consumer awareness is reached, and sales grow rapidly. Eventually, the rapid growth cools, and the product enters a sustained period of slow growth, or level sales. Eventually, sales will decrease, at first slowly, then perhaps more rapidly. Once sales fall below some threshold level (which may be different for each company), the product will eventually be terminated, and sales will drop to zero. The life cycle is typically divided into four phases (see Table 5), though some authors add an initial phase of development, and others add a final phase of cancellation, as is shown in Figure 16.

Stage in PLC	Characteristics of the stages of the Product Life Cycle
Introduction:	This phase represents the time when a new product is first brought to the market. This time must be kept as short as possible because of the fast moving and highly competitive market. Often there doesn't exist proven demand for it, and often it hasn't been fully developed technically. Sales are low.
Growth:	In this phase the demand begins to accelerate and the total size of the market expands quickly. This stage is therefore also referred to as the 'take-off stage'.
Maturity:	When the growth is over, demand levels off and growth can only be realised by replacement and new product family introductions.
Decline:	When the product is phased out, the decline phase emerges. In this phase the technology is often replaced by new technology because further improvements become very difficult to achieve.

Table 5: Characteristics of the stages of the Product Life Cycle (Levitt, 1965)

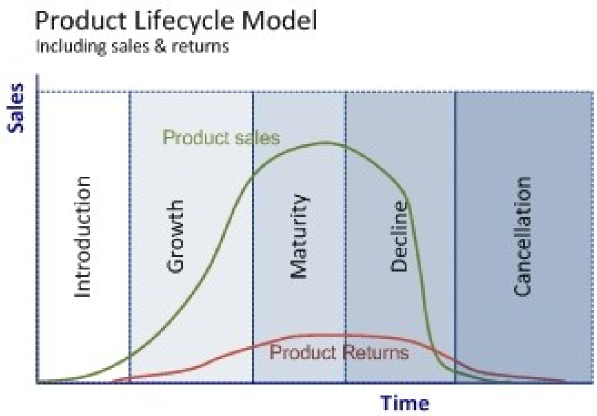

Figure 16: Product Life Cycle Model (Tibben-Lembke, 2002)

Instead of reflecting on the lifecycle of a product model, a more integral view of the lifecyle can be gained by reviewing the lifecycle of the model in relation to the life cycle of the product form and product class.

Tibben-Lembke (2002) differentiate between the following 3 data levels upon which life cycles can be analysed:

1) The life cycle of the product model
2) The life cycle of the product form
3) The life cycle of the product class

Product model: At the product model level, changes from one model to the next will be relatively minor. When sales of the product class are growing, holding strong, or even declining, the vendors will continue to offer new models of the product, which may offer slight differences over previous models.

Product form: The life cycle curve of the product form is obtained by adding up the sales of all products being sold in this particular form. A significant technological improvement, marks a stage in the evolution of the product from one generation to the next. The changes from one form to the next might represent "major product changes" or "partially new products."

Product class: The life cycle curve of the product class is the sum of the sales of all forms of the product. The introduction of a significantly different technology may lead to demise of the previous technology. The appearance of new products of this type would be "unquestionably new products".

The literature does not relate the state in the life cycle on product model, product form or product class with the suitability for redeployment.

3.2.3 Economic and Technical Lifetime

The final section in MIR 4 is dedicated to economic and technical lifetime. Differentiation between these perspectives on lifetime shows that there are certain characteristics in the failure rate curve that are for example particularly relevant for products with a short economic lifetime. This section elaborates upon the relevant phenomena in failure rate curves.

A. *Business processes depending on products where the economic lifetime is much shorter than the technical lifetime.*

Especially thanks to recent developments in semiconductor industry and, related, developments in information technology it is for products in this category not uncommon to be discarded and to be replaced by a product with more/better functionality. In this case the economic life (often 0–3 years) of a product is shorter than the technical life. Manufacturers of disposable products typically belong in this category, but also manufacturers of short cycle consumer products. Companies in this category will try to employ the latest technology in the shortest possible time in order to achieve (or maintain) a competitive advantage.

B. Business processes depending on products where the economic lifetime is comparable to the technical lifetime.

This second category consists of the business processes that generate products with an extended (3–10 years) but still moderate lifecycle. Products like cars or more traditional consumer products have a modest degree of innovation (and the inherently related time pressure in their development process is also modest). Since in these business processes the emphasis is not on innovation but mainly on product costs this category will use different business processes and therefore different methods and tools to assure product performance, quality and reliability.

C. Business processes depending on products where the economic lifetime is much longer than the technical lifetime.

The third category concerns business processes that are depending on systems with a long lifecycle (10 years and beyond). The companies build, use, and maintain these systems to generate other types of products: mostly raw materials like chemicals or food. Here the degree of innovation is low due to considerations with respect to safety and the impact of failures when things go wrong. If a new technology becomes available it is rigorously tested before it is applied. In contrast with the earlier processes the emphasis will be on avoidance of (functional) risks, on system availability (uptime) and on the safety of the systems used.

The class A business process, generating short lifecycle products, distinguishes itself by its focus on ‘time’. Since new technology keeps becoming available at a high speed companies will want to take maximum benefit from this technology. Therefore in order to maximally benefit from new technology, companies will drive for the shortest possible ‘time to market’.

Business processes of type C, concerned with systems where high capital investments are required, will have a focus on maximizing the utilization of the investments made. The product has therefore to fulfil its function with a high efficiency during a long period of time. Safety, availability and reliability are important issues, requiring business processes that are quality-driven.

Although a business process of class B can be seen as an ‘in-between’ type of process there are some remarkable differences. Often the main driver in B-type business processes will be on costs. People buying typical products generated by these business processes will not buy them for their innovative character or because of very high availability. Since business processes in this group do not share the innovative advantage of class A and do not have the requirements on capital investments of class C the competitive advantage will often be the price of the end-product.

3.3 MIR 3

Adequate knowledge on the cause of the failure is available (Boersma et al., 2005).

3.3.1 Factors That Determine Product Reliability

Various authors have identified and classified a range of factors that influence product reliability. Toshiba (2011) differentiates between design factors, manufacturing process factors and operating environment factors that influence product reliability. Figure 17 displays the impact of these factors.

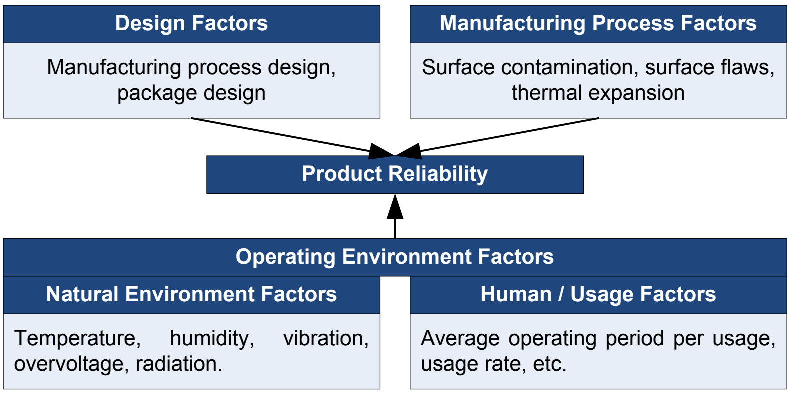

Figure 17: Factors Impacting Product Reliability

Manufacturing process factors include factors that degrade reliability include processing variances (dimensions, property values, etc.) that inevitably occur during product manufacturing, defects and damage that occur in the manufacturing process, handling errors due to human error, and equipment operation errors.

Design factors largely determines product reliability. As the physical design begins, reliability assessments will guide trade-offs in the system architecture and part selection, although functional and performance characteristics play the dominant role. Individual components must not be considered to be the only, or necessarily the major, source of failures. Interconnections and structures must also be selected properly (Pecht and Nash, 1994).

Vichare et al. (2007) differentiate the various operating environment factors between natural environment factors and usage factors. The natural environment contains factors such as temperature, humidity, etc. whilst human factors refer to average operating period per usage. Identifying and finding the root causes of reliability problems is the important element for successfully removing the problems (Petkova, 2003). Further, Petkova (2005) states that technical information on product reliability is particularly relevant on the operational level. The following section (Section 3.5.2) describes the methods that can be used for tracing the root cause of a reliability problem.

3.3.2 Root-Cause analysis

Section 3.3.1 showed a categorisation of the factors that determine product reliability. This section shows techniques that can be used to determine the root-cause of problems.

The main reliability factor analysis methods are (Toshiba, 2011):

1. Design Review

Design Review refers to checking for any inconsistencies in the design of such items and correcting any problems so as to yield a more complete product. Normally, a design standard is defined to simplify this process and incorporate corrections in advance.

2. Fault Tree Analysis

FTA (Fault Tree Analysis) is used to analyse factors contributing to device failure, such as circuit configuration, pattern design, manufacturing process, package design and method of use.

3. Failure Mode and Effects Analysis

FMEA (Failure Mode and Effects Analysis) is an analytical method used to confirm that corrective measures have been established for all possible failures in relation to aspects such as design, the manufacturing process and method of use. The analysis divides aspects such as design, manufacturing process, packaging and methods of use into well-defined detailed smaller functional items. The possible failure modes for each item are then catalogued, and the effects of the failure on the product as well as failure causes are investigated. These items are then weighted so that countermeasure priorities can be defined and established.

Factors that affect the reliability can entail: temperature; airborne contaminants; shock and vibration; humidity; voltage; radiation; power; packaging; handling, storage and transportation; manufacturing; duty cycle; use; maintenance.

3.4 MIR 2

Adequate deployment of information is ensured (Boersma et al., 2005).

In a MIR 2 organization, the analysis of field failures not only confirms or rejects the predictions made, but deviations from predictions are translated back into the product creation/product realization process. This translation can be made even without a full root cause analysis of failures.

In a MIR 2 organization, the role of the service organization is not only to replace and report failures, but also to analyse the field performance of a product in terms of failure location; e.g. is the failure relating to the customer application of the product, to the design of the product, to the manufacturing of the product, or to the material used. Current statistical techniques allow to discriminate between design failures, production failures, failures in material and failures relating to the application of the product in the field.

3.5 MIR 1

Adequate metrics are in place (Boersma et al., 2005).

Although a MIR 1 organization is not able to improve the reliability of its products on a structural level, the current capabilities of the current products are known to the organization. Although MIR 0 to MIR 1 appears to be a small step, it will require a considerable effort of the organisation. Especially the role of a service organisation (or testing centre) in a MIR 1 organisation differs from that of an organisation at MIR 0.
In MIR 0, the main task of service is to repair products, and in MIR 1, a second role of the service organization is to continuously monitor the reliability performance of products.

The main difference between a MIR 0 and a MIR 1 organization lies in two facts:

- An organization uses a basic control loop in order not only to predict the reliability of a product, but also to validate the actual achieved reliability at the customer.
- An agreement has been reached in the organization on the relevant reliability metric or metrics that will be used in this control loop.

The same as for the other MIR levels, it is not specified which methods, tools, literature, etc. should be in place in an organization in order to satisfy MIR 1; i.e. what 'adequate' metrics should be in place. In this report, the following structure has been chosen. Section 3.5.1 introduces the Quality and Reliability Reference model. By means of this reference model different types of problems can be differentiated. Subsequently, now being able to differentiate the for KPN important problems, Section 3.5.2 presents various reliability indicators. Subsequently these indicators can be used for analysis. Section 3.5.3 presents various reliability modelling models that use the earlier defined indicators.

3.5.1 Quality and Reliability Reference Model

Brombacher et al. (2005) define a model of wide-range reliability problems in three important different dimensions. They are (see Figure 18):

- Different failure classes: Physical or functional failures
- The relevance of statistics: Failures happening only in certain sub-groups of products or in all products
- The influence of time: Random failure or failures due to accumulation of time or customer use of a product

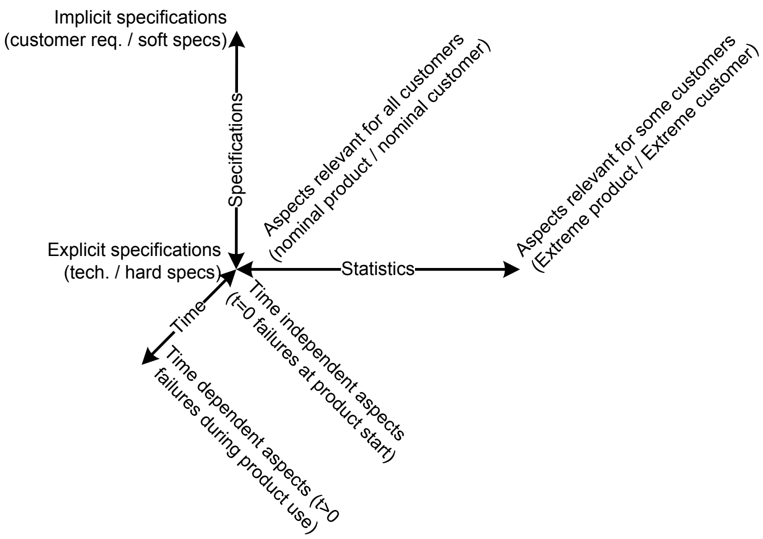

Figure 18: Defining reliability problems (Brombacher et al., 2005)

Using this model it is possible to describe the reliability problems with the factors of time, statistics, and specifications. Time covers the period of product usage by customers. Statistics from field data cover groups of customers that use the product. Specifications cover technical/hard specifications to soft specifications. Therefore, a broad range of reliability problems can be presented by the combination of these factors (see Figure 19). Brombacher et al. (2005) differentiate between 8 categories that result from the three dimensions (see Table 6).

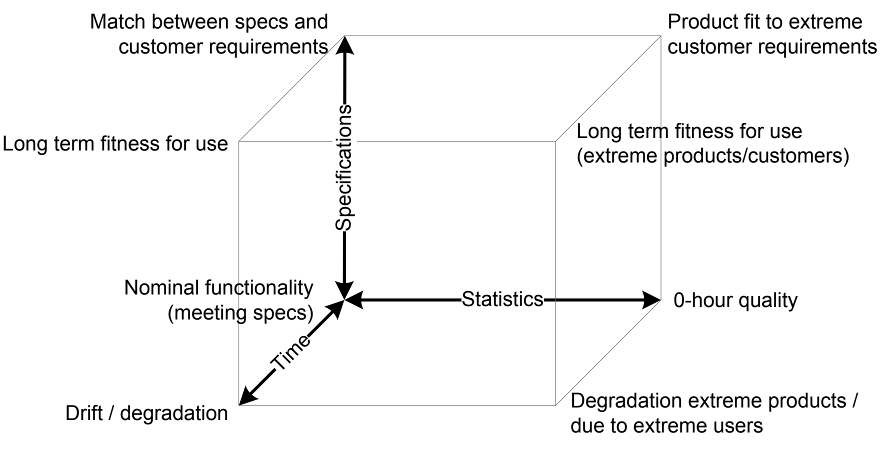

Figure 19: Quality and Reliability Reference Model (Brombacher et al., 2005)

Description	A. Time Dependency	B. Failure Class	C.Statistics	Customer perspective
Nominal functionability	No	Soft	No	Certain functions in the product do not work
Functional yield	No	Soft	Yes	Some of the products don't work
Nominal rate (over-) stress	No	Hard	No	The product is defective-on-arrival (DOA)
0-hour failure hard failure probability	No	Hard	Yes	Some of the products are defective on arrival (DOA)
(Nominal) functional drift	Yes	Soft	No	After a while the product is no longer able to function
Long term functional yield	Yes	Soft	Yes	After a while some products are no longer able to function
Nominal hard degradation	Yes	Hard	No	After a while the product fails
Long term hard failure probability	Yes	Hard	Yes	After a while some of the products fail

Table 6: Different Types of Reliability Problems (Brombacher et al., 2005)

A Time Axis - Time dependent failures/time independent failures (Brombacher et al., 2005)

From a customer perspective the main reason to report a (reliability related-) complaint is that, at a certain moment in time, there is a mismatch between customer requirements and the product performance. A cause for products unable to meet with customer requirements only after a certain amount of time, could be the due to gradual change of behaviour in time due to a gradual change in physical properties (drift or degradation). All these events can occur either systematically at all products due to inherent (structural or physical) product properties, can happen only at some products depending on individual products or users, and can be structurally present in a product or can manifest itself in a product only after a certain amount of time or product use.

B Specifications Axis - Hard/soft reliability problems (Brombacher et al., 2005)

Next to these physical failures, a second group of failures consists of the so-called functional failures; there can be situations where there are no physical failures in a product but in spite of the absence of physical failures the product does not meet customer requirements. For problems in this class 2 categories can be identified:

- Specification violations/hard reliability problems: Situations where the product is not able to meet both the explicit (technical) product specifications and customer requirements.
- Customer expectation deficiencies/soft reliability problems: Situations where in spite of meeting with the explicit product specifications, a customer explicitly complains on the (lack of) functionality of the product.

A special category in this context, is the situation where the product is only partially specified. With simple mono-functional products it can be assumed that a product can be (almost) fully specified. Both the functionality (does the product do what it should do) and the freedom from adverse effects (does the product not do what it should not do) can be written down in a set of explicit specifications. Especially in the case where software is involved, due to the large state-space of software products, it can be very difficult to write a specification with a high coverage. Failures can be structurally present in the product but occurring only intermittently (due to the occurrence of so-called 'triggering events'). In other situations the product just may not be able to meet with the requirements of (some) customers.

C Statistics Axis - The influence of product/customer statistics (Brombacher et al., 2005)

As argued in the previous sections the differences in products and differences in users must be taken into account. If, with respect to time related effects, user profiles influence the degradation rate some products will have different failure characteristics than others. Also product internal aspects, such as product tolerances, can play a role. Especially with respect to soft reliability problems: since there are no clear-cut specifications that are violated the situation that causes a customer complaint may be different from product to product and from customer to customer.

3.5.2 Reliability Indicators

Petkova denotes that the analysis of field information is not well described in the available literature (Petkova, 2003). Petkova describes relevant quantitative information about the field behaviour of products/subsystems/modules/components by the following characteristics (Petkova et al., 2000):

- the fraction of customer complaints within the warranty period
- the fraction of customer complaints within a particular time-interval
- the fraction of zero-hour failures (dead-on-arrival)
- the hazard function

The field behaviour of products is affected by several characteristics. The most important ones are the following (Petkova et al., 2000):

- the time of production
- the date the product is put into use
- the quantity of use (amount of time, number of cycles, etc.)
- the way of use (whether or not according to the user specifications)
- the environment in which the product has been used (for example warm and humid or cold and dry)

The main difference between the information about problems in production and problems in the field is the influence of the factor time. The fall-out in production concerns instantaneous failures and in principle the performance of production is well known at any moment. A quantitative analysis of the number of field failures is much more complicated, because at time t only the number of failures that occurred before time t is known. This does not affect the estimation of, for example, the fraction of zero-hour failures, but it does affect, the estimation of the reliability and the hazard function. Furthermore, the estimation of some characteristics is also complicated by the fact that it is far from easy, even during the warranty period, to determine the total number of sold products, the total number of products still in use, and the total number of customer complaints (Petkova et al., 2000).

For consumer electronics, field data are usually restricted to the time between purchase data and the date on which the failure is reported. As long as calendar time is proportional to the real characteristic that causes product failure, calendar time is useful information. Technically, however, it is no problem to register and use the most important aspects of customer use, such as the number of times the product is switched on. However, the collection and use of this information is not common practise (Ion et al., 2007).

Limitations to using field data

Various authors have devoted effort towards identifying limitations of using field data. The major drawbacks of using field feedback information flows are:

- Internal priorities of various parties result in loss of information (Molenaar et al., 2002). Service organizations are cost based and collecting valuable information for quality improvement is not their business drive (Petkova et al., 1999).
- It might be extremely difficult to collect the required information. Example: after the warranty period it is far from easy to collect representative field information about product reliability (Blischke and Murthy, 1994).
- The required information may be available 'somewhere' in the company, but the information flows are not structured in such a way that the information is available at the right place and the right time, and therefore the information cannot be used (Güthenke and Leiters, 1999).
- The component related failure information describes only a small part of the current failure mechanisms of consumer electronics products. As service centres only collect component related failure information, the collected information is incomplete (Petkova, 2003).
- The speed of the current field feedback information flow does not seem high enough for timely product quality improvements (Petkova, 2003).
- The currently available prediction and analysis techniques are mostly based on the constant failure rate assumption, although this assumption is usually not valid (Petkova, 2003).

These limitations should be taken into account when assessing the validity of the field information collected.

Visualising Product Reliability

Baskoro (2006) presents various forms of graphical representation of product reliability information. From the graphical presentation, such as the Pareto of failure and/or MISMOP, the information regarding NFF, the early failure, and the Time-To-Failure can be gained (Baskoro, 2006). A Pareto of Failure can depict the type of failure, categorized by year and frequency of occurrence. MISMOP is a method for presenting the frequency of product failures on the basis of month-in-service versus month-of-production (Petkova, 2003). The basic idea of MISMOP is to map the distribution of the product failures so that the situation can be examined. Note that theoretically MISMOP can be presented in two time based methods (1) calendar time and (2) real usage time.

3.5.3 Product Reliability Modeling

This section consists of models that described product reliability. Section 3.5.3.1 is dedicated to the traditional bathtub curve for modelling product reliability. Subsequently, in Section 3.5.3.2, the four-phase rollercoaster model is handled.

As high-volume consumer products are seldom repaired more than once, only concepts that are based on the time to (first) failure are considered. Product reliability is defined as the probability R (t) that a product starting at time zero will survive a given time t. During the life of non-repairable items the failure rate λ(t) is the instantaneous probability of the first and only failure (Petkova, 2003).

3.5.3.1 The Bathtub Curve

According to Nelson (1982) the bathtub-curve concept provides a useful model for the hazard of some product populations. Systems and materials begin to wear out during use, and various mechanisms can contribute to failure. Early failures may come from poor design, improper manufacturing, or inadequate use. It is also known that failures result from the aging process; material fatigue, excessive wear-out, environmental corrosion, and undesirable environment can contribute to this process (Broek, 2001).

A study of many systems during their normal life expectancies has led to the conclusion that failure rates follow a certain basic pattern. It has been found that systems exhibit a high failure rate during their initial period of operation, called the infant mortality period. The operating period that follows the infant mortality period has a lower failure rate and is called the useful life period. At this period, the rate tends to remain constant until the beginning of the next phase, called the aging period. Failures during the last period are typically due to aging or cumulative damage. Typical failure rate behaviour follows a distribution known as the bathtub curve (see Figure 20).

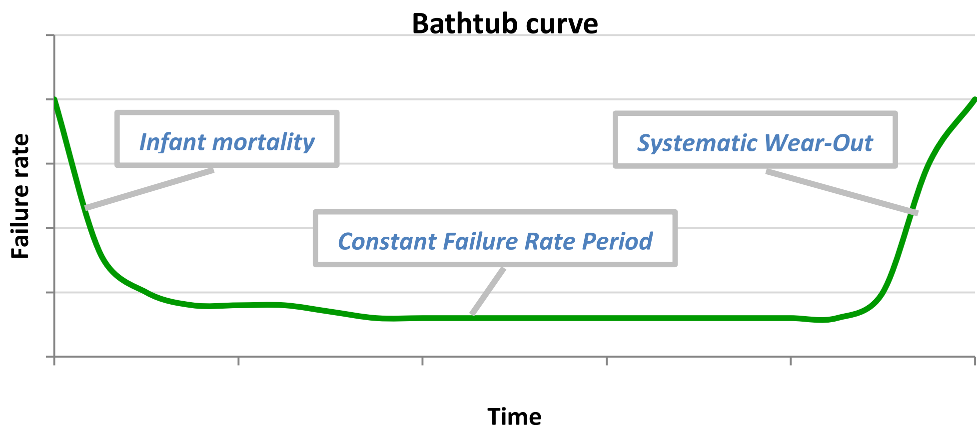

Figure 20 : Bathtub curve

During much of the useful life of the product, the failure rate function (or hazard function) may be approximately constant because failures are caused by external sources that occur random; late-life failures are due to wear-out and therefore not being constant (Brombacher et al., 2000). However, research from Brombacher (2000) has shown that in several branches of the electronics industry, the requirements for a constant failure rate are not applicable. In order to replace this model Brombacher developed a 'roller-coaster' curve to model and fit this product behaviour in the field, containing an additional phase called early wear-out (Broek, 2001).

3.5.3.2 The Four Phase Rollercoaster Model

The four-phase rollercoaster model considers reliability problems from the perspective of product physical failure. Generally, the reliability models classify reliability problems into time dependent and time independent problems. Time independent problems occur immediately after the product is used by the customer e.g. an early failure problem, or problems that happen even before customer uses the product, e.g. dead-on-arrival. Time dependent problems take place a certain time after the customer has been using the product. The classical method of modelling reliability problems uses a curve that plots the failure rate λ versus the time t. The model helps the process of product failure analysis. The four-phase rollercoaster model describes the failure rate curve that products have over time and is divided into four regions (see Figure 21).

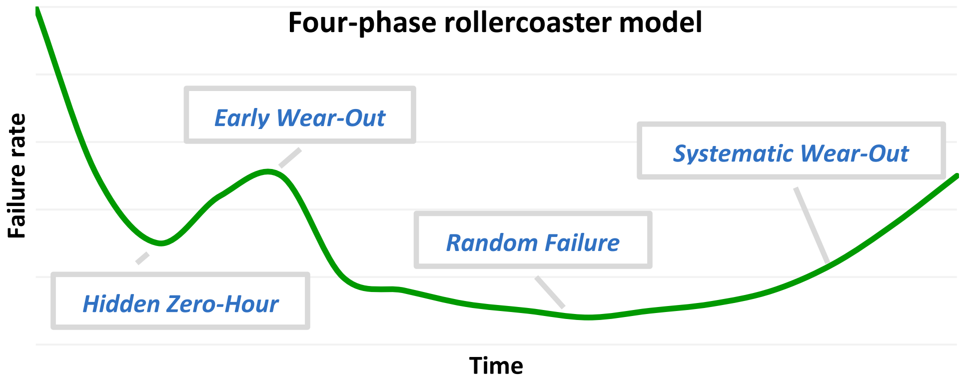

Figure 21: The four-phase rollercoaster model (Brombacher et al., 2000)

The characteristics of the 4 phases are as follows (Baskoro, 2006):

1. *Hidden Zero-Hour failures:*

Products that arrive out-of- (customer[18]) specification at the customer. Although, theoretically, these (often performance or quality related) failures should all be observed at the moment of commissioning of the product, complex functionality (software) or delay in customer reporting can cause delay in observing and reporting a failure. Possible explanations are that these products have either slipped through final tests, have been damaged during transport, or are used by (certain groups of-) customers in an unanticipated manner.

2. *Early wear-out:*

In some cases situations are observed where a distinct sub-population of products, due to some discrete event during manufacturing or due to a discrete difference between users in product use, shows different quality and reliability behaviour compared to the main population with respect to wear-out. Examples are products that are produced with internal flaws. In contrast with products of class 1 these products are able to function for a while but due to the extremes in the product (flaws) or the customers they show a different, faster, wear-out than the main population. These subpopulations are quite difficult to test during production because on the product level they initially perform according to specifications.

3. *Random failures:*

Products are designed to be used against anticipated (‘normal’) user conditions. It is, however, difficult to anticipate and to design against all events to which a product can be subjected. External events with a strong ‘random’ character, such as lightning and mechanical shocks, can cause product failure at any moment in time.

4. *Systematic wear-out:*

Many products, particularly mechanical products but also certain categories of electronic products, show some form of degradation over time. Well-known time effects are corrosion of metals and increased brittleness of plastics.

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[18] It can be argued that, in case of a design flaw, phase 1 failures are not be considered as reliability problems since they are not technically defective products. This can be the case if a mismatch exists between the technical product specification and the (often implied) customer specification. From a customer’s perspective, however, the product is not able to meet the customer requirements and therefore included in this class.

3.5.3.3 *Economic and technical lifetime in relation to 4 phases of 4-phase rollercoaster model*

In Section 3.2.3 the 3 different settings for economic and technical lifetime were introduced. The 3 different settings that Brombacher identified can be related to the four phases of the four-phase rollercoaster model (Figure 21). Brombacher (2005) presents the following findings:

A. Business processes depending on products where the economic lifetime is considerably smaller than the technical lifetime.

Due to the short economic lifetime detailed considerations on phase 4 failures are not very relevant; at the moment it can be safely assumed that the start of phase 4 is beyond the economic lifetime of the product. Due to the constant evolution of new technology the related business processes show a very strong pressure on time to market and limited provisions to ensure flawless designs and will only to a certain extend use proven, mature, technology. Therefore the most relevant reliability problems for this type of business processes is phase 1 and 2. That failures in these categories exist is, generally speaking, not a problem but the number of failures should be limited in order to keep economic benefits.

B. Business processes depending on products where the economic lifetime is comparable to the technical lifetime.

Because of the limited degree of innovation and modest time-pressure and the often large impact of especially phase 1 failures, not too many risks are taken with the application of new technology[19]. Maintenance strategies to handle phase 3 and 4 problems are, to a limited extent, accepted but, if possible, avoided by taking adequate measures in the design. Replacement strategies in this category resemble class A business processes but, due to the lower degree of innovation and the larger economic consequences of replacement, with a lower frequency.

C. Business processes depending on products where the economic lifetime is much larger than the technical lifetime.

Many systems in this class of products require very high investments. Therefore replacement of a total system due to some innovation is done only when this is economically justified. Phase 1 an 2 failures are not common in these systems (Due to excessive testing involved with the investment). Phase 3 and especially phase 4 reliability problems can be expected here, due to the long lifecycle. Some parts of a system are susceptible to degradation and/or random failures and these failures are often accepted. Management of reliability for these products is therefore often concentrating on the selection of adequate redundancy or the application of adequate maintenance strategies to minimize the risk of an accident, within economic boundary conditions.

Hazard plots

Hazard plots provide estimates of the distribution parameters, the proportion of units failing by a given age, percentiles of the distribution, the behaviour of the failure rate as a function of their age, and conditional failure probabilities for units of any age (Rai and Singh, 2003).

The hazard function specifies the instantaneous failure rate at time t given that an item has survived until t.

$$h(t) = \frac{Number\ of\ failed\ units\ during\ time\ t\ and\ t+1}{Number\ of\ operational\ units\ at\ time\ t}$$

Huijben and Luitjens (2001) indicate that, although the hazard function can be used to find the age at which most errors will occur, limitations to the use of failure rate functions are the long time required the gather data and the delay in information that hinders a pro-active and quick action. Furthermore, there are 2 aspects to take into account when creating Hazard plots:

Use of warranty data, or otherwise censored data:

Hazard plots using warranty data may not capture the entire life cycle of a subsystem or component as the data availability is often restricted to reported failures within the warranty period. Warranty data are restricted only to the reported failures within warranty coverage and such incompleteness can lead to inaccurate estimates of field failure rate or hazard rate. Factors such as inexact time/usage data and vague reported failures in a warranty claim make warranty data unclean that can suppress inherent failure pattern (Rai and Singh, 2003).

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[19] In car-industry, for example, a ‘drive by wire’ system is technically feasible and, economically speaking, very attractive but it is likely the application will wait until the technology has a proven maturity (Brombacher, 2005)

Time dimension in hazard plots

Huijben and Luitjens (2001) in setting up a failure rate function differentiate between the ways in which the 'time' dimension is used: time (use age) versus calendar. They suggest the hazard function to print the error probability or error rate as a function of the use age of the product. This makes it possible to share experiences on different products and be able to aggregate, even if the products are produced, sold or put into service at different times. In this way all products are dealt with as if they are of the same 'type'. Thereby the failure probability as a function of the operating time of the product is obtained.

3.6 Barriers & Facilitators in Managing Reverse Logistics

Janse et al. (2009) have identified various barriers and facilitators to reverse logistics. The barriers and facilitators, summarized in Table 7, are discussed in the following.

Barriers & facilitators in managing reverse logistics:

Barriers	Facilitators
B1 Lack of clear return policies	F1 Top management awareness
B2 Little recognition of reverse logistics as a factor in creating competitive advantage	F2 Strategic partnerships with supply chain partners
B3 Lack of appropriate performance management system	F3 Detailed insight in cost and performance
B4 Inadequate information technology support	F4 Strategy on avoiding returns
B5 Limited forecasting and planning	F5 Reclaiming value from returned products
B6 Insufficient tax know-how	F6 Capability to put products rapidly back into the market

Table 7: Barriers and facilitators to managing reverse logistics (Janse et al., 2009)

Barriers:

- *Lack of clear return policies:* Sales departments are often not held responsible for commercial returns. This results in unclear warranty conditions, varying service levels, and take-back policies in commercial agreements with channel partners hindering proper management of reverse logistics.
- *Little recognition of reverse logistics as a factor in creating competitive advantage:* Companies are organised around the forward flow of goods. Returns are perceived as the appendix of the company and treated as such by several departments.
- *Lack of appropriate performance management system:* Managers report that measuring and managing the true performance of reverse logistics is very hard. Internal and operational metrics are in place, but metrics for end-to-end process performance are seldom used or available.
- *Inadequate information technology support:* Companies make extensive use of systems that are run independently from their corporate enterprise resource planning systems. Notable observations include:
  - Product embedded information devices such as radio frequency identification are in the infancy stage of use for reverse logistics.
  - High use of serial number identification clears the path for installed base management.
- *Limited forecasting and planning:* Accurate return forecasts are hardly available. This is a direct barrier for both strategic and operational planning.
- *Insufficient tax know-how:* Janse et al. (2009) found that tax managers were not at all involved in decisions made in the reverse supply chain.

Facilitators:

- *Top management awareness*: The awareness of senior management of the complexity and risk for commercial, repairable, end-of-use, and end-of-life returns facilitates performance in reverse logistics.
- *Strategic partnerships with supply chain partners:* Collaboration with suppliers, sales channel partners, and third party service providers on strategic level facilitates reverse logistics.
- *Detailed insight in cost and performance:* Insight in internal failure and external failure costs, including measuring the right indicators and understanding what indicator imply what performance, determine how well reverse logistics can be managed.
- *Strategy focus on avoiding returns:* Avoidance of returns is part of a clear reverse logistics strategy. At a strategic level attention and focus should prevent channel partners and end-users to return products.
- *Reclaiming value from returned products:* Part of cost of goods sold can be reclaimed by collection of returns and asset recovery from them. Literature described that product characteristics heavily influence applicability of asset recovery (Geyer et al., 2007).
- *Capability to put products rapidly back into the market:* Mainly for products in the early phase of the economic life cycle can value depreciation be an issue. With products losing value several percent a month the return cycle time can be a key indicator for management of returns operations. Cycle times in practice depend on stage in product life cycle, type of rework required, company policies on reselling, and—to a large extent—availability of spare parts (Janse et al., 2009).

3.7 Chapter 3 Summary & Conclusion

This chapter dealt with the literature study required to answer the second research question : "*Which insights does literature provide with respect to reverse logistics information and product reliability monitoring?"*

The starting point for the literature study is the Maturity Index on Reliability. The MIR model is clarified in Section 3.1. It started by identifying the pro-active actions possible and factors to take into account. The MIR model consists of 5 levels; (0) uncontrolled; (1) measured; (2) analysed; (3) controlled and (4) improving. These are treated in reversed order. By doing so, the goals of the MIR model are first established and subsequently the information requirements per MIR level are established.

Section 3.2 deals with MIR 4 related literature. This section is comprised of the pro-active actions and the factors that determine which pro-active action is pursued. Both about the range of pro-active actions that could be undertaken as well as about the conditions for which these actions would be appropriate little literature is available. Furthermore, on MIR 4 an overview of costs to be taken into account in a pro-active action is provided.

Section 3.3.1 identified the factors that influence product (un)reliability. In order to define the root causes of reliability issues, which can be classified into design factors, manufacturing process factors and operating environment factors. Section 3.3.2 showed various root-cause analysis methods, out of which Failure Mode and Effect Analysis is applied most frequent in practise.

Section 3.5.1 identified the types of reliability problems that can exist by using the Quality and Reliability Reference Model from Brombacher (2005).The Quality and Reliability Reference Model differentiates between 3 axis: different failure classes (physical or functional failures), the relevance of statistics (failure effecting sub-group or all products), the influence of time (time dependent or time independent problems).
Section 3.5.2 elaborates upon relevant quantitative indicators for quality and reliability. This section describes the most important characteristics to take into account when using field information.
Section 3.5.3 explores suitable metrics for product reliability modelling. The four-phase-rollercoaster model (including: Hidden Zero-Hour, Early Wear-out, Random Failure and Systematic Wear-Out) is discussed for the describing the failure behaviour of products. This curve is used as a thinking model in the sense that the curve, in particular the indications of hidden 0-hour failures, early wear-out, random failures and systematic wear-out, refer to well-known phenomena that can be seen in reality.

Furthermore, Section 3.5.3 indicates that for products that have a shorter economic lifetime than technical lifetime, the phases "hidden 0-hour defects" and "early wear-out" of the 4-phase rollercoaster model are particularly relevant failure statistics.

In Section 3.6 describes various barriers and facilitators to managing reverse logistics. Barriers are: the lack of clear return policies, little recognition of reverse logistics as a factor in creating competitive advantage, lack of an appropriate performance management system, inadequate information technology support, limited forecasting and planning and insufficient tax know-how. Facilitators to managing reverse logistics are: top management awareness, strategic partnerships with supply chain partners, detailed insight in cost and performance, strategy on avoiding returns, reclaiming value from returned products and the capability to put products rapidly back into the market.

In Chapter 4 the findings from this literature chapter are applied in practice.

Chapter 4:
Application of the Maturity Index on Reliability on KPN

4 Application of the Maturity Index on Reliability on KPN

Chapter 4 is dedicated to the application of the Maturity Index on Reliability and the related literature per MIR level that was identified in chapter 3 on the KPN situation. The application of the MIR model follows the same structure as outlined by the literature in chapter 3, starting with MIR 4 and ending with MIR 1. On each of the MIR levels the differences between the situation at KPN and the requirements that follow from the interpretation of literature for the KPN situation are listed as 'problems'. In this research, these problems actually became more apparent and concrete when the case study for Digitenne was performed (the Digitenne Case Study will be described in chapter 5). The case study showed powerfully the difference between what should be possible at KPN, and what is actually possible. For example, data integration with suppliers should be possible at KPN, but by actually trying to achieve such integration one finds exactly which problems occur in practise. This allows us to be more detailed about the problems that occur, and as a result, the list of problems for all MIR levels is extensive. Note that particularly because product reliability management is not a standard (embedded and documented) process within KPN, the case study is required to gain insight on such a pragmatic level. The solutions to these problems follow both from a translation of literature to the KPN situation as well as pragmatic thinking for problems that had not been covered by literature.

Section 4.1 till Section 4.4 deal with the application of MIR 4 till MIR 1 on KPN. Section 4.5 is related to other problems that were identified, but do not fit within the MIR Model. Section provides 4.6 solutions and a prioritization of these solutions. Chapter 4 concludes with a summary and conclusion of the main findings.

4.1 MIR 4

Ability to continuously adapt business processes in such a manner that potential problems will be anticipated (Brombacher, 1999).

The main difference between a MIR level 3 and a MIR level 4 organization is the difference between a reactive and a pro-active organisation. A MIR level 4 organisation is not only able to learn from previous events in such a manner that possible differences between prediction and actual performance are well controlled, but is also able to continuously adapt its business processes in such a manner that potential problems will be anticipated.

The structure of this section is similar to the structure of Section 3.2, in which the literature regarding MIR 4 was discussed. Section 4.1.1 starts by exploring the pro-active action possible at KPN and the factors that should be taken into account when determining which action should be taken. One of the factors that determines if and which pro-active action should be taken, is the strategic added value. Section 4.1.2 explores the Product Life Cycle implications that are input to this strategic input.

4.1.1 Pro-active actions and factors to be taken into account

On MIR level 4, KPN aims to observe primarily 2 phenomena[20]:

1) Early wear-out: Production models/series that are particularly prone to failure.
2) Systematic wear-out: Development of the installed base of products and products reaching their technical end-of-life (en mass[21].)

One of these 2 phenomena deviates from findings in literature. It was found that hidden-zero hour and early wear-out are the most important aspects in the failure curve, but because hidden-zero hour defects are limited in the KPN situation because samples are taken when products are delivered to KPN to limit the number of dead-on-arrival products distributed. However, the presumption exists that systematic wear-out occurs (causing the high number of returns), and hence this aspect is taken into consideration.

[20] Another objective from return flows is to use knowledge gained from returns (such as design, materials used) to improve future models. Though this is important to KPN, in this research it is subordinate to the above two objectives. This is mainly because KPN is not a producer/supplier of the hardware, and therefore design of a product, resides primarily with suppliers.

[21] The underlying hypothesis is that the failure behaviour of the electronic products follow similar patterns, and that there is a common age at which the majority of the products break down. However, KPN has not verified if this hypothesis holds and has not used this expectation to improve the control (i.e. take pro-active action when required) of its installed base.

By moving towards a higher MIR level, KPN aims to be able to observe these phenomena in an early stage, so that adequate pro-active action limits the negative impact on the rest of the installed base. Figure 22 displays the phenomena, the subsequent decisions KPN takes and the output in the form of a suitable pro-active action. The pro-active actions are grouped into 4 categories of pro-active action.

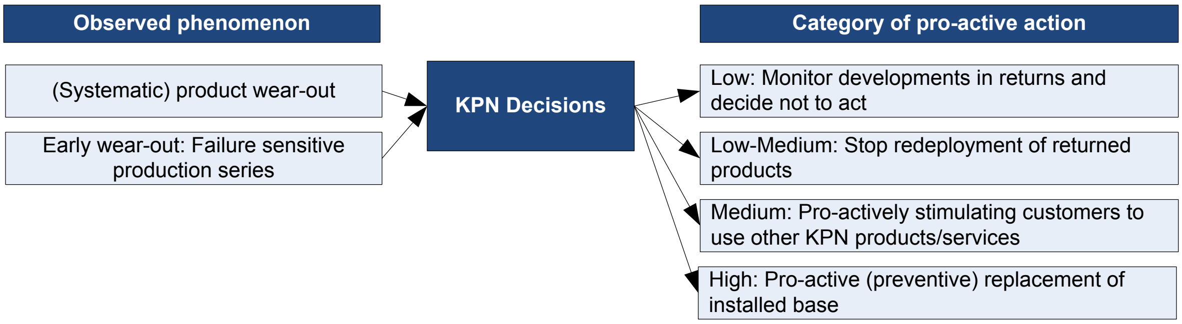

Figure 22: Observed phenomena and intended pro-active actions

Observed phenomenon:

As described in the problem description (Section 1.4) registration of returns data is a relatively new field to KPN. KPN does not forecast the expected returns, and therefore the identification of irregularities is not straightforward. Improvements in lower MIR levels should enable KPN to observe the variables that indicate systematic product wear-out and failure sensitive production series.

Pro-active action suitable:

The output of MIR 4 is the decision to take a pro-active action if the data shows trends upon which should be acted. Examples of pro-active actions include actively motivating customers to switch to another service or replacing the installed base by newer products. To differentiate between various alternative courses of action, we identify 4 categories of pro-active actions. We choose these four, since these are undoubtedly distinct categories, and because a brainstorm with KPN employees did not result in more categories. The categories are depicted in Table 8. Within each of these categories, various strategies may exist. In for example the category 'high' one can imagine the existence of various strategies, such as: which series, which series first, against which contribution from customers, should customers be stimulated to switch to another services by offering them 'extra's', which mode of transport to use, et cetera. This research will not elaborate in depth into the strategies out of which these categories exist.

Category of pro-active action	Description
Low	Take no action, but monitor the developments of returns. A *decision* not to act.
Low – Medium	Stop distribution/redeployment of a selected product[22], prevent the growth of the installed base of bad quality products
Medium	Pro-actively stimulating customers to use other products/services; I.e. stimulation of migration to another service or accelerated introduction of a successor model
High	Pro-active, preventive replacement of (a part of) the installed base

Table 8: Examples of pro-active actions to influence consumer products of Installed Base

KPN Decisions:

In MIR level 4 it is decided whether some action should be taken and which action should be taken. A decision should incorporate both *if* an action should be taken as well as *which* action should be taken. As depicted in Section 3.2.1, literature had suggested several factors upon which to base the decision for preventive/pro-active action. Amongst these factors were: safety factors, product quality/image and learning potential. For this study at KPN these factors are found to be deficient. This is because aspects such as costs and planning interests are not taken into account. Together with the employees of KPN, a brainstorming session was held to decide upon the factors that KPN should incorporate. The following factors were determined to be key: Safety, Customer base affected (impact), Costs, Netto Promotor Score, Strategic interests/planning, Time line (see Table 9). These

[22] Selected product: returned products of failure sensitive or products reaching their technical end-of-life stage

factors are separated into factors that represent benefits (factors 1-5) and factors that represent costs (factors A&D). The distinction between these factors is clarified in the following. However, first the factors are explained.

	Factor	Brief description
1	Safety	Does the product 'merely' break down or is there other danger such as danger for customer health
2	Customer base affected (impact)	Problem orientated: # of customers affected and level of disturbance Solution oriented: # of customers unnecessary informed
3	Netto Promotor Score	Effect on brand reinforcement or brand damage
4	Stategic interests/planning	Availability of substitute product, migration to other service
5	Time line (problem)	Development of the problem over time (gradual degradation or disruptive breakdown)
A	Costs (per customer)	Trade-off between the costs and expected benefits
B	Time line (solution)	Timeline for implementing solution; eg. helpdesk capacity and product availability

Table 9: Factors affecting pro-active action

The factors 1-5 describe the factors to be taken into account as factors of benefits; safety issues that can be taken away from customers, the number of customers that are helped by a new instead of a bad quality model, the customer's appreciation of the pro-active action by KPN, strategic/planning issues that can be combined with the pro-active action and the time-line for the development of the problems over time for customers.
Factors A&D describe the costs and feasibility of a pro-active action to KPN.

1 Safety

KPN should take into account the effect of a product failure; does the product 'merely' break down or does it cause damage to the environment of the product. Should there be danger for health of the customer, because for example there is a chance the product catches fire, than this undoubtfully results in a pro-active (recall) action.

2 Customer base affected (Impact)

The number of customers affected and the level of disturbance are important factors to take into account. This factors reflects how many customers are helped, because if KPN would not take action, they would suffer from a product breakdown. Note that KPN cannot always target specific customer groups, since it has not registered which products each group is using. As a consequence, KPN needs to take into account the effects of communicating about shortcomings to a large group of customers, whilst the potential problem only pertains to a subgroup of these customers.

3 Netto Promotor Score

The effect on customer satisfaction for alternative courses of action, measured by NPS value, should be taken into account. This value reflects the positive or negative evaluation of the course of action taken by KPN, and allows for differentiation between the customers perception of various courses of action by KPN. In particular the effect of brand damage should be taken into account.

4 Strategic Interests/Planning

Strategic interests may be a reason to, or not to, engage in a pro-active action. For example, if the business strategy involves the large scale introduction of a service that successes Digitenne, then this should be incorporated into the current decision of whether or not to perform a pro-active action. Planning refers to the opportunity of combining the pro-active action with other hardware exchange at the customer. Since the relative costs of transport would than decrease significantly, the pro-active action could be more feasible.

5 Time line (development of the problem over time)

The development of the problem over time, i.e. a gradual degradation of product quality or disruptive breakdown should be taken into account. If a problem is found that causes only mere image quality loss, the impact is smaller than when a product completely breaks down

A Costs (per customer)

Costs (per customer) refer to the trade-off between the solution provided to customers and the costs incurred, out of which the most important, determined by KPN and in line with literature are:

- Depreciation costs (depending on the age and depreciation method of the products): the products that are replaced are depreciated. The costs of this depreciation and the extent to which costs can be claimed from suppliers should be taken into account by KPN.
- Investment costs of replacing products: the costs of the replacing products should be taken into account. Also, potential investments in IT systems to ensure process improvements should be incorporated.
- KPN logistics 'menu' option used: If reliability issues are found for a product, KPN can choose no longer to swap the product (since it cannot redeploy the unreliable product). Instead it simply sends a replacing product, thereby significantly lowering the logistics costs.

And from a revenue perspective:

- Cost of a Call to KPN Contact: Due to a pro-active action KPN expects to receive fewer customers calls related to the reliability issue. On average a customer call costs KPN 10 euro, hence fewer customers calling results in a significant decrease in costs.
- Missed income: What is the missed income from customers that cancel their services KPN if their products are not working as they should.
- Opportunity costs: Costs that are incurred because the opportunity of performing a pro-active action is seized for other purposes, such as replacing antennas.

B Time line/feasibility (for implementing a solution)

From a solution perspective the time path for KPN to able to deliver alternative products and inform its helpdesk is important.

Relating the arguments to pro-active decision making:

Whether a pro-active action should be taken ultimately remains a business decision made by KPN employees. In order to facilitate KPN in this decision making process, we create the tool depicted in Figure 23. This tool assists KPN by plotting the factors that express benefits to customers against the costs the KPN incurs when it choses for a pro-active action (with categories as defined before in Table 8). The outcome of the tool is a category of pro-active action.

By using factors 1-5 the categories of pro-active decisions are narrowed down. Subsequently, the remaining range of pro-active decisions, should be plotted against factors A & B. Thereby this model assists in well-argued, structured analysis of pro-active decision-making.

The weights of the different factors have been determined by inquiry amongst employees of KPN. The employees that were selected are those that are (financially) responsible for the business areas that are relevant in taking a decision to pro-actively act. Each employee has distributed 10 points amongst four factors (with the safety factor described as a veto-factor). See Table 10 for the points assigned by the KPN employees. The general weight assigned if the weighted sum of the factors over all employees.

			Category of pro-active decision			
	Factor	**Weight** (sum 100)	**Low**[1]	**Low - Medium**[1]	**Medium**[1]	**High**[1]
1	Safety					Always
2	Customer base affected (impact)	45	X <0.1%	0,1% < X ≤ 1%	1% < X ≤ 10%	X >10%
3	Netto Promotor Score	30	-3	0	+4	+15
4	Stategic interests/planning	15	None			Many
5	Time line (a) - Development of the problem over time	10	If gradually developing			If disruptive
		A	Time-line (b) - Time to implement solution			
		B	Costs per customer			
	[1]: The categories are illustrated in Table 8.					

Figure 23: Decision making tool for pro-active decision making

The threshold values for the categories 2 and 3 have been defined by brainstorming with the same employees that determined the weights for the factors. With respect to the impact, the starting point has been the warranty agreements. From the discussion it followed that if 10% of the customer base is affected, a pro-active replacement action should occur. Furthermore it was decided that is <0,1% of the customer base was affected, the failure rate would exceed the warranty agreements, but the level would be 'acceptable', i.e. monitoring the development would suffice. The values for the other categories followed from a discussion.

The Netto Promotor Score for the pro-active action is unknown; KPN has not yet asked customers how they would value a pro-active action by KPN. The values provided are estimates by the program manager NPS Esther Hoeve.

	Customer Base Affected (impact)	Netto Promotor Score	Strategic interests/ planning	Time line (problem)	Sum
Producthouse manager	4	3	2	1	10
Finance	7			3	10
Delivery-chain manager	5		2	3	10
Service-chain manager	5	5			10
NPS-program manager	2	8			10
Purchasing manager	7		3		10
Manager Customer Processes & Products	3	3	3	1	10
Sum	33	19	10	8	
Rounded weight	**45%**	**30%**	**15%**	**10%**	

Table 10: Weights assigned to factors in pro-active decision making tool

Problems in current situation

The following problems are identified in the current situation for MIR 4. The solutions to these problems are discussed in Section 4.6, together with the solutions to problems identified in other MIR levels.

1. Limited embeddedness of reverse logistics in business operations

Following Janse et al. (Janse et al., 2009) a barrier in managing reverse logistics is "little recognition of reverse logistics as factor in creating competitive advantage." This barrier refers not specifically to managing product reliability management, but to managing reverse logistics in general. At KPN we see that reverse logistics processes, as a precondition to performing product reliability analysis, are not well developed and embedded into the business operations.

Upon introduction of new products the structural assessment of elements such as take-back method, spare part management, life cycle length, inventory control of returns, and other aspects are insufficiently considered. As a result KPN can only act re-actively as opposed to pro-actively, which can result in higher cost and/or a lower service level towards the customer.

2. Insufficient registration of customer details hinders approach of specific customers

The vision underlying the monitoring of reliability is that KPN will be enabled to take preventive actions. However, one of the major obstructions is the availability of customer data. In order to be able to make pro-active decisions, a pre-requisite is knowing how many and which customers are affected. Since KPN has not registered the serial numbers of the products, or in cases not even the product that the customer uses. As a result, targeted pro-active actions are not possible without informing the entire installed base.

3. Customer appreciation of pro-active action uncertain

Though a substantiated view of the added value for customers resulting from a pro-active action exists, the actual NPS impact of a pro-active decision is uncertain. As the customers appreciation of a pro-active action is an important decision factor for the pro-active action, not knowing this exactly is problematic.

The solutions to these problems are dealt with in Section 4.6.1.

4.1.2 Product Life Cycle Implications

-- KPN Classified Information --

Problems in current situation

Product take back and redeployment not included in the hardware strategy

The conclusion that can be drawn from this section is twofold. Firstly, the different stages at which the products are on a class level in business processes are not incorporated in a product take back or redeployment strategy. This has an impact on the decision to take a pro-active action in the following way. The stage in the Product Life Cycle should be related to the investment costs inherent to the pro-active decision. I.e. due to the mature state of Digitenne, it could be best not to spend too much on this service, whilst this decision can be greatly different for ITV.
Secondly, implicitly, this section has shown that the threshold value for how much a service (i.e. product class) is still 'worth' to KPN, and closely related how much KPN is willing to invest in the service, is either not present within KPN or insufficiently taken into account in the context of reverse logistics and multiple product deployments.
The solutions to these problems are dealt with in Section 4.6.1.

4.1.3 Economic versus Technical Lifetime

The depreciation of products occurs via a generic depreciation method, that does not take into account both the domain of the product (KPN infrastructure or consumer electronics) nor the differences in the length of the (technical) lifetime of the products.
The KPN consumer products (contrary to KPN network infrastructure equipment) are generally of class A and possibly class B; their economic lifetime is either considerably smaller or equal than the technical lifetime[23] . For class A products Brombacher (2005) indicates that the most relevant class of reliability problems are phase 1 and phase 2 problems (hidden zero-hour and early wear-out). For class B products, especially phase 1 failures. Strategies to handle phase 3 and 4 problems are to a limited extent accepted, but if possible avoided by taking adequate measures in the design.

The discrepancy between economic and technical lifetime serves as an input for the decision making tool presented in Section 4.1.1, Figure 23. It allows KPN to strategically incorporate the technical and economic lifetime of the product in the decision whether or not to pro-actively act. It is important to view technical and economic lifetime separately, because the product needs to be within the strategic plan of KPN, for which the economic lifetime is relevant.

The conclusion that can be drawn is that different failure rates as a function of time are acceptable for the different services. Thus, the threshold value for the failure rate for Digitenne products after one year may be different than the likewise threshold value for ITV. An indication of these values is provided by the warranty agreements, but it would be useful to have more insight into what the acceptable failure levels are, and thereby which failure rates should be seen as 'extraordinary' and thereby indicating products that are extra sensitive to failure.

However, it was found that due to the current maturity in reliability state of KPN, these threshold values for failure sensitive production models cannot be defined. Once KPN reaches MIR 1 maturity such levels can be determined in cooperation with amongst other the purchasing department, that negotiates the warranty agreements with suppliers.

Problems in current situation

4. Economic valuation not in line with technical capabilities

With the valuation of products and their depreciation, multiple redeployments of products have not been taken into account. In reality, depreciation is based on a term of for example 3 years, during which a newer, lower priced model can be introduced. As a result, inconsequent price-setting occurs. Older models with lower specifications are higher valued than their younger, improved, successors. Not only does this affect accounting and control, it also affects the re-deployment decision, since one of the aspects that undoubtedly will be taken into account is the cost of the reverse processes (taken into account yield) versus the cost of buying a new model. A prerequisite for this is that the costs of the reverse processes are known, a point that has already been asserted in the lack of process overview.
The solution to this problem is dealt with in Section 4.6.1.

[23] This contributes to also perform reliability analysis for the production month, and not only on the lifecycle length.

4.2 MIR 3

Adequate knowledge on the cause of the failure is available (Boersma et al., 2005).

In a MIR level 3 organization, the reliability of products is controlled, because root causes of problems are known problems can be avoided in future products. A MIR level 3 organization is not only able to allocate reliability problems to the various activities in their business processes but is also able to identify the root cause of the problem. The knowledge of these root causes enables the organisation to modify the existing products. Ensuring the prevention of problems in future products is not always possible in a MIR level 3 organisation, especially where the prevention of problems will require adaptation of the business processes involved.

4.2.1 Factors That Determine Product Reliability

Literature differentiates between design factors, manufacturing process factors and operating environment factors. As the 'production and usage side' of Figure 24 depicts, these factors together determine the product reliability. The 'testing and analysis' side indicates that by using test results the failure rate of products is analysed. Design factors that have an impact on product reliability are analysed primarily by using information from call center agents. The manufacturing process factors, but more particularly the operating environment factors that influence product reliability are unknown to KPN and therefore it is impossible in practise to register these input variables an to research their correlation with product reliability. KPN limits itself to instructing its customers about ways in which customers should use the product (i.e. don't use the product in a humid environment) based on general recommendations that are applicable to consumer electronics devices.

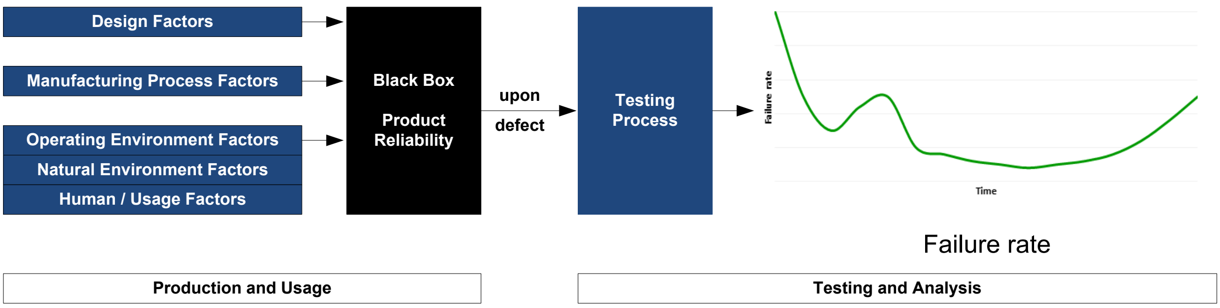

Figure 24: Black Box Product Reliability

KPN should also bear in mind that, since it is not possible to trace back these factors for the current installed base, changes in for example hardware that will allow KPN to analyse these factors only for models that are introduced in the future.

4.2.2 Root-Cause Analysis

This thesis focuses on product reliability, and in particular on product failure behaviour and bad production series. The key element of a MIR level 3 organization is that it is able to identify root causes of problems and to ensure reliability control by avoiding the known problems in future products. For identifying the root-cause of a problem, the front-end helpdesk operations, the back-end product testing and also the collaboration between the two are crucial.

The fundamental difference between the front-end and back-end with regard to reliability management is that whilst the front-end is interactive, as opposed to the testing center, and mainly based on qualitative information, the back-end is quantitatively oriented, but more detailed (on a serial number level) and decisive.

Front-end irregularities in the number of calls about a topic or product are reported. In this way also problems related specifically to customer hardware are identified. During each call, call center agents can inquire about the problem that a customer faces. As such, the front-end is interactive, as opposed to the testing center, but the analysis performed at the helpdesk is rather abstract. Later, KPN Producthouse and the Device Competence Center[24] can use the information collected by KPN contact to track the error.

Note that this front-end is particularly useful immediately after the introduction of a new product, as unforeseen problems that customers experience that did not show up during pilot runs then first reveal itself. Typical

[24] The device competence center is the body within KPN that is specifically responsible for testing customer products

improvements that result from the front-end operations are solved by software updates for RG's. The helpdesk thus contributes to product improvement, its usability for reliability management is limited.

The back-end product testing at Drake & Farrell provides a decisive outcome of whether the consumer product is defect or not. Though decisive, the depth of the analysis of the failing component is limited. In order to be able, on a MIR level 4 organization to pro-actively act, the MIR level 3 organization should be able to perform failure analysis on a greater level of detail. It should be possible to trace back technical problems to component level, and also to identify which models use the same components.

In order for KPN to meet MIR level 3, the root-cause analysis should be extended to be able to identify failures on component levels. Furthermore, component tracing should improve, so that it can subsequently be determined which/how many other products might incur the same problem.

Problems in current situation

5. Front-end call center processes not suitable for reliability analysis

Janse et al. (2009) identify inadequate information technology support as a barrier in managing reverse logistics. At KPN contact, registration of the range of types -swap or collection, service or new model, rental or bought, etc- is essential to ensure that any conclusion regarding the returns is drawn based on the correct information. For this purpose it is essential that both these categories are available/well registered (whereby KPN will be retrieve this information) and reliable. For the latter purpose it is essential that the agents can enter the information unambiguously. Currently, the only way to deduce if a return is a collection or a swap order is by means of the 'service format' field, which is entered rather arbitrarily by call center agents.

6. Limitations in root-cause analysis

The complexity of the organization and the multitude of different processes, involved employees and product changes make analysis of the return flow complex. It is difficult to be certain about the cause of an observed phenomenon. Since there is no one overview of all the changes that occur in all areas of KPN, it is difficult to determine with certainty to which cause data irregularities should be attributed. Think of changes in test-results that can result from changes in the front-end policy, the testing method, a particular failure sensitive production serie or even more outside the control of KPN such as the impact of lightning on an area of houses.
Cause-and-effect analysis is particularly related to the stakeholders that are related to the SRET process, since different business areas draw different conclusions from the same data sets.

The solutions to these problems are dealt with in Section 4.6.1.

4.3 MIR 2

Adequate deployment of information is ensured (Boersma et al., 2005)

In a MIR 2 organization, the analysis of field failures not only confirms or rejects the predictions made, but deviations from predictions are translated back into the product creation/product realization process.

As was explained in the introductory section of this chapter, the MIR 2 analysis is executed on a more generic level. In a MIR 2 organization, the role of the service organisation is not only to replace and report failures, but also to analyse the field performance of a product in terms of failure location.

In order to identify KPN's ability classify problems into customer application, the design of the product, manufacturing of the product or material used. It is important to differentiate between the front-end and the back-end information flows (recall Section 2.1.2). Within the front-end call center processes it is possible to inquire about the customer application of the product. Theoretically the other types of problems can be identified by means of inspection in the back-end processes. Since the back-end test process provides little insight into the root-cause of the problem. At KPN such distinction between location of problems does not occur structurally.

Furthermore, the categories identified in literature are not completely suitable for application within KPN. At KPN it would make sense to add a category "software problem" referring to problems related to software on the device. Particularly for RG's this would support the analysis of high failure combinations between the KPN infrastructure and RGs.

4.4 MIR 1

Adequate metrics are in place (Boersma et al., 2005).

The structure of MIR 1 application at KPN has the same structure as Section 3.5 in the literature chapter. It thus consists of four sections. Firstly, reliability problems that can occur within KPN are segmented in the Quality and Reliability Reference Model. Secondly, reliability indicators that are available within KPN are explored. Thirdly, the use of these reliability metrics to model failure behaviour takes place. Fourthly, the relevant characteristics of these failure rate curves that comes forth from the economic and technical lifetime are discussed.

4.4.1 Quality and Reliability Reference Model

The 3 variables that comprise the Q&R reference model are time dependency, failure class, statistics. Table 11 indicates the selected problems issues to which KPN it limits itself. The items printed in bold are those upon which KPN focuses.

Time dependency: Both time dependent as well as time independent failures are studied in modelling the product failure behaviour. However, though KPN aims to identify time-independent hard failure class problems, the instruments to do so are currently not in place.

Failure class: In practise failures are either hardware defects or software defects, which in general can be resolved by replacing the software stored on the product with newer software versions.

Statistics: Both reliability issues that affect only a share of the total installed base as well as issues that affect the entire installed base are within the scope of KPN's reliability monitoring efforts.

	Description	A. Time Dependency	B. Failure Class	C. Statistics	Customer perspective
1	Nominal function ability	**No**	Soft	No	Certain functions in the product do not work
2	Functional yield	**No**	Soft	Yes	Some of the products don't work
3	Nominal rate (over-) stress	**No**	**Hard**	**No**	The product is defective-on-arrival (DOA)
4	0-hour failure hard failure probability	**No**	**Hard**	**Yes**	Some of the products are defective on arrival (DOA)
5	(Nominal) functional drift	**Yes**	Soft	No	After a while the product is no longer able to function
6	Long term functional yield	**Yes**	Soft	Yes	After a while some products are no longer able to function
7	Nominal hard degradation	**Yes**	**Hard**	**No**	After a while the product fails
8	Long term hard failure probability	**Yes**	**Hard**	**Yes**	After a while some of the products fail

Table 11: Different Types of Reliability Problems (Brombacher et al., 2005)

This classification helps to structure the different types of reliability problems that can be distinguished. KPN is interested in the failure behaviour, which implies the development of product quality over time. Because there is currently no product quality control at the intake of products, it is currently not possible to register Defect-On-Arrivals (DOA's). Hence, this report can only go as far as suggesting improvements in order to enable KPN to register DOA's.

Though soft failure reliability problems are of interest to KPN, they are not the primary focus of reliability analysis in this thesis. Soft reliability problems in the vast majority of all cases refers to software versions on RGs that may not be compatible with the infrastructural requirements. For a supply chain analysis the combinations that are extraordinary prone to failure are relevant. However, because various processes are in place to limit the number of such cases, and since this thesis uses the information differently, these soft failure problems will not be focussed upon. Hence, in general KPN is interested in all reliability problems, but within this thesis the class 'soft reliability problems' are not reviewed.

KPN is particularly interested in statistics, does a problem occur for a subgroup or is the entire base of a product affected. This information is a vital starting point for the decision to act pro-actively.

Problem in current situation

7. Insufficient stakeholder perspectives have been taken into account when designing SRET processes

The service and returns program has been implemented by the Producthouse department and is primarily focused on achieving product quality and logistical performance. As such the improvement actions and performance indicators are geared towards mainly logistical performance, such as decreasing the time window of execution of a swap order. Other departments within KPN, such as the procurement department, could benefit from the SRET program by measuring the number of defects against the contract agreements. However, due to the infancy state of the reverse process, the processes are not directed towards measurement and improvement of these stakeholders' interests.

The solution to this problem is dealt with in Section 4.6.1.

4.4.2 Reliability Indicators

For discussion on which environmental factors to take into account and which factors to register to account for factors such as the way of use, the quantity of use and the environment in which the product has been used, refer to the MIR discussion. This thesis is limited to observations of primarily 2 phenomena:

1) Early wear-out: Production models/series that are particularly prone to failure.

2) Systematic wear-out: Development of the installed base of products and products reaching their technical end-of-life.

The variables that are used for these 2 phenomena are the following:

- **Failure curve modelling variables**

Currently, KPN is able to monitor the development of the number of returns and defects. These are used for modelling the failure rate over the age of products, and thereby to gain insight into their technical end-of-life age. Note that products that are tested are both models that result from a collection order as well as products that result from a swap order. There needs to be a differentiation between swap and collection orders. Furthermore, particularly the change of the these values and the ratio of these two variables should be followed over time.

- **Failure sensitive models**

To account for failure sensitive models, KPN can monitor the number of returns/defects per month of production. Other ways by means of which to segment series (such as production site) are not possible. The product and component trace-ability is very limited.

When using the above mentioned variables, the following aspects can be analysed:

- Development of the ratio defect/returns
- Development of the ratio defect/ per month of production
- Percentage of distributed tuners that is returned
- Mean time to failure

Petkova (2005) notes that information is often hidden in a huge amount of data that is difficult to analyse. In order to keep the people who acquire the data motivated, they should get feedback about the value of the data. This can be formulated in a more general sense: there should be a closed loop between the one(s) who (should) collect data, the one(s) who (should) analyse the data and the one(s) who (should) use the final results (analysed data). This closed loop principle should make sure that the people who collect information are aware of the information that is needed.

Problem in current situation

8. Test methodology at test center is not flawless

The testing method used for returns requires further improvement. Both the correctness of the outcome of the test as well as its completeness are to be reviewed. In January 2011 a new testing methodology was adopted for Digitenne tuners, in which also the antenna output voltage is measured. It thereby led to a different testing result than the previous testing method, detecting more defects.

The completeness of the measurement refers to the extent to which the measurement is a suitable indicator for the phenomenon that is attempted to be measured. For example, it is questionable if age is the best indicator for product wear-out. Additional information such as the details of the components used in that particular model, the production batch, the production location, or the usage time are not available. The absence of this data limits the applicability of reliability analysis. The solution to this problem is dealt with in Section 4.6.1.

4.4.3 Product Reliability Modelling

There is no reason to assume that the characteristics of the four-phase roller coaster model (Early Wear-Out, in fact, Hidden 0-hour, Random failure, Systematic Wear-out) is not applicable to the hardware that KPN uses. In this thesis the Four-Phase Roller Coaster-Curve is accepted as a thinking model in the sense that the curve, in particular the indications of hidden 0-hour failures, early wear-out, random failures and systematic wear-out, as they refer to well-known phenomena that are recognized by KPN employees (Rob van der Meij, 2011).

Problems in current situation

9. Lack of overview over (reverse) processes

Janse et al. (2009) stress the importance of detailed insight in cost and performance of reverse logistic activities for the success of reverse logistics. A primary problem related to the current situation at KPN is the lack of overview of (reverse) processes and their costs, which makes control over reverse processes and product reliability complex. In order to model failure behaviour correctly, it is essential that factors in the environment are rightly interpreted and taken into account. The lack of overview can be divided into lack of overview into *how* return flows develop and *why* certain phenomena are observed.

Lack of overview over *how* return flows develop. With respect to product reliability analysis, it is vital to monitor: what part of the returns is defect, what is the change of the number of defects over time, what is the share of the installed base that has been returned (on a production month detail, not merely on product detail). With respect to reverse flows the share of products that requires rework and how long do products have to wait for spare parts are of interest.

Lack of overview on *why* certain phenomena are observed. Daily, numerous changes occur in the way call center agents are instructed, in the tools they are using, in marketing campaigns that are started, in software updates in the network and so on. It is important to take notion of these factors in the interpretation of the reverse flows. A peak in the number of tuners returned may result from a successful marketing campaign offering people to switch to ITV and should not be misinterpreted with unsatisfied customers.

10. Information integration throughout the supply chain is limited

Information sharing and information integration between various entities within the supply chains is limited. For example, suppliers are reluctant in sharing information regarding the production quantities of production series.
The non-constructive attitude between KPN and its suppliers also hinders the improvement of processes. Employees at KPN feel that the process improvement mostly follows from their ideas, and not from suppliers, even if is in the suppliers domain.

11. Deficient registration of time

Huijben and Luitjens (2001) indicate that the use age (how many hours has the product been used) is a more appropriate measure than the calendar age. KPN is not only not able to monitor the usage time for its entire portfolio, its ability to monitor the time from production to failure is also limited.

12. Timeliness of information

As Petkova (2005) points out, “the usability of information strongly depends on the moment at which the information is available.” Since product reliability management is not structurally embedded into processes, the results of a product reliability analysis (a) costs relatively much time, since the information is not widely available and (b) can hardly be used pro-actively because of the time consumed for gathering data.

The solutions to these problems are dealt with in Section 4.6.1.

4.5 Other improvements

Aside from the problems that are directly related to MIR requirements, other improvement areas were identified that could impede the advancement on MIR levels, but are not covered by the literature used for the respective MIR levels. This section describes these other problems. Note that these problems have in common that they are related to reverse logistics in general, and not limited to product reliability analysis. Solutions to these problems are provided in Section 4.6.1.

13. IT limitations impede process changes

KPN has a complex IT infrastructure which impedes swift process changes. This becomes apparent in the following problems. The first is the legacy of a high number of (old) systems. This results in the inability to implement apparently simple processes. For instance, an effective tool for insuring that STBs are returned upon contract termination would be to issue a deposit which is returned to the customer once the STB is returned. The second problem is that the IT change capacity is limited. Since many (internal) parties require IT changes for change and innovation in their processes, changes in IT are carefully planned and competition exists for place in the IT releases. Many changes are solved ad hoc, resulting in a large number of 'work arounds'.

14. Needless costs due to duplicate operations

Due to poor warranty agreements of, for example, Digitenne tuners, Digitenne tuners are scanned upon return at Teleplan (at least) twice. For Digitenne tuners, a return & repair warranty agreement exists, i.e. repair takes place at the site of the supplier. The defective Digitenne tuners that are sent to suppliers are sent to the respective suppliers in batches. After being tested, at which point it is determined that the products are defect or not, the tuners are collected to form a batch. Before batches are sent to suppliers, they are scanned for a second time (in order to register the serial numbers). Not only are additional costs incurred due to the costs of scanning twice, there are also tuners that lose their right for warranty-claims (i.e. they remain in the warehouse too long).

15. Unanticipated negative side effects in controlling the return flow

The increased attention for the return flow has resulted in negative side-effects. Due to the implementation of the improved testing of returns, it was found that a relatively large portion of the returns by KPN service engineers were non-defect defects. As a result, the managers of these service engineer concluded that service engineers did not do their job properly and sanctioned the service engineer that had a high number of non-defect defects. Service engineers in turn responded by demolishing returns, in order to ensure that they reached their 'defect-ratio targets.'

16. Spare-part supplier conflict

Janse et al (2009) indicate that the capability to put products rapidly back into the market is an important facilitator to managing reverse logistics. Currently, the reverse flows are scarcely taken into account during contract negotiations. Spare part management in particular has not been arranged sufficiently. This results in 'chaos', since it is not possible to determine the overall yield and redeploy ability of STBs. As a result part of the STBs become obsolete and are shredded. KPN has little influence in improving the delivery times of spare parts. Furthermore, legal issues, such as the permitting of usage of spare parts from alternative suppliers are ambiguous.

17. Capability to put products rapidly back into the market

Mainly for products in the early phase of the economic life cycle can value depreciation be an issue. With products losing value several percent a month the return cycle time can be a key indicator for management of returns operations. Cycle times in practice depend on stage in product life cycle, type of rework required, company policies on reselling, and—to a large extent—availability of spare parts (Janse et al., 2009).

18. Professionalism of the suppliers and the LSPs

Janse et al (2009) indicate the importance of strategic partnerships with supply chain partners for the success of reverse logistics. A factor that has a large impact on the success of reliability analysis and reverse logistics in general is the size and professionalism of the firm with which is dealt (both suppliers as well as LSPs). Motorola, as a large corporation, is a more pro-active and trustworthy organization than Topfield, an organization that is notorious for delivering incomplete and incorrect information. The LSPs, in turn also vary in level of experience and professionalism, a point that closely relates to the level of pro-activeness exhibited by the LSPs.

19. Unclear roles and job descriptions

Since reliability analysis is currently not structurally performed, and in case of an epidemic error is only executed in a limited way, there are no structured processes to manage product reliability analysis, nor are the process owners clearly defined. This has various effects, for example, tasks are not done because KPN expects the LSPs to complete these tasks, whilst the LSPs expect KPN to complete the tasks. Also, the LSPs contribution to improvement areas and new ideas is limited.

20. Financial stimulus for LSPs ineffective

Currently, there is a limited financial stimulus for improvement for LSPs. Since KPN pays the LSPs per operation performed, LSPs gain a greater revenue by for example performing operations twice. This limits the ideas for improvement proposed by the LSPs. KPN should strive towards a reward-system in which both KPN as well as the LSPs benefit from improvements.

4.6 Solutions to problems in the current situation

Section 4.6.1 is dedicated to the solutions to the problems in the current situation. Section 4.6.2 is dedicated to a ranking of these solutions, in order to determine the priorities for each of these solutions.

4.6.1 Solutions

By using literature and knowledge from practise solutions can be deduced for solving the problems indicated in Section 4.1 – Section 4.5 for the KPN specific situation. Table 12 lists these solutions, and displays the key stakeholder involved in 'driving' the solution. The key stakeholder stems from the department that is capable of implementing the solution and is affected the greatest. Note that these solutions can be solutions to more than one problem. In the following we will elaborate on each of these solutions. To gain an easy overview of which solution is related to which problem refer to Appendix G.

	Solutions to problems in the current situation	Key solution driver
A	Embedding reverse logistics and product reliability analysis	Management Customer Processes
B	Modify processes to automate part of the reliability analysis	Teleplan
C	Improving the overview of reverse logistics and product reliability (including the registration of distributed products)	Teleplan
D	Increase strategic partnership with supply chain partners	Corporate Procurement Office
E	Including multiple deployments in the product hardware strategy	Productmanagers Producthouse
F	Incorporation of 'worth' and economic value	Finance dep.
G	Incorporation of more stakeholder perspectives	Finance dep.
H	Modify financial stimulus for LSPs	Producthouse, Finance dep.
I	Improved registration of time dimension	Device Competence Center, Teleplan
J	Determination of customers appreciation of pro-active actions	NPS Program

Table 12: Solutions to problems in the current situation

A Embedding reverse logistics and product reliability analysis

(Solutions to problems in MIR 4; (1) limited embeddedness of reverse logistics in business operations and (2) insufficient registration of customer details hinders approach of specific customers. On MIR 1 this is a solution to (7) insufficient stakeholder perspectives have been taken into account when designing SRET processes and (9) lack of overview over (reverse) processes. Lastly it is a solution for 'other problems' (17) capability to put products rapidly back into the market*)*

The implications of reverse logistics, in particular multiple deployments of products, can be embedded by gaining support from management. As Janse et al. (2009) found "awareness of senior management facilitates the management of reverse logistics." The management of the customer processes department can include the product returns in the quality improvement program, to ensure sufficient resources are dedicated to reverse information flows and product reliability on a structural basis.

The lack of embeddedness of these operations can be countered by changing the key performance indicators upon which the corporate procurement office is assessed, such that their attention moves towards more reliable, future-proof products, that have a longer time in which they can de be redeployed.
Furthermore, the return flows and the implications of multiple product deployments should be included in the performance indicators of the relevant stakeholders. An important relevant stakeholder is the procurement

department. Their attention should move towards, reliable, future-proof products, that have a longer time window in which they can be redeployed. The evaluation of the performance of the procurement department should include how well it corporates multiple deployments.

Furthermore, the procurement department needs to review if the conditions that are imposed upon preferred suppliers should be modified to incorporate the requirements of product returns. This incorporates both contractively arranging that information regarding production months is shared with KPN as well as arranging the supply of spare parts. This encompasses the spare part availability and the duration of the spare part availability.

<u>*B Modify processes to automate part of the reliability analysis*</u>

(Solution to problems in MIR 3; (5) front-end call center processes not suitable for reliability analysis. On MIR 2 (6) limitations in root-cause analysis. On MIR 1 this is a solution to (8) Test methodology at test center is not flawless and (12) Timeliness of information. Finally for 'other problems' (14) Needless costs due to duplicate operations)

Furthermore, by ensuring that the non-standardized production month for all suppliers and all products is easily accessible, KPN reduces the margin for errors and increases the speed and frequency with which reliability can be assessed. Until the adaptations for this data extraction (i.e. the deduction of production month from serial number) are realised, the excel tool provided complementary to this report can be used.
Note that it is essential to equip the employees that will monitor the product reliability with the appropriate software (excel 2003 is not suitable for the amount of records that are analysed yearly).

The extraction of the basic information required to perform a product reliability analysis, including the number of tuners distributed of a production month, the number of defects per month, should be simplified. This includes The front-end registration, in particular the IT systems in which call center agents enter the customers information, should be modified such that critical indicators that are summed in Table 3 (swap versus collection order, rental versus buy, etc.) are more easily identified. These characteristics are vital to the improvement of the front-end processes.

By automating a part of the product reliability analysis, the speed with which the information is gathered increases, and the timeliness of information problem improves.

<u>*C Improving the overview of reverse logistics and product reliability*</u>

(Solution to problems in MIR 4 (1) limited embeddedness of reverse logistics in business operations and on MIR 1 (9) lack of overview over (reverse) processes)

Janse et al. (2009) describe that a detailed insight in cost and performance of reverse logistics facilitate the management of reverse logistics. The lack of overview of (reverse) processes and their costs required for such insights is a primary problem related to the current situation. It makes control over reverse processes and product reliability complex. In order to model failure behaviour correctly, it is essential that factors in the environment are rightly interpreted and taken into account. The lack of overview can be divided into lack of overview into *how* return flows develop and *why* certain phenomena are observed.
KPN would benefit from the development of tools or other solutions to provide overview of the reverse processes. Such solution would consist of for example, indications of irregularities in the return flow with regard to types of tuners that are returned and for example the share of the installed base that is returned. With respect to *how* product returns and product reliability develop, it is vital to monitor: what part of the returns is defect, what is the change of the number of defects over time, what is the share of the installed base that has been returned (on a production month detail, not merely on product detail). With respect to reverse flows the share of products that requires rework and how long do products have to wait for spare parts are of interest. For this matter it is important to distinct between:

- The number of collection/swap orders executed successfully (between 10-20% of the orders fails because customers are never at home, have thrown away their modem, etc.).
- The costs vary for collection orders and swaps. With the implementation of the KPN logistics 'menu', the costs will vary for the different menu options.
- The number of non-defect returns, i.e. the share of products that can be re-used
- Allocation of absorption of indirect costs over product returns

In order to make it possible to analyse the different flows, particularly swaps versus collection order, these flows should be separated at the test center.

KPN and its suppliers can improve the trace-ability of components, in which case other segmentation would also be useful, such as segmentation on production-site level, production batch and series (if different hardware series exist for one model).

The second part of the lack of overview on why certain phenomena are observed. Daily, numerous changes occur in the way call center agents are instructed, in the tools they are using, in marketing campaigns that are started, in software updates in the network and so on. It is important to take notion of these factors in the interpretation of the reverse flows. A peak in the number of tuners returned may result from a successful marketing campaign offering people to switch to ITV and should not be misinterpreted with unsatisfied customers.

In order to gain more insight into *why* certain phenomena are observed, overview can be created by developing an event list in which changes that are expected to have a large impact on the return flow are listed. By doing so the pitfall of jumping to conclusions regarding causes of return flows is limited. Furthermore the overview should indicate the expected term of impact. I.e. if in increase in the number of returns is expected due to a marketing campaign, then how many additional returns are expected and when should the effects of the campaign be gone? Note that the communication of this event-list is particularly relevant if the reliability analysis is performed by Teleplan/D&F who generally are less aware of for example KPN marketing campaigns that increase returns.

As is clear, the value of being able to both accurately assess how many products are currently installed as well as being able to approach these specific customers, is of great importance to KPN. Future products should either be registered before they are sent to customers, or if they are connected to the network, their serial numbers/production month should be registered. By maintaining a database of customers and their products, the accuracy of the reliability analysis and the impact of a pro-active action can be greatly improved. The level of detail required should be the serial number (which inherently should imply information about month and date of production). The database should be kept up-to-date by incorporating products that are returned.
By measuring how customers will appreciate the pro-active actions KPN intends to initiate, the NPS values can be better substantiated. The values presented in Figure 30 are based upon the expert opinion of the NPS program manager, but should be refined with actual customer valuation.

<u>D Increase strategic partnerships with supply chain partners</u>
(Solution to 'MIR1 (10) information integration throughout the supply chain is limited and 'other problems' (16) spare-part supplier conflict and capability to put products rapidly back into the market, (18) professionalism of the suppliers and the LSPs and (19) unclear roles and job descriptions)

A key issue that was found is the lack of information sharing with suppliers. The result is that there is a gap between what is theoretically possible within KPN and what is practically achievable. For example, theoretically it is already possible to share information about the number of STBs distributed of a certain production month, but since this information is not shared by suppliers, it is not possible in practise. Furthermore, suppliers could learn from the product returned to KPN, whilst KPN could benefit from the suppliers knowledge on a detailed product level, as well as the knowledge the suppliers have had with other customers. The extent to which the sharing of information can be contractually enforced should be sorted out by the procurement department.
Aside from the information sharing with employees, the information exchange between the call center and the test center and between, should improve substantially.

KPN and the LSPs should find ways to constructively cooperate. What strongly came forward during this research, is that numerous improvements can be obtained on an operational level. Irrespective of whether the goal is to improve reliability analysis, primary handling of reverse flows and reverse information flows, etc. is that for most of these issues it holds that they can be improved at the 'side' of the LSPs. Though Teleplan and Ceva are large (inter)national organisations, there seems to be (too) little experience with within these LSPs to proactive bring up ideas for improvements. Employees of KPN strongly feel that the ideas for improvement are brought by KPN and too few improvements are brought by LSPs.

<u>E Including multiple deployments in the product hardware strategy</u>
(Solution to problems in MIR 4 (1) limited embeddedness of reverse logistics in business operations and on MIR 1 (9) lack of overview over (reverse) processes)

Furthermore, KPN should include product returns in the consumer hardware strategy. The current hardware strategy is centred around the introduction of new products, and does not incorporate decisions regarding the redeployment of the products in the installed base. In this hardware-strategy KPN should include until when products are to be redeployed. The discussion of multiple deployments should include the preferred life time of the product and the required quality and features to make the product suitable to cope with future technologies.

F Incorporation of 'worth' and economic value (solution to (4))
The finance department should either review its depreciation methodology, to ensure that the economic depreciation is in line with the value or worth to KPN (i.e. newer, better products are 'worth' more to KPN) or it should have a strict 'controlling' role. The latter implicates that the finance department is the devils' advocate by challenging whether products that have a book value are actually suitable for redeployment.

G Modify financial stimulus for LSPs (solution to (7))
KPN should review the financial incentive for LSPs. Generally, LSPs are paid a fixed amount per operation performed. I.e. scanning an item, testing it and cleaning it all have their respective costs. As a result, LSPs earn more money by performing more operations. KPN needs to work towards a price structure where improvement by LSPs is financially attractive for the LSPs too.

H Incorporation of more stakeholder perspectives (solution to (20))
As was indicated in the Chapter 1, a wide range of perspectives exists about the use of information in return flows. In line with findings by Petkova (Petkova et al., 2005) KPN should clarify various stakeholder perspectives, to ensure that their needs are incorporated in changes in the reverse processes. This is meant to improve the dedication to the reverse processes, such as less careless data entry by KPN Contact call center.

I Improvement of the registration of time dimension (solution to (11))
As Huijben and Luitjens (2001) point out, it is preferable to make use of the use age (i.e. power-on time) of a product instead of calendar age.

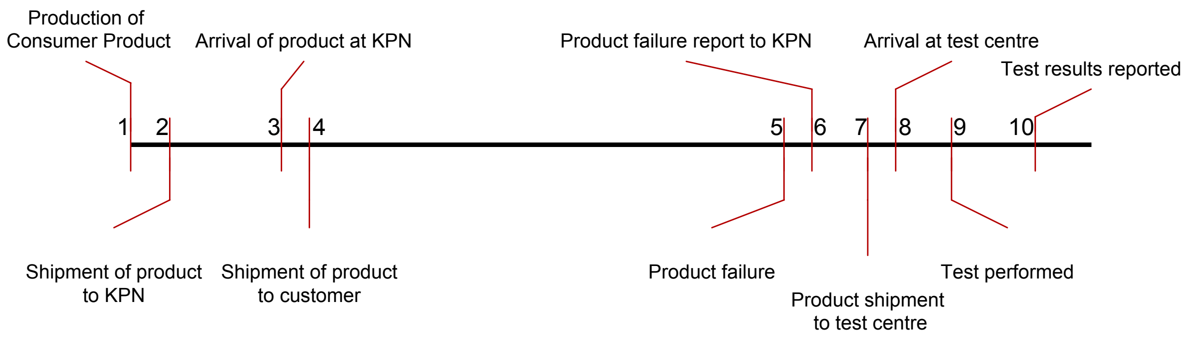

Figure 25: Overview of the registration of time

When using the calendar age, a range of improvements can be achieved too. Figure 25 depicts the moments in time that are relevant for registration of time. Currently, the production month and the date of testing at the test centre are registered. The date of reporting of a failure is registered at KPN, but these are currently not yet matched with the product test data. As a result, the indication of the age of a customer product is rather unreliable.
The age or time the product is used, can be estimated by the time between the production and the testing date. This is a very limited way of estimating the length of 'life', because the time between the product failure at the customer (5) and the product being tested (9) can be substantial. For example due to returns-inventory build-up at the test site, the registration becomes distorted.

J Determination of customers appreciation of pro-active actions (solution to (3))
Frankly, the customers appreciation of pro-active action needs to be determined by simply asking customers how they would value a pro-active action. This should be done for all categories of pro-active action and preferably for several strategies per category.

4.6.2 Prioritizing solutions

Table 13 repeats the solutions listed in Section 4.6.1. The final step in this chapter is to determine the priorities for implementing these solutions. The priorities for the solutions are determined by inquiry amongst relevant employees in a similar way as the weights were determined in Section 4.1. However, since the key solution driver could also be Teleplan, Jan Bol (Teleplan) is asked for his priorities too. The results of the weights that have been assigned to various solutions is depicted in Table 14.

	Solutions to problems in the current situation	Key solution driver
A	Embedding reverse logistics and product reliability analysis	Management Customer Processes
B	Modify processes to automate part of the reliability analysis	Teleplan
C	Improving the overview of reverse logistics and product reliability	Teleplan
D	Increase strategic partnership with supply chain partners	Corporate Procurement Office
E	Including multiple deployments in the product hardware strategy	Productmanagers Producthouse
F	Incorporation of 'worth' and economic value	Finance dep.
G	Incorporation of more stakeholder perspectives	Finance dep.
H	Modify financial stimulus for LSPs	Producthouse, Finance dep.
I	Improved registration of time dimension	Device Competence Center, Teleplan
J	Determination of customers appreciation of pro-active actions	NPS Program

Table 13: Solutions to problems in the current situation

Solution area:	A	B	C	D	E	F	G	H	I	J	Sum
Producthouse manager	2	1	3		3					1	10
Finance	2					4		4			10
Delivery-chain manager					3		4		3	3	10
Service-chain manager			4	2	2					2	10
NPS-program manager					3					7	10
Purchasing manager					4	4	2				10
Manager Customer Processes & Products			4				2			4	10
Producthouse manager		4	3						3		10
Sum	4	5	14	2	15	8	8	4	3	17	
Rounded Weight	5%	6%	18%	3%	19%	10%	10%	5%	4%	21%	

Table 14: Weights assigned to solutions for problems in the current situation

As follows from Table 14, priority should be given to the following 3 solutions:

1) The determination of the customers appreciation of pro-active actions, within the NPS program.
2) Including multiple deployments in the product hardware strategy by productmanagers within the Producthouse department.
3) Improving the overview of reverse logistics and product reliability, driven by Teleplan.

4.7 Chapter 4 Summary & Conclusion

This chapter was dedicated to answering the third research question *"What can be learned from applying the Maturity Index on Reliability to KPN?"* Application of the MIR model has resulted in the following findings:

The findings on MIR 4 are limited to observations of primarily 2 phenomena:
1) Early wear-out: Production models/series that are particularly prone to failure.
2) Systematic wear-out: Development of the installed base of products and products reaching their technical end-of-life.

The main categories of pro-active actions that KPN can use are:
- Take no action, but monitor the developments of returns. A *decision* not to act.
- Stop distribution of the product, prevent the growth of the installed base of bad quality products
- Pro-actively stimulating customers to use other products/services; I.e. stimulation of migration to another service or accelerated introduction of a successor model
- Pro-active, preventive replacement of (a part of) the installed base

In taking a decision regarding pro-active action, the following aspects were identified within KPN to be required to take into account: the size of the affected customer base, the consequences for the Netto Promotor Score, the time line of both the problem and the solution, the costs of various courses of action, strategic interests/planning and potential danger for customer health. The weights to be assigned to each of these factors is determined by the relevant involved KPN employees.

With respect to the product life cycle the product life cycle of Digitenne is notably longer than the product life cycle of ITV. The dominant factor for new model introduction is technical support of new technology. The technical lifetime is either larger than, or equal to the economic lifetime. For such items Hidden Zero-Hour and Early Wear-Out errors are of particular importance. However, it followed that due to the current maturity on reliability at KPN, the threshold values that are appropriate to indicate these Hidden Zero-Hour and Early Wear-Out errors cannot yet be determined. These can be determined when KPN improves MIR 1 measurements.

On MIR 3 it followed that, surely for the currently installed base, the factors that influence reliability cannot be measured. The products are therefore more or less viewed as a black-box, with the main output 'defective' or 'working' and only little, if any, additional information on the status of the product.
It should be noted that because fewer attention was paid to MIR 2 and MIR 3 it cannot be concluded that the requirements of these levels are satisfied well, these can remain subject of further research.

On MIR 1 it followed that KPN should monitor both the development of the number of returns (and defects) as well as the number of returns (and defects) per month of production. Other production related factors (mainly location and hardware version) cannot be deducted yet. The month of production can be used for analysing the following aspects:
- Development of the ratio defect/returns
- Development of the ratio defect/ per month of production
- Percentage of distributed tuners that is returned
- Mean time to failure

Throughout the chapter the problems faced as a result of the gap between literature and the current situation were identified. Subsequently, the solutions to these problems were elaborated upon and ranked. It followed that priority should be given to:
1 The determination of the customers appreciation of pro-active actions, within the NPS program.
2 Including multiple deployments in the product hardware strategy by productmanagers within the producthouse department.
3 Improving the overview of reverse logistics and product reliability (including the registration of distributed products), driven by Teleplan.

Chapter 5 now follows with a case study for Digitenne tuners to indicate the possibilities and observations from reliability analysis in the current situation.

Chapter 5:
Case Study Product Reliability Digitenne

5 Case Study Product Reliability Digitenne

-- KPN Classified Information --

5.1 Problems following from Digitenne case

In Chapter 4 problems that pertain to reverse logistics and product reliability analysis in general were explained and solutions were formulated. Next to these problems, the following problems pertain particularly to the case of Digitenne tuners.

Distorted figures (# tested) due to new and improved testing method

The amounts tested in the beginning of 2011 are greater than the average monthly returns. When in November 2010 the defective Digitenne tuners were identified, the testing of products at Drake & Farrell was brought to a standstill, so that a plan of action regarding this series could be determined. This has had two implications that are visible in the data results:

1) When late December 2010 the new testing process was started, an inventory of untested returns had built up. This inventory was tested during the first couple of months 2011, hence the number of tests are significantly higher in these months.

2) There is slight dip in the number of products tested in December 2010.

A consequence of these data errors is that the product age measured in 2011 is an overestimation of the actual age (since products have on average waited longer to be tested).

New testing method test results should be reviewed separate from test results of 2010

Because the improved testing method, the test-results of 2010 and 2011 should not simply be mixed. The *No Fault-Found percentage* of tests in the improved test method (2011 test results) is consequently lower than for the old testing method. Hence, the test results of 2010 provide a lower limit for the actual number of defects tested in 2010.

Problems in registration of production month

Registration of production month (required not only for reliability analysis, but also for warranty claims) is problematic. For Digitenne tuners by Topfield, the production month is coded into the serial number. The method to retrieve the production month from the serial number has changed over the years, however the recognition at the testing center has not been adopted accordingly. Appendix F explains in greater detail the problems that are related to registration of the production month.

Targeted approach towards customers

A pre-requisite for a pro-active action is that KPN knows which customers to contact. As described in the process description, the products that are distributed are not uniquely matched to customers. Here it is necessary to differentiate between the current installed base and the products that are distributed now and in the future. Though, for modern ITV tuners and RGs it is possible to match the product with the customer, by using the serial number and Mac-address that are registered in the KPN network. Thereby it is able to handle a targeted approach, affecting only those customers it intends to reach. This is not possible for Digitenne customers, since their products have not been registered uniquely at KPN, and their hardware is not connected to the KPN infrastructure. Also, for older RG's (I.e. Thomson 780 and elder) KPN is not able to target customers uniquely.

Different hardware versions of the same model

Topfield did not communicate that it would start to use Sun-Ho type PCB's from December 2008 onwards. Whilst hardware changes should be reported to KPN, reality shows that this occurs only exceptionally. Not only are these sub-series difficult to identify for KPN, KPN is also dependent on its suppliers regarding information about different hardware configurations. I.e. should inferior components be identified, than KPN is dependent on its suppliers to provide information.

Administration of number of products distributed

Reliability is determined by analysing the returns, and investigating the irregularities between the expected amount of returns and the actual number of defective returns. However, this is not straightforward. The number of products distributed is ambiguous on a high level and unknown on a detailed level. They are ambiguous

because the actual installed base of a model was not accurately kept track of. This is for example because the returns are not deducted from the installed base on a 'model'-level, but on a 'service'-level instead.
And, since the serial numbers are not registered before the tuners are distributed to the customers, it is not possible to determine how many products per production month are delivered to KPN, without the supplier sharing such information. As a result, it is difficult to determine whether an amount of defective returns is extraordinary high or not, since it cannot be determined high or low to which benchmark.
Gap between warranty agreements agreed upon by KPN and application in practise
Although the procurement department has agreed with the supplier Topfield on a term of 27 months warranty period, the testing center only uses a warranty term of 24 months. The 27 months of warranty period that has been agreed upon by the procurement department and Topfield, is built up of 24 months to refer to the 'actual' warranty period and 3 additional months to compensate for logistics time and time the products are kept on stock. Remarkably, the alignment of this agreement between the procurement department and the Test Center is not good and 3 months of warranty upon which KPN has a right, are omitted.

Re-use of smartcards complicates redeployment of tuners
An issue that had not been considered before is the related to the '*smartcard.*' A smartcard is required for access to KPN Digitenne, and ensures that it is not possible to decode the Digitenne signal without a subscription at KPN. However, The Topfield TF 6000 is encrypted in a way that they only accept Smartcards that start with "013-XXX" and "014-XXX". Unfortunately, in August, KPN was informed by its suppliers of Smartcards, that the numbers in the domains "013-XXX" and "014-XXX" were exhausted. This encryption can be deleted by KPN such that the new "020-XXX" type smartcards can also be used, but in order to do this, KPN must physically have the tuner. This further complicates processes and instructions to call center agents and customers.

Solutions to problems for Digitenne case
Notably, the problems that stand out to be most problematic are *"different hardware versions of the same model"* and *"administration of number of products distributed."* These problems are tightly related to the generic problem identified in Chapter 4 "data integration throughout the supply chain". More specifically, they involve the information sharing with suppliers. As Section 4.6 has already pointed out "increase strategic partnership with supply chain partners" is an important solution to this problem that can be pulled by the procurement department.

The case study underlines the differences between what should be possible within KPN and what actually is possible. Though suppliers should be able to provide a detailed view of the number of products per month of production, the Digitenne case shows that in practise, due to other conflicting interests, such data is not shared.
Furthermore the case study concretizes the difficulties of estimating the number of customers affected, due to which the impact of a pro-active action, and the related costs to the pro-active action, are unclear.

With respect to the data available, it becomes clear that it is difficult to draw conclusions when key characteristics for determining the impact (rental or buy, number of tuner of this type and production month in the installed base, etc.) are not available.

5.2 Chapter 5 Summary & Conclusion

This chapter was dedicated to a case study of Digitenne. It is centred around the question "*How does modelling failure behaviour currently work out in practise for Digitenne?* This chapter showed the possibilities and limitations of product reliability management under the current information availability for Digitenne.

In Section **Fout! Verwijzingsbron niet gevonden.** the choice for Digitenne as case study was explained. The main arguments for choosing Digitenne are the level of information available and the fact that it is known there is a reliability issue with Digitenne tuners, for which the number of affected tuners is uncertain.

Section **Fout! Verwijzingsbron niet gevonden.**
-- KPN Classified Information --

Section 5.1 is dedicated to problems that follow from the Digitenne case study and therefore pertain particularly to Digitenne. It follows "different hardware versions of the same model" and "administration of number of products distributed" are the largest problem areas.

Chapter 6 will now follow with providing an answer to the main problem statement posed in Section 1.6.

Chapter 6:
Conclusions & Insights

6 Conclusions and insights

This section provides an answer to the main research question posed in Section 1.6. It does so by reviewing the answers to the sub questions 1 till 4. Section 6.1 is dedicated to answering the problem statement, whereas section 6.2 is dedicated to recommendations, recommendations for further research and a discussion of the assumptions made in this research.

6.1 Conclusions and insights

The concluding section of this report aims to provide an answer to the problem statement that was introduced in Section 1.6: “Which **insights** can be **gained from the information collected** from **reverse flows** with respect to **product failure behaviour** and which adaptations are required in these reverse processes to enable and embed the **structural monitoring of product failure behaviour** in order for KPN to **timely pro-actively act?**”

The problem statement is answered by the following sub-questions:

The first research question was: “*What is the current situation regarding product reliability management and reverse logistics information for CM fixed products?”*
We concluded that there is no structural method of monitoring returns information and product reliability. Furthermore, analysis of the current situation indicated the complexity of the return flow, and more particularly the wide range of differences in products, product characteristics and product propositions that form the reverse flow. Primary determinants in the reverse process are (1) the type of order (collection or swap), (2) rental or bought STB (3) pre-announced or non-pre-announced order.

The second research question was: *“Which insights does literature provide with respect to reverse logistics information and product reliability monitoring?”*
We chose to use the Maturity Index on Reliability (Brombacher, 1999) as a framework for this section and the remainder of the research. The MIR model can be used for monitoring the maturity of an organisation on reliability management, and thereby is appropriate for indicating the improvement areas in organisational processes to perform and improve product reliability analysis. The MIR model consists of 5 levels; (0) uncontrolled; (1) measured; (2) analysed; (3) controlled and (4) improving. On MIR level 0 chaos exists, and product reliability is not managed. On MIR level 1 there is a basic feedback system that gives quantitative information. On MIR level 2 quantitative information is available on the failure location. On MIR level 3, adequate knowledge on the cause of a failure is available. On the highest MIR level, MIR level 4, an organization has the ability to continually adapt business processes in such a manner that potential problems will be anticipated (Boersma, 2001). Notably, the MIR model does not define which literature should be used per MIR level, nor does it define clearly/measurably when MIR level requirements are satisfied. MIR level 1 and MIR level 4 receive greatest attention.

On MIR 4 we find that both about the range of pro-active actions that could be undertaken as well as about the conditions for which these actions would be appropriate little literature is available. An overview of costs to be taken into account in a pro-active action, and differences between technical and economic lifetime are provided. On MIR 3 we find that Failure Mode and Effect Analysis is the most common method to perform root-cause analysis. On MIR 1, the Quality & Reliability Reference model was used to make a distinction can be made between hard (product breakdown) and soft (performance error) reliability problems. This research is limited to hard reliability problems. Furthermore, the four phases suggested by the four-phase rollercoaster model (hidden zero-hour, early wear-out, random failure and systematic wear-out) are accepted as a phenomena for reliability modelling. In particular it followed that for the products that have a technical lifetime that is either larger than, or equal to the economic lifetime ‘hidden zero-hour’ and ‘early wear-out errors’ are of particular importance.
Aside from literature related to the MIR levels, reverse logistics literature is consulted in order to identify the barriers and facilitators for reverse logistics.

The third research question was: “*What can be learned from applying the Maturity Index on Reliability to KPN?”*
From application of MIR 4 to KPN it is concluded that there are two phenomena which KPN aims to observe:

1) Early wear-out:	Production models/series that are particularly prone to failure.
2) Systematic wear-out:	Development of the installed base of products and products reaching their technical end-of-life.

The following 4 ways of acting pro-actively were identified:

- Monitor the development of returns and decide not to act.
- Stop distribution of the product, i.e. prevent the growth of the installed base of bad quality products
- Pro-actively stimulate customers to use other products/services; i.e. stimulation of migration to another service or accelerated introduction of a successor model
- Pro-active replacement of (a part of) the installed base

The relation between the observed phenomena and the pro-active decision to be taken is supported by a tool that incorporates safety, customer base affected (impact), costs, Netto Promotor Score, strategic interests/planning, time line (problem). The tool weights these arguments against: time line/feasibility for implementing the solution and the costs per customer (see Figure 23).

On MIR 3 it followed that, surely for the currently installed base, the factors that influence reliability cannot be measured. The products are therefore more or less viewed as a black-box, with the main output 'defective' or 'working' and only little, if any, additional information on the status of the product.
On MIR 1 it followed that KPN should monitor both the development of the number of returns (and defects) as well as the number of returns (and defects) per month of production. These variables can be used for analysing the following aspects:

- Development of the ratio defect/returns
- Percentage of installed base returned
- Development of the ratio defect/ per month of production
- Mean time to failure

At each MIR level, gaps between literature and the current situation at KPN were identified. For these problems, combined with other problems that had not been covered by previous MIR levels, solutions were introduced. Subsequently the solutions were prioritized, and the following 3 solutions were determined to be most important:

1. The determination of the customers appreciation of pro-active actions, within the NPS program.
2. Including multiple deployments in the product hardware strategy by productmanagers within the Producthouse department.
3. Improving the overview of reverse logistics and product reliability (including the registration of distributed products), driven by Teleplan.

RQ 4: How does modelling failure behaviour work out in practise for Digitenne?
-- KPN Classified Information --

Answer to main problem definition problem
The answers from the previous sub-questions make it possible to answer the main question.

It can be concluded that KPN is on a low level of structural product reliability management. KPN aims to observe two phenomena; production models/series that are particularly prone to failure and the average age at which products reach their technical end-of-life.

The information currently available is inadequate to determine the average age at which products reach their technical end-of-life. This is mainly the result of the infancy of the returns process and a wide range of process problems and problems in the returns information registration. In order to improve KPN the following solutions have the greatest priority:

1) The determination of the customers appreciation of pro-active actions, within the NPS program.
2) Including multiple deployments in the product hardware strategy by productmanagers within the Producthouse department.
3) Improving the overview of reverse logistics and product reliability (including the registration of distributed products), driven by Teleplan.

Despite the shortcomings of the current situation, it is possible to gain insight into the product reliability of Digitenne, which showed the presence of bad quality production models. By implementing the suggested solutions KPN will be able to improve its insight and will be able to make grounded decisions regarding pro-active actions, and thereby set a step towards being the best service provider of the Netherlands.

Recommendations:
The recommendations to KPN result mainly from Chapter 4, within which the MIR model is applied to KPN. The solutions that follow can be interpreted as recommendations to KPN in order to improve their maturity on product reliability management. Here we will suffice by repeating the solutions found in Section 4.6 (see Figure 26) . Refer to Section 4.6 for an extensive explanation of these solutions.

	Solutions to problems in the current situation	Key solution driver
A	Embedding reverse logistics and product reliability analysis	Management Customer Processes
B	Modify processes to automate part of the reliability analysis	Teleplan
C	Improving the overview of reverse logistics and product reliability (including the registration of distributed products)	Teleplan
D	Increase strategic partnership with supply chain partners	Corporate Procurement Office
E	Including multiple deployments in the product hardware strategy	Productmanagers Producthouse
F	Incorporation of 'worth' and economic value	Finance dep.
G	Incorporation of more stakeholder perspectives	Finance dep.
H	Modify financial stimulus for LSPs	Producthouse, Finance dep.
I	Improved registration of time dimension	Device Competence Center, Teleplan
J	Determination of customers appreciation of pro-active actions	NPS Program

Figure 26: Solutions to problems in the current situation

6.2 Discussion , limitations and recommendations for further research

This section contains a discussion on the assumptions and limitations of this research. Furthermore, recommendations are given for further research on the subjects of reverse (information) flows and product reliability.

6.2.1 Discussion and limitations

This research has delivered a valuable contribution to the insight into reverse (information) flows and their usage at KPN. It is the first time this type of research is performed at KPN. Due to for example time limitations some assumptions were made that are now clarified.

A primary observation regarding the MIR model are the shortcomings with regard to the definitions of the MIR model. The MIR model structures the way of viewing reliability management, however, since the levels are ill defined, it is both not clear which literature or which methods should be reviewed per MIR level nor is it clear how the performance within these models should be in order to satisfy the requirements per level. In this way it is rather arbitrarily at which point the requirements of a MIR level are satisfied, and thereby also on which level the organization could best develop. The lack of definition is further strengthened by other authors that interpret the MIR model differently. Hence, one may argue that the literature studied in this report is deficient to be able to legitimately conclude on the organisations maturity on product reliability management.

Another shortcoming of the MIR model is that the link between quantitative test-data results and qualitative information gathered by helpdesk agents is not well supported. It thereby fails to describe how best to take into account various information sources as sources of clarification of observed data patterns. During the research the pitfall of jumping to conclusions, without having knowledge of the interrelatedness of all processes, became more and more apparent. This research can be improved by incorporating possible explanations of the data patterns.

Furthermore, a key element in the decision tool depicted by Figure 23 are the values that determine which category of pro-active action is appropriate. There are at least two limitations to using this model. The first is that these static levels do not take into account factors that result from the environment. I.e. if for example, a region is hit by lightning, at may be expected that the number of returns is greater. Such environmental factors are not well incorporated in the model. The second limitation is that, although the weights were carefully chosen, they might not reflect all stakeholders appropriately. Before using this model in practise, both these weights as well as the scores per category should be reviewed by a group of stakeholders within KPN. Further, note that the model does not incorporate ‘business politics’. I.e., not only rational arguments, but also the status of the decision maker impacts which pro-active decision will be taken.

The classification of problems in order to determine what are the main problems that should be given priority is depend on the position of the analyst in the organisation. Since solutions for problems might have a large added value for one department, but a small added value to another, it depends largely on which perspective is chosen. Note that the classification of these problems took place from a reliability management perspective. As a result, the impact on other business processes, referring to the problem complexity, could have been overlooked. The classification should take place by bearing different perspectives in mind, which could change the outcome or prioritization of the problems.

Note also that the SRET process in general is an ‘immature’ process. One main observation that reverse logistics and the integral concept of re-using products more times, is not embedded into the business processes. However, such change requires a change in mind-set, and it takes time before this mind-set is embedded into the culture.

6.2.2 Recommendations for further research

The final section provides discussion and limitations to the performed research and provides recommendations for research that are familiar with or willing to do research with reverse (information) flows and product reliability analysis. With the increasing importance of corporate social responsibility, and ever shorter product development times, reverse flows and reliability analysis and reverse flows in general will remain increasingly important.

The first recommendation is to further research how to embed reverse logistics information and product reliability monitoring. This complex exercise consists of various parts, such as analysing how to ensure that multiple deployments are taken into account in the design and/or specifications of STBs. But also, how warranty agreements should be changed such that spare parts are included properly.

The second recommendation is to further research the possibility of creating an overall model, which includes not only the test results, but also changes in call center instructions, market developments, developments in the otherwise relevant environment and qualitative information provided by customers. Such a model would contribute heavily to the analysability of phenomena observed in the return flows, and will ensure that the information is not wrongly interpreted.

The third recommendation is to refine the categories (L, L-M, M, H) in Table 9. These categories consist of distinct strategies that can be pursued, for example what strategy to use for pro-active replacement. Further research should provide more insight into these strategies, and methods of determining which of these strategies is most appropriate.

The fourth recommendation is to further research in which ways KPN and the LSPs can more constructively cooperate. This consists of several aspects, ranging from creating more financial stimulus, to a culture change that facilitates *Best-In-Class* conviction and a greater knowledge base.

The fifth recommendation is regarding the development of performance tools & dashboards. Methods need to be developed for the continuous monitoring of product reliability and reverse (information) flows. Due to the broad range of learning's that can be gained from the reverse flows, it is important that these requirements are first investigated.

The sixth recommendation is regarding the value of improving the time-registration with respect to warranty agreements. Further research should indicate which improvements can be obtained with respect to structural evaluation and control on warranty agreements. As is pointed out in this report, the lack of information and process loops to perform checks on warranty agreements, impedes the assessment of the appropriateness of warranty agreements. Not only does the information need to become more reliable, more importantly, there needs to a structural method by which the warranty control is performed. In turn the effectiveness of the different sorts of warranty agreements should be evaluated.

The seventh recommendation is that further research should identify if it is desirable to include other components, such as cables and manuals, into the reverse flow. This research is based on the current reverse logistics policy, in which only the main component is collected.

The eight recommendation has strong technological roots. It involves further exploration of the possibility to adapt the products and/or testing process such that a better view of their technical state can be gained.

The ninth recommendation is to perform a more extensive stakeholder analysis. In order to prioritize the changes required in the reverse processes a more extensive stakeholder analysis needs to take place.

The tenth recommendation is to further investigate the other perspectives on the use of reverse information (see Appendix A), and particularly on how to limit the number of returns.

The final recommendation is to analyse if the Bass Model can contribute to the strategic/planning factor in MIR 4. The literature reviewed regarding Product Life Cycle of class, form and model in Section 3.2.2 can be extended by using the Bass Model. "The Bass Model provides a useful framework for viewing the diffusion of new products and technologies so as to permit realistic guesses about the pattern of sales growth and the timing of the peak in sales" (Bass, 2004). Thereby the Bass Model supports sales expectations (see Figure 27), and thereby serves as an input to the 'strategic' aspect of (pro-active) decision making.

The Bass model has a behavioural rationale that is consistent with studies in the social science literature on the adoption and diffusion of innovations (e.g., Rogers 1983) and is based on a simple premise about the hazard function (the conditional probability that an adoption will occur at time t given that an adoption has not yet occurred). Thus if f(t) is defined as the probability of adoption at time t, or the fraction of the ultimate potential which adopts the innovation at time t and F(t) is the fraction of the ultimate potential which has adopted by time t, the fundamental premise is that the likelihood of adoption at time t given that one has not yet occurred is: $f(t)/[1 - F(t)] = p + qF(t)$.

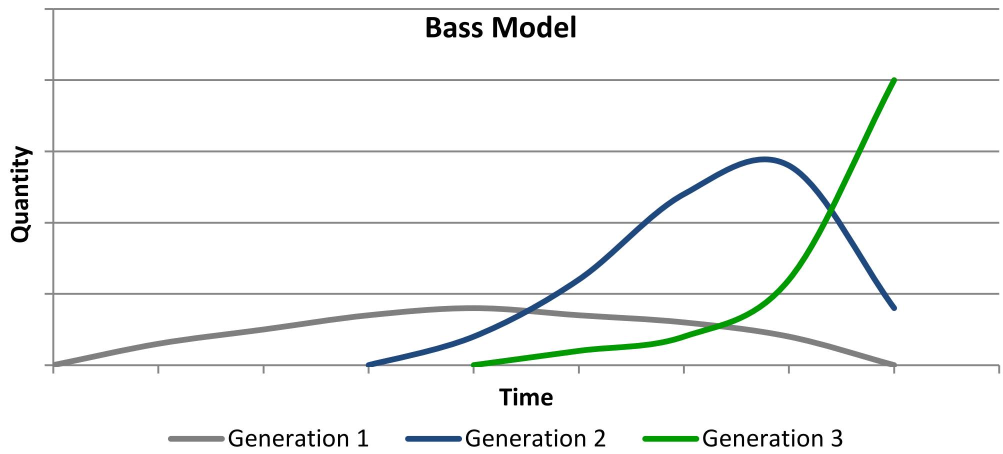

Figure 27: A series of technological generations

Glossary

Abbreviations

Concept	Definition
CM, CM fixed	Consumer Market, Consumer Market fixed market segment
CPO	Corporate Procurement Office
CSR	Corporate Social Responsibility
Digitenne	Digitenne, wireless digital television service offered by KPN
DOA	Defect-On- Arrival (or Dead-On-Arrival)
DVB-T	Digital Video Broadcasting – Terrestrial
EOL	End-of-Life product
EOU	End-of-Use product
FEF	Front-End-Filtering Front-end-filtering refers to the process of matching the received products with the information about the announced returns, as indicated by KPN Contact.
IPB	Internet plus (wireline) calling
ITV	Interactive Television
IP	Internet Protocol, technical basis for ITV
KP&P	*Klant Producten & Processen; Customer Products & Processes,* sub-department in the Consumer Market within which Producthouse is established
LSP	Logistic Service Provider (Ceva and Teleplan for KPN)
Multiplay	Synonymous with IPB (Internet plus wireline calling)
NPS	Net Promotor Score: the performance indicator used by KPN to measure the quality of services provided to consumers
PVR	Personal Video Recorder
RMA code	Return Material Authorization code
RG	Residential Gateway or Modem
RGU	Revenue Generating Unit
SC	Supply Chain
SP(M)	Spare Part (Management)
SRET	Service & Returns program (swaps and collections program)
SCSC	Supply Chain Service Center
STB	Set Top Box
VVP	Price (Vaste Verreken Prijs)
W&O	Wholesale & Operations
ZM	Business Market

Frequently used definitions

Concept	Definition
Backbone	Part of the network infrastructure used for transmission of data
Backwards compatible	A product or a technology is said to be backward compatible when it is able to fully take the place of an older product, by inter-operating with products that were designed for the older product (Zeldman, 2006)
Call ratio	Call ratio: Fraction of the calls that KPN contact receives that concerns a certain topic. I.e. the call ratio of 'Digitenne cancellations' concerns the fraction of the calls (either total calls or all 'Digitenne' calls) that is dedicated to cancellation to a Digitenne contract.
Cannibalization	This involves selective disassembly of used products and inspection of potentially reusable parts. Parts obtained from cannibalization can be reused in the repair, refurbishing or remanufacturing process (Thierry et al., 1995b).
CE	Consumer Electronics
CM, CM fixed	Consumer Market, Consumer Market fixed market segment
Content Provider	Provider of online services. Content providers focus on the content of the service (as opposed to access providers).
CSR	Corporate Social Responsibility
Digitenne	Wireless digital television service offered by KPN
DOA	Defect-On-Arrival (or Dead-On-Arrival). A DOA is a situation in which the product is not working directly after the customer purchases it (Baskoro, 2006)
DVB-T	Digital Video Broadcasting – Terrestrial. The technical basis for Digitenne.
EOL	End-of-Life product. Those returns for which the product as such is at the end of its economic or physical life. (de Brito, 2004)
EOU	End-of-Use product. Those situations where the user has a return opportunity at a certain life stage of the product (de Brito, 2004)
Installed Base	The total number of residential gateways/Digitenne tuners/ITV STBs that is working in the Netherlands (Baran,2011).
IP	Internet Protocol, technical basis for ITV.
IPB	Internet plus (wireline) calling *(Internet Plus Bellen)*
ITV	Interactive Television
KP&P	Klant Producten & Processen; Customer Products & Processes, sub-department in the Consumer Market within which Producthouse is established
KPN Contact	KPN helpdesk that is dedicated to answering questions from customers and resolving customer problems with KPN hardware.
KPN Save team	Team within KPN contact that aims to maintain customers that call to cancel their subscription. The team will persuade the customer to stay with KPN by offering him/her custom-tailored promotions.
LSP	Logistic Service Provider (Ceva and Teleplan for KPN)
Multiplay	Synonymous with IPB (Internet plus wireline calling)
NPS	Net Promotor Score: the performance indicator used by KPN to measure the quality of services provided to consumers.
Product Recovery Management (PRM)	"Product Recovery Management (PRM) is the management of all used and discarded products for which a manufacturing company takes responsibility. The objective of PRM is to recover that amount of products that economically and ecologically justifiable, while satisfying the legal constraints" (van der Laan, 1997)
PUDO point	Pick Up and Drop Off (PUDO) point. PUDO points are reviewed as a manner of exchanging products with customers without the necessity to make an appointment. PUDO points are an element of the KPN logistical 'menu'.
PVR	Personal Video Recorder. In case of Digitenne this product is also known as the double or dual tuner, since it has a tuner for recording as well as one for viewing a channel.
Recycling	Materials rather than products are recovered. These materials are reused in the manufacturing of new products.

Refurbishing	Products are upgraded to some pre-specified quality standards. Typically these standards are less than those for new products but higher than those for repaired products.
Repair	Products are brought to working order. This implies that typically the quality standards of repaired products are less than those for new products. Usually repair requires minor (dis)assembly, since only the non-working parts need to be repaired or replaced.
Residential Gateway (RG)	Residential Gateway: A residential gateway is a home networking device, used as a gateway to connect devices in the home to the Internet or other Wide Area Network (Baran, 2011).
Returns	term used to describe all products entering the reverse flow, regardless of their age and status. Returns thus include both working products, products that are returned in the trial period and supposedly defect products
Reverse logistics (RL)	The process of planning, implementing, and controlling the efficient, effective inbound flow, inspection and disposition of returned products and related information for the purpose of recovering value (Srivastava, 2008).
SRET process	SRET process encompasses the collection of consumer products in case a service is ended or the replacement of a product by a substitute product in case of a defect.
STB	Set Top Box, the universal term for the box that connects the television with the television signal. A Digitenne tuner is also an STB, however for convenience we refer to *STB's* for ITV propositions and to Digitenne *tuners* for the Digitenne proposition.
Supposedly defect	Supposedly defect articles are treated as defect until they are tested at an LSP to conclude binding with regard to it being defect or not. Supposedly defects result from the non-decisive analysis that is performed by call-center agents.
Triple Play	Term used for households that are connected for their telephone, internet and television needs (KPN, 2011).
Video-On-Demand	Video-on-Demand: systems which allow users to select and watch/listen to video or audio content on demand.
VVP	Price *(Vaste Verreken Prijs)*

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Frans Schutte, Jan Bol

Drake & Farrell
Hielke van der Schaar

Ceva Logistics
Jacques Hartman, Peter Lammers

KPN CM ST KP&P Producthouse
Manager:
Rutger van der Leeuw - Manager Producthouse

Product Managers:
Suzanne Cox - Product Manager ITV/ Digitenne (strategic)
Jaap Zegwaard - Product Manager ITV/ Digitenne (operational)
Erol Baran - Product Manager IPB

Supply Chain team:
Rob van der Meij - Architect
Erik Hofland - Contract Manager reverse logistics
Sjors Janssen - Supply chain Analyst

Consumer Experience team:
Clemence Tamboer - Installation assistent
Elsbeth van Hout - ITV
Janna de Feijter - Digitenne
Marlous Kelder - Do it yourself

Eddy van Dijk - Engineer (Digitenne)

KPNCC PO SCSC Planning & Consultancy
Ben van Lieshout - Vakmanager
Paul van Bohemen - Planner (IPB, ITV)

KPNCC PO Marketing, Media & call center
Ronald Truijens - Purchasing manager

W&O N&S INN T&D Devices
Theo Mol - Vakmanager

Willem van Egmond - Chain manager delivery Digitenne

Reporting team Digitenne
Adri van Moorsel

Base marketing Digitenne
Dian van de Griendt

Legal:
Heleen Lamers

Company documentation

Interviews and meetings

Rutger van der Leeuw	Producthouse Manager	19-05-2011
Topic:	*Strategy Interactive Television*	
Susanne Cox	Senior Commercial Product Manager	12-05-2011
Presentation	*Hardware-strategie Interactieve TV*	
Rob van der Meij	Architect	29-03-2011
Erik Hofland	Contract manager reverse logistics	
Erol Baran	Product Manager IPB	
Joep ter Avest	Graduation intern reverse logistics	
	Meeting inventory strategy returns	

Documentation:

Jaap Zegwaard-1	Meeting ITV growth	12-5-2011
Jaap Zegwaard-2	Meeting TF-6000 problems	30-06-2011
SRET Tool by Erik Hofland	Contract manager reverse logistics	22-02-2011
SRET development update	Jan Bol-1	25-06-2011
CM fixed hardware	Erol Baran	2011
Baran-1	Wisselbestand ModemNormalisatie	2010

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Appendixes

Appendix A: Different perspectives on information resulting from reverse flows

The following perspectives indicate the range of perspectives that people have on reverse flow. The wide range of perspectives indicates that different perspectives would require different processes and/or different variables for the improvement objective.

1) What can KPN learn from defects in returns to coordinate call center agents at KPN contact? (KPN Contact)
2) In what way can the information from returns be used to create insight into pro-active replacement of the installed base? (Rutger van der Leeuw)
3) How can KPN incorporate the age of returned products in determining a product state for which it is unadvisable to redeploy the product? (Erik Hofland, Rutger van der Leeuw)
4) How can we minimize the number of unnecessary reverse movements be minimized? (Rob van der Meij)
5) Can the number of returned products and product defects be forecasted? (Erik Hofland)
6) Can KPN use the information from returns to improve the warranty agreements with suppliers? (Supply Chain Service Center)
7) Can KPN use the information from returns to improve the performance of the Logistics Service Providers? (Erik Hofland)
8) How should the reverse flows be incorporated into the inventory- and spare part management at KPN? (Erik Hofland)
9) In which way should the information of reverse flows be used to facilitate Corporate Social Responsibility (Olaf Kriek)
10) How can the flow of product returns be minimized? (Rob van der Meij)
11) Is there any law and regulation present that pertains specifically to product returns?
12) How can the product returns be integrated to the current inventory management practices? (Supply Chain Service Center)
13) Can we use the information from returned products to contact customers who have terminated their services at KPN whilst using a defective product? (Willem van Egmond)
14) Who should bear the responsibility of monitoring and guaranteeing the processes (Erik Hofland)

Appendix B: Warranty Agreements

-- KPN Classified Information --

Appendix C: KPN Logistics 'Menu'

The logistics 'menu', depicted in Figure 28, outlines the delivery and collection methods that KPN has decided upon for the coming years. For these options it is now determining which it will use for which products for an environmentally responsible and economically viable retrieval of products. This research provides a contribution to the decision making regarding these options, but it will limit itself to the options already identified by KPN.

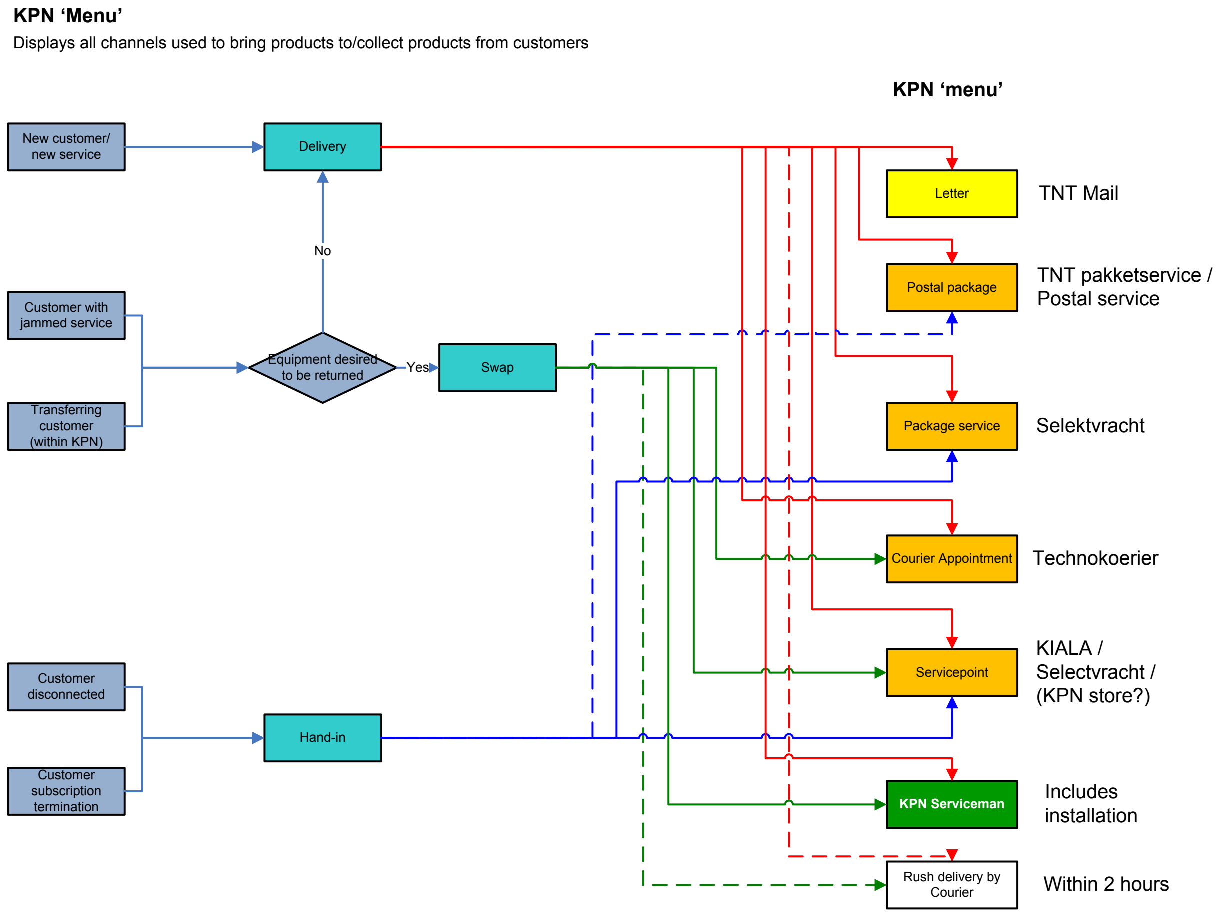

Figure 28: KPN Logistics Menu

KPN logistics menu

The KPN logistics menu displays the options that are considered to be used for the distribution and collection of goods. From left to right, the diagram displays the trigger (such as new customer subscription, customer subscriptions stops, etc.), the consequential operation (delivery, hand-in, swap) and the menu option that KPN offers to complete the operation. Partly inherent to the trigger and otherwise chosen by KPN a return results in delivery, swap or hand-in. When a new customer subscribes, it is inherent that some sort of delivery will take place, but that no equipment is taken back (which would take place with a swap or hand-in of material). However, if a customer cancels a service it is up to KPN to decide if it wants to retrieve the consumer product at the customer.

The arrows indicate the possible menu options per operation. The KPN logistics menu is a project that is currently implemented and is still subject to changes. For example, the 'servicepoint' option does not exist currently. It is also uncertain if the KPN stores will be used for the 'servicepoint' option, and it is also unclear if customers will be charged corresponding to their choice of option.

KPN Logistics Menu Defined

Menu option	Description
Letter	The letter is only used for communication concerning the service used from KPN. In case of for example internet subscriptions, e-mails do not suffice.
Postal Package	Postal package refers to packages 'without customer contact'. These are products sent by KPN, that fit in the mailbox, and can be distributed similar to postal letters.
Package service	Package service, contrary to postal package, refers to packages that do not fit in the mailbox, and hence are delivered at the door, but without a customer appointment.
Courier appointment	A courier appointment is similar to the package service, with the difference that this appointment takes place during a previously arranged timeslot. The courier hands over the product, but does not assist in connecting the products.
Servicepoint	For the servicepoint option a customer is able to collect its products at one of the servicepoint locations.
KPN service engineer	Contrary to the options previously described, the KPN service engineer does assist in connecting the products during a pre-specified timeslot.
Rush delivery	A rush delivery aims to provide a solution for situations in which timely replacement of products is critical.

Table 15: KPN Logistics Menu defined

Appendix D: Product Life Cycle Stage

-- KPN Classified Information --

Appendix E: Product reliability modelling background

In formula: λ(t)=f(t)/R(t)
where:
t – relevant lifetime characteristic (like calendar time, or time in use)
f(t) – probability density of the relevant lifetime
R(t) – reliability/survival function

Product reliability is defined as the probability R(t) that a product starting at time zero will survive a given time t:
$R(t) = P(T \geq t) = \int_t^{\infty} f(\tau)d\tau,$
Where T is a suitable continuous random variable representing time to failure with failure probability density function f(t).

Hazard plots
Hazard plots provide estimates of the distribution parameters, the proportion of units failing by a given age, percentiles of the distribution, the behaviour of the failure rate as a function of their age, and conditional failure probabilities for units of any age (Rai and Singh, 2003). For a continuous nonnegative random variable T representing lifetimes of individual items, hazard function is defined as:

(1) $$h(t) = \lim_{\Delta t \to 0} \frac{P(t \leq T \leq t + \Delta t | T \geq t)}{\Delta t}$$

Where Δt denotes a very small time interval. The above equation can also be written as: (Rai and Singh, 2003)

(2) $$h(t) = \lim_{\Delta t \to 0} \frac{N(t) - N(t + \Delta t)}{N(t)\Delta t}$$

Where $N(t)$ is the number of operational units at time t. The hazard function specifies the instantaneous failure rate at time t given that an item has survived until t. If Δt is taken as one week, which can be regarded as a very small time interval considering a useful life for a Digitenne tuner, (2) can be written as

(3) $$h(t) = \frac{N(t) - N(t+1)}{N(t)}$$

Or

(4) $$h(t) = \frac{Number\ of\ failed\ units\ during\ time\ t\ and\ t+1}{Number\ of\ operational\ units\ at\ time\ t}$$

Using $h(t)$, cumulative hazard rate is estimated by

(5) $$H(t) = \sum_{u<t} h(u), \qquad u < t$$

Appendix F: Topfield serial number structure

-- KPN Classified Information --

Appendix G: Relating problems to solutions

MIR 4:
1. Limited embeddedness of reverse logistics in business operations
2. Insufficient registration of customer details hinders approach of specific customers
3. Customer appreciation of pro-active action uncertain
4. Economic valuation not in line with technical capabilities

MIR 3:
5. Front-end call center processes not suitable for reliability analysis
6. Limitations in root-cause analysis

MIR 1:
7. Insufficient stakeholder perspectives have been taken into account when designing SRET processes
8. Test methodology at test center is not flawless
9. Lack of overview over (reverse) processes
10. Information integration throughout the supply chain is limited
11. Deficient registration of time
12. Timeliness of information

Other:
13. IT limitations impede process changes
14. Needless costs due to duplicate operations
15. Unanticipated negative side effects in controlling the return flow
16. Spare-part supplier conflict
17. Capability to put products rapidly back into the market
18. Professionalism of the suppliers and the LSPs
19. Unclear roles and job descriptions
20. Financial stimulus for LSPs ineffective

	Solution	Related Problems
A	Embedding reverse logistics and product reliability analysis	1,2,7, 9, 17
B	Modify processes to automate part of the reliability analysis	5, 6, 8, 12, 14
C	Improving the overview of reverse logistics and product reliability reliability (including the registration of distributed products)	1, 9
D	Increase strategic partnership with supply chain partners	10, 16, 18, 19
E	Including multiple deployments in the product hardware strategy	1,9
F	Incorporation of 'worth' and economic value	4
G	Incorporation of more stakeholder perspectives	7
H	Modify financial stimulus for LSPs Improved registration of time dimension	20
I	Improved registration of time	11
J	Determination of customers appreciation of pro-active actions	3

No solutions were offered for problems 13 and 15. We believe that for these problems the solution was offered by simply describing the problem.

Appendix H: Test results case study Digitenne

-- KPN Classified Information –