MASTER

Organization of NPD and innovation using a modular approach

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Organization of NPD and Innovation using a Modular Approach

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Abstract

Many benefits of modularity could be found in the literature. But in practise companies are often struggling with some technical, commercial, and organizational issues of a modular approach. The modular New Product Development (NPD) approach of a company in the security systems industry was analyzed and evaluated from a technology, innovation, market, organization, and coordination perspective: the drivers, issues and risks were explored. Insights and recommendations were given with regard to the business drivers cost and time of the development process, the choice between commonality versus diversity in the scope definition, and the organizational structure with better utilization of innovative capacity.

Executive summary

This thesis is part of my final project's deliverables for the degree of Master of Science in Innovation Management within the study Industrial Engineering and Management Science at the Eindhoven University of Technology (TU/e). The subject of this research assignment was the organization of New Product Development (NPD) and innovation using a modular approach. The company under investigation in this case study was a company in the security systems industry, further denoted as 'Company A'.

Company and development

Company A is part of the Corporate Group. The emphasis of the corporate vision lies on quality, innovation, and customers. The focus of the thesis was on the Business Unit (BU) Closed Circuit TeleVision (CCTV) in The Netherlands. The products that the company develops are mainly positioned in the professional market segments for the high-end and mid-range market tiers. The competences of this BU include Digital Video Recorders (DVRs), imaging, vision IC development, and camera modules but the scope of the research involved a focus on IP surveillance cameras (e.g. dome cameras, box cameras, modular dome cameras, and high resolution cameras). Like other companies in the industry, Company A is experiencing some market trends that have influence on the processes (Boersma et al., 2004): 'increasing product functionality and complexity', 'strong cost erosion', 'strong pressure on time-to-market', 'increasing customer demands on quality and reliability', and 'increasing business process complexity'. To have faster throughput in terms of product introductions, higher performance and reliability, and improved schedule accuracy Company A implemented the Product Line Approach (PLA). In general this meant a Reference Architecture was created and maintained, that describes how platforms will be portioned into subsystems (the Standard Designs (SDs)), that defines the re-useable SDs, and defines the interfaces between these SDs. The idea was to separate SD development from product development, and to develop Innovation Projects to explore new ideas with high-potential. There was assumed that the domain- and technology know-how is allowing Company A to do so. The practical gap involved the evaluation of the whole PLA.

Theoretical findings and research directions

In the thesis, modular NPD is defined as *'a set of subsystems and interfaces intentionally planned and developed to form a common structure from which a stream of derivative product can be efficiently and effectively developed, marketed, and produced'* (Muffatto and Roveda, 2000, p.619). Modularity exists when components can be disaggregated and recombined into new configurations, possible with new components, with little loss of functionality (Schilling and Steensma, 2001). This approach is opposed to what in this thesis is called the integral 'traditional product development' approach: complex (N-to-M) mappings between functions and building blocks, and interfaces are coupled (Oosterman, 2001). The theoretical benefits could be categorized into increased (product) quality, reduction in development time, easier customization and upgrades, cost efficiencies, higher flexibility, and better design standardization. The risks could be classified into technical, commercial (market), and organizational risks (Riek, 2001).

The theoretical gap is that there is much known about the technological possibilities and benefits of a modular approach but that in practise the market and organizational issues are not always recognized, not managed in the right way, and there is not enough anticipation on the risks. The way-of-working and the entire knowledge of the company is strongly shaped by the existing architecture and the company's (development) culture (Sanchez, 1999). A company that is using the modular approach tries with using existing products, and creation of new product ideas, following the company strategy, and listening to the customer demands to coordinate the development process to develop a successful modularized product platform and planning (Ericsson and Erixon, 1999).

Assignment

The research tangle of the modular approach consisted of on the one hand finding a balance in resources between Project Management (main goal: efficiency) and Product / Innovation Management (main goal: effectiveness) and on the other hand finding a balance in the roadmap between the short and long term. The following research question was stated:

'What are recommendations for effectively and efficiently managing the issues and anticipating on the risks related to the organization of the process, the implementation, and innovation of modular NPD (by making use of the benefits of modularity)?'

The deliverables involved an internal analysis: insight in the objectives and issues of the company's development process, recommendations for improvements: the tools and methods to improve particular important issues, and implementation: application of the redesign options to the organization and the different roles involved. The planning consisted of a front part: the preparation of the project, and an execution part of the project. The execution part consisted of the following steps: an internal analysis on the current situation, the exploring of improvement options, clear options for redesign, and an implementation in the company. The methodology used for data collection were introduction activities, product training sessions, documentation studies, questionnaires, interviews, meetings, and development data studies. The results of the research were derived with the help of different software tools for modelling, calculation and (graphical) presentation.

Analysis

In the internal analysis a questionnaire was sent and interviews were performed that tried to provide insight in the issues and risks related to the modular approach within Company A. These were further explored from different perspectives to be clustered and rated. This resulted in three improvement areas to further focus on: first, **'insight in the development process business drivers' performance cost and time'**, second, **'making the trade-offs in the scope (commonality versus diversity)'**, and third, **'structuring the organizational and innovation processes'.**

Redesign recommendations

The first improvement area was getting insight in the costs and throughput times of the development process. First, the costs of the integral 'traditional product development' approach were compared with the costs of the modular approach (costs of the platform, SD, and product development). The average development cost per product did not improve at the moment. Furthermore, the costs of the platform (platform and SD development cost) were compared with the (separated) costs of the product development with the PLA. There was no trend visible that the product spin-offs (the 'variants') will take significantly less development costs. There should be noted that it was still difficult to calculate the gains in product development of the modular approach because the first products will be finished in the future and the gains can not easily be expressed in hard figures.

The same insight was created in the development times and it appeared that there was no significant acceleration of product development time achieved by using the modular approach. On the other hand, more (SD) projects were performed in parallel.

The recommendation was made that Company A should make more use of platform-based performance indicators in the future. For the platform cost efficiency this means the *'costs of product variants'* should be divided by the *'costs of the platform and SD development'*. For the platform cycle time efficiency this is the *'time to develop product variants'* divided by the *'development time of the platform and SDs'* (Meyer and Lehnerd, 1997). This relative indicators show how efficient a platform still is.

The second improvement area was making trade-offs in the scope. Some recommendations are made with regard to trade-offs between commonality and diversity. The main message was that Company A should keep a vision in mind with an emphasis on investing more in being innovative, defining a clear scope and stay with the scope, and exploring multiple market segments but keeping the functionality high.

The third improvement area was structuring of the organizational and innovation processes. Actions were already taken for improvement of resource availability (with a tool like Critical Chain Project Management (CCPM)) and coordination within and over sites (in the role of Program Manager Officer (PMO)). The role of (the infrastructure of) ICT requires attention for better supporting the organization and the integration of (modular) processes and (ICT) systems. For more cross-functional integration, Company A should verify the presence of factors like quality of internal and external communication, an open group climate and task related doubt, and collaborative leadership (Gebert et al., 2006). Moreover, innovation is 'the successful implementation of creative ideas by an organization' (Amabile, 2000, p. 332). The recommendation on the innovation process was that Company A should not solely rely on acquisitions as the primary source for introducing innovation to the company. Innovation should come from within the company and creativity is very important for the company's success. Furthermore, Knowledge Management is a relatively undiscovered area within Company A. There are two strategies that should be taken into account for securing of knowledge: codification, which is directed at a technical ICT system solution. And personalization, the creation of a social network (Hislop, 2005). To overcome the related issues of a 'not-invented-here' culture in certain areas, there should be made better use of organization learning and external sourcing.

Implementation

In the implementation part the recommendations were applied to Company A's organization. First, the development process was monitored using the platform-based cost efficiency indicator. It appeared that one product variant will be relatively more efficient (more suitable for re-use) than the other. A sensitivity analysis showed possible outcomes when some assumptions are made for the worst or best case scenarios.

For better definition of the scope of a SD before and during a project a checklist form was made. Factors that were taken into account were scope description, SD target, resource allocation, estimated duration, estimated budget, deliverables (output criteria), way-of-working, and process deliverables.

The roles and responsibilities of the organizational structure were defined guided by the three factors that are required for a modular approach: ownership, empowerment, and constancy (Meyer and Lehnerd, 1997). Especially, the roles of the (System) Architects and PMOs are important in modular Program Management.

Conclusion

The main message about the achievement of the objectives was that the development times in terms of product introductions and the costs per product variant have not been improved. On the other hand, the objectives of quality in terms of performance and reliability and project schedule accuracy were actually better. The separation of the platform (SDs) and product development was still not always observed. Nevertheless, the technical risk mitigation in mini projects was successful. At the moment, it is not clear which SDs can be re-used and whether the specific domain- and technical know-how will be sufficient in the future. The overall conclusion about the closing of the (theoretical) gap was to take the learned lessons into account, take a broad organizational view, and improve the processes on these points. Finally, the main recommendation for future research was to have a closer focus on the relation between the modular approach and innovation.

Preface

Although this Master Thesis report was one of results of an individual project, it was made with the direct or indirect help of a lot of people. I would like to thank everyone who contributed in some manner to this project: my colleagues at 'Company A' not only for their input to the questionnaire and interviews and their enthusiasm regarding the subject but also for the good atmosphere. There was special gratitude to my company supervisor, Frank Verschuren, for his always challenging questions, the discussions that we had, and giving me the opportunity to experience the way-of-working in a big company. Also thanks to Frank Engelen for his efforts in getting me started and the evaluation of the development process. My supervisors of the TU/e, Jimme Keizer and Peter Sonnemans, were very valuable in providing me academic theories, literature, standards, and insights. It was nice to see that you all made some time free in your busy schedules.

The main motivation and focus of my study was bridging technology and people to search for innovative solutions. This final project not only concludes my study Innovation Management (Industrial Engineering and Management Science), but also an exiting time of my life. I enjoyed working with fellow-students and learned a lot of lessons that made me ready for the practise.

I would like to contribute this work to my near- friends and –family. Especially, the investments and efforts of my parents made this chance possible. Last but not least I would like to thank Tessa. Your support and love helped me along this way. See you all in the future!

Maarten Feskens
Eindhoven, June 2008

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Table 1 List of abbreviations

Abbreviation	Explanation
A&SD	Architecture & Standard Design
BoM	Bill-of-Materials
B. Sc.	Bachelor of Science
BU	Business Unit
CAD	Computer Aided Design
CAGR	Compound Annual Growth Rate
CCPM	Critical Chain Project Management
CCTV	Closed Circuit Television
CPU	Central Processing Unit
CTO	Chief Technology Officer
DSP	Digital Signal Processing
DVP	Digital Video Processing
DVR	Digital Video Recorder
EMC	Electro Magnetic Compatibility
IC	Integrated Circuit
ICT	Information & Communication Technology
IFP	Innovation & Feasibility Process
IG	Innovation Gate
IP	Internet Protocol
IT	Information Technology
LAN	Local Area Network
MFD	Modular Function Deployment
M. Sc.	Master of Science
NPD	New Product Development
OEM	Original Equipment Manufacturer
OSM	Organization Science & Marketing
PCB	Printed Circuit Board
PLA	Product Line Approach
PMO	Program Manager Officer
PRP	Product Realization Process
PTZ	Pan Tilt Zoom
QRG	Quick Reference Guide
R&D	Research and Development
SD	Standard Design
SDK	Software Development Kit
SMART	Specific, Measurable, Acceptable, Realistic, and Timed
TU/e	Technische Universiteit Eindhoven
USA	United States of America
VAR	Value Added Reseller
VCA	Video Content Analysis
WAN	Wide Area Network
WBS	Work Breakdown Structure

1. Introduction

This thesis is part of my final project's deliverables for the degree of Master of Science in Innovation Management within the study Industrial Engineering and Management Science at the Eindhoven University of Technology (TU/e). The subject of this research assignment was the organization of New Product Development (NPD) and innovation using a modular approach.

The company under investigation is active in the security systems industry and is part of the 'Corporate Group'. In this thesis the company is further denoted as 'Company A'. These names are fictive, to conform to the company policy. For the same reason not all figures were disclosed and sensitive data was masked.

The major driver for choosing the subject was that it was clear from theory that modularity can provide many opportunities. Modularity really appeals to one's imagination. A company that uses a well-managed modular approach can benefit both in efficiency and effectiveness. The main goal of Company A for using a modular approach was 'developing a broader range of products with relatively less effort'. Or as the management gurus Meyer and Lehnerd (1997, p. 23) stated: 'cost efficiencies, technological leverage, and market power can be achieved when companies redirect their thinking and resources from single products to families of products built upon robust product platforms'. A successful modular approach means thinking in different building blocks, abstraction levels and synergies.

But what I already experienced during my final Bachelor of Science project was that in practice the ideal circumstances are just not there to profit from all of the benefits. It depends mainly on how the scope is defined to find a good balance between factors like technology, market, organization, being efficient, being effective, the short, and the long term. Architectures can be structured as the perfect modular example of Lego® blocks. But market forces and people in organizations posses an inherent uncertainty and can not always be structured the same way. That is why it interesting how, on the one hand flexibility can be created to be innovative and effective, and on the same time standardization can be created in the internal process for being efficient.

1.1 Company A's organization

In this first chapter an introduction will be given to the Corporate Group and Company A's organization. Also the products, market tiers and segments, IT sector, industry trends, and market position will be explored. Furthermore, insight will be given in the development process, roadmap process, objectives of the Product Line Approach (PLA), innovation process, and the practical gap.

1.1.1 The Corporate Group

Company A is part of the Corporate Group. The company was founded by a charismatic person at the end of the 19th century, and today it is a leading global manufacturing, sales and after-sales service

network with about 280 subsidiaries in over 140 countries. The special ownership structure of the Corporate Group guarantees financial independence and entrepreneurial freedom.
The company is able to undertake significant up-front investments to safeguard its future, as well as meet its social responsibility in a manner reflective of the spirit and will of its founder. 92% of the shares of the Coporate Group are held by a charitable foundation.
The Corporate Group generated a sales of € 46.3 billion and had about 271,000 associates in 2007. The Group is structured in business sectors with a technology emphasis on automotive, industrials, and consumer goods & buildings. Company A is part of the business sector consumer goods & buildings. The focus of the research in the Corporate Group was on the BU CCTV.
Having the highest quality standards and supporting and promoting innovation are key principles of the Corporate Group's policy. Around the world scientists, engineers and technicians are involved in developing new products and innovative manufacturing processes as well as the continuous improvement of existing products. Thanks to their R&D efforts, Company A applied for patents for a total of 3,300 new inventions in 2007. That innovation is important within the company can be seen in Figure 1; R&D investments are steadily increasing. Company A has an investment focus: R&D should be a double-digit percentage of product sales volume.

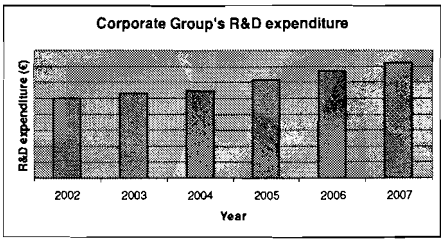

Figure 1 Corporate Group's R&D expenditure

The Corporate Group aims for lasting economic success and a leading market position in everything it does ('rather lose money than trust'). The Group is not a joint-stock company, and is therefore not driven by the stock market. This entrepreneurial independence enables the Group to have an individual corporate policy and long-term-oriented business. The key factors in their customer satisfaction are innovation, economy, reliability, and quality. The Corporate Group has standard principles that allow them to achieve their goals together with their customers. That quality always has been the key to the Corporate Group's philosophy can be seen in the following quote by its founder:

> 'It has always been an unbearable thought to me that someone could inspect one of my products and find it inferior in any way. For that reason I have constantly tried to produce products which withstand the closest scrutiny, products which prove themselves superior in every respect...'

Guided by the corporate vision, the Group works on a wide range of projects with which it constantly optimize its internal processes. The corporate vision represents more speed in everything that is done, focusing on quality, innovation, and customers.

1.1.2 Company A's organization

The corporate vision is reflected in the mission of Company A:

> 'We are an innovative, customer-oriented and global supplier of security and communication products and solutions. Our systems offer high-quality solutions backed by excellent service. Our goal is to be the preferred partner of our customers.'

The company is striving to be reliable with award-winning advanced technology. Also the worldwide manufacturing network is internationally acknowledged top-rate performance on the basis of uniform Company A quality standards. Company A manufactures products like fire and burglar alarms, video surveillance systems, and time management and access control systems. Company A had a sales of €1.4 billion and 10,757 associates in 2007. Geographically Company A is divided in three regions; first: Europe, the Middle East, and Africa; second: North and South America; and third: the Asian and Pacific region. The three business areas are: Products, Buildings, and Communication Centers. The sites of these business areas are located worldwide.

1.1.2.1 Products

The product portfolio consisted of three classes: security, safety, and communications. These classes together with their characteristics are depicted in Table 2. The focus of Company A is on video systems, also called Closed Circuit TeleVision (CCTV).

Table 2 Products: product portfolio

Security	Protection for buildings, infrastructure and assets	• Intrusion • CCTV • Access
Safety	Protection for people's life, building and assets	• Fire • Evacuation • Care solutions
Communications	Communication of voice, sound and music	• Fixed installations • Mobile installations

1.1.2.2 Buildings

The business area of building security has headquarters in Germany, The Netherlands, and Hungary. The area aims at creating complete, customized systems, products and services with easy-to-install and user-friendly technology for maximum protection. This means security in all stages: offer phase, implementation phase, and operation phase.

1.1.2.3 Communication Centers

The third business area, provide reliable, high-quality monitoring and communication services around the clock. The monitor service is a security service for monitoring and securing individuals and property, while the communication service supplies innovative services for all aspects of customer communication. Finally, there are also trust centers: comprehensive services for secure electronic communication.

1.2 Products

The focus of this Master thesis project was on the Company A (CCTV) in The Netherlands. At this site two series of cameras are developed: (regular) fixed box cameras and fixed dome cameras. Other competences of this location include (embedded) DVR's, imaging (key components), vision IC development, and camera modules. The 'internal customers' of the Company A are located at a German site (Video Surveillance Software), another Germany site (IP products and Video Content Analysis (VCA)), and a site in the USA (dome cameras and video SDKs). To provide an idea of what kind of key components a camera consists of, there was in Figure 2 a simplified illustration given of the inside of a dome camera. A security camera is characterized by relatively complex technology. The key components with the number of possible combinations are: **B**ubbles (3 combinations), **L**enses (4 combinations), **S**ensors (4 combinations), **P**rocessing, and **I**nterfaces (3 combinations). In theory, the combination of these key components results already in 144 (= 3 x 4 x 4 x 1 x 3) combinations.

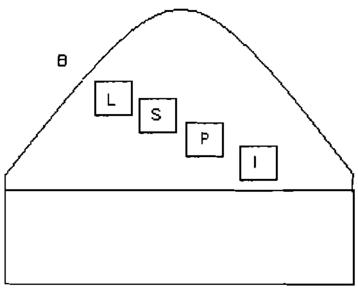

Figure 2 Simplified illustration of dome camera's key components

1.2.1 Camera market tiers and segments

The products are mainly distributed to professional installers and wholesalers according the process that is depicted in Figure 3. These 'external customers' have different needs. There is a distinction between market tiers and market segments. The market tiers are mainly based on high-end and mid-range cost / performance ratio (basic performance cameras are phased out). For the different market segments, the cameras require different functionalities. The basic functionalities that could be separated are controlling, detecting, recognizing, and identifying. The main camera portfolio consists of four different series with all their own general functionality: dome cameras, with perfect design for discrete surveillance; box cameras, flexible high-quality solutions for demanding locations; modular dome cameras, robust PTZ cameras with high speed for surveillance in all circumstances; and high resolution cameras, with ultra high resolution for displaying the finest details. The main focus of the assignment was on CCTV IP camera system platforms that Company A is developing in the higher and moderate market tier (professional products). IP camera technology means video and other data is distributed over an IT network and the internet. In Appendix 1 an example is provided of how a camera system with related products can be set-up in a given situation.

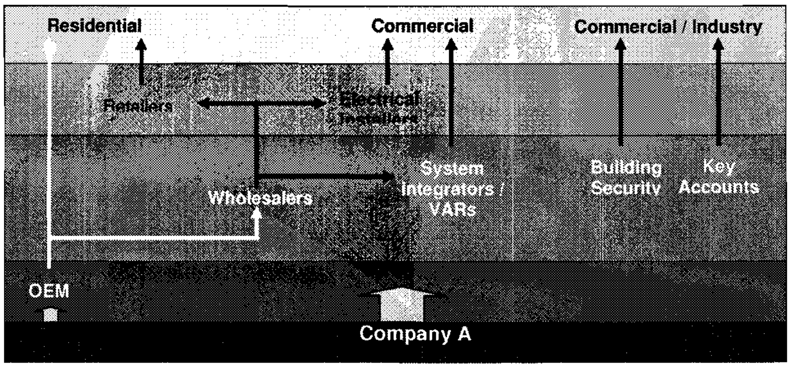

Figure 3 Distribution channels

1.2.2 IT and the security sector

The focus on IP is particularly interesting because developments in the IT sector are going faster than in the traditional CCTV sector. The sector is characterized by a good price / performance ratio; high economies of scale and Moore's law (two times performance every 18 months). Other IP factors relevant to CCTV are that in theory distance does not matter (e.g. there are always some inefficiencies due to resistance of materials), a bigger role for the IT system administrator, and CCTV over (existing) IT networks. There should be mentioned that IP products are estimated to be still in the first phases (not mature) and that they soon will cannibalize a much bigger part of the analogue products.

1.3 Market trends

With today's market pressures and increasing technological and organizational complexity there is clearly a trend in favor of more modular products (Baldwin and Clark, 1997). Five major trends are influencing modular New Product Development business drivers in the security systems industry (Baldwin and Clark, 1997; Boersma et al., 2004; Sander and Brombacher, 2000; Wolters, 2002):

1.3.1 Increasing product functionality and complexity

Business driver: functionality. Functionality means that a product is able to fulfil an intended function (Sander and Brombacher, 2000). The increase in product functionality leads to higher interdependency-complexity (more interaction arises with the user due to increasing product functionality), while the increase of technological intensity leads to a higher frequency of generations and more technical complexity (Minderhoud, 1999). Higher product connectivity leads to higher combinatorial-complexity (more elements can be connected to the product due to increasing number of product-interfaces). In the case of Company A there is increasing functionality and complexity observed in cameras, transmission, detection, imaging, and storage due to the technology Digital Video Processing (DVP).

1.3.2 Strong cost erosion

Business driver: cost. Cost erosion is related to the increasing competitive intensity that leads faster to more new products (Minderhoud, 1999). If quantities go up, prices come down or vice versa. Thus if prices come down the quantities sold go up. In order to sell more, prices have to come down resulting in continuous pressure to reduce cost of the product (Minderhoud and Fraser, 2005). Price erosion means that it is even more difficult to make profit on each separate sold product (Sander and Brombacher, 2000). Company A has some percentages of cost erosion per year. The basic and standard market (small shops and individuals) is growing in popularity. The profit margins per product are also much lower, so if Company A wants to direct more resources at this market in the future, they have to sell more products than in the professional market.

1.3.3 Strong pressure on time-to-market

Business driver: time. Time-to-market means the required moment in time that the product reaches the market (Sander and Brombacher, 2000). A shorter time-to-market leads to shorter life cycles (Minderhoud, 1999). As can be seen in Figure 4, the development time is steeply decreasing in the recent years, while the feedback information from the field is staying ratter stable. The hardly non-decreasing feedback time of this figure shows also the implications of the next trend on 'increasing customer demands on quality and reliability': the customer warranty demands are continuously increasing, while the feedback time stays almost the same.

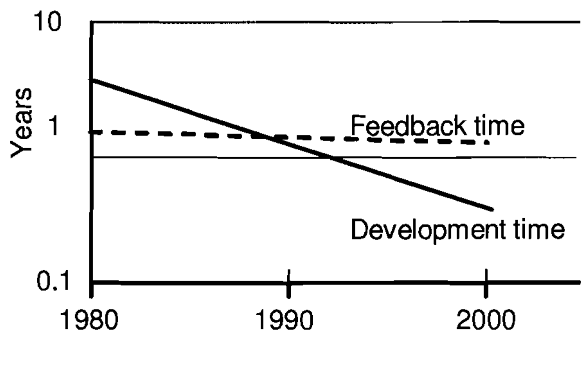

Figure 4 Shorter development times

An example of the time pressure can be found in Company A: the CCTV market segment is a heavily growing with about 10% per year, so to gain new profits it is essential to be fast to the market.

1.3.4 Increasing customer demands on quality and reliability

Business driver: quality. Quality means that the product fulfils customer requirements at 'all' customers not only at the moment of purchasing but also during operational life of the product

(Sander and Brombacher, 2000). Reliability is the probability that a system will perform its intended function for a specific period of time under a given set of conditions (Lewis, 1996). The increasing customer demands are related to the move towards a more extended definition of product quality. The definition of quality is changing from 'conformance to requirements' to 'conformance to customer expectations' (Berden et al., 2000). Currently, more and more manufacturers tend to follow a 'no questions asked' policy: in case of a complaint the product is simply exchanged for a new one or the client gets her money back (Sander and Brombacher, 2000). This leads to an increase in warranty coverage not only in scope but also in time. Figure 5 illustrates this trend towards extended definitions.

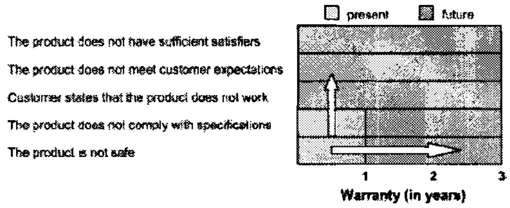

Figure 5 Quality and reliability

Company A has an image of providing quality to customers. Issues that are playing are e.g.: the change from analog to IP cameras and the growing system capacity (cameras with better Digital Signal Processing (DSP), higher demand of video transmission and storage, and more powerful switch and surveillance equipment).

1.3.5 Increasing business process complexity, globalization and outsourcing

Business driver: business process. The nature of the market has changed dramatically with the increased competition and globalization (Minderhoud and Fraser, 2005). Market globalization leads to more variants per product (Minderhoud, 1999). The development of a product is spread all over the world. Disintegration as with outsourcing makes the processes also far more difficult. Thus not only the product complexity has increased, also the (global) processes with which they are made, are far more complex. Also Company A's business process and system complexity is high, which can be seen in trends like: the integration of CCTV in other system applications, the integration of other system applications in CCTV systems, and the increase of indirect sales. Finally, a growing number of installers are installing larger and more complex systems.

1.3.6 Market position

The Company A has a good market position all over the world. According to IMS Research (www.imsresearch.com) Company A was in comparison to key competitors the global number three. The security market is a big market and is heavily growing with average Compound Annual Growth Rate (CAGR) of an estimated 5.7% for the period between 2006 and 2014. This CAGR is used to describe the estimated growth of sales over a certain period.

1.4 Development processes

1.4.1 The development process

In Figure 6 the Architecture and Standard Design (A&SD) process is illustrated (see Appendix 2 for a complete overview of the different phases).

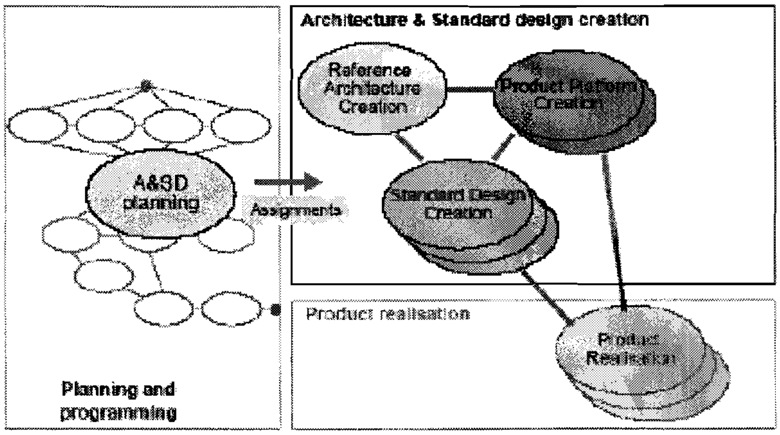

Figure 6 A&SD process

For multiple generations of products, Standard Design (SD) projects are planned and created. These common (modular) building blocks are the (physical) realization of a subsystem which complies with one or more Reference Architecture(s) and are designed for re-use / multiple-use. A SD is the largest possible combination of sub-functions which can be re-used as a whole. A Reference Architecture is a document describing how the product family (which is a group of products that share a common, managed set of features that satisfy the specific needs of selected market segments) will be partitioned into subsystems or components. This Reference Architecture also documents the interfaces between the subsystems and with the environment, and how to apply and design (guidelines and constraints) the SDs. A validation platform is used to implement and pre-integrate SDs, subsystems, and interfaces to form a common structure from which a stream of derivative products can be efficiently and effectively developed and produced. The SD projects can be directed at improving a Functional Domain. A Functional Domain is a grouping of technical and user functions and features (capability of a function) that can be put together in a logical way. Some examples of Functional Domains are: video processing, user interface, or interconnection. From the roadmap could be seen whether the product platform is still capable of delivering feasible new products. For product / process improvement and innovation there are also Innovation Projects planned. Innovation Projects are in general more complex and uncertain in nature, so it is difficult to plan those projects. It becomes even more difficult to plan not only for the short term (less than three years) but also for the long term (more than three years).

1.4.2 The roadmap process

The Product Platform Creation and Platform-based Product Realization Process (PRP) projects of Company A are planned in a roadmap, also called a Master Plan, which is illustrated is Figure 7. A roadmap describes a market trend to identify the required products and functions for the coming years. These are high level product requirements and describe what a product should do. Plans are made to phase in or phase out product. The purpose of the roadmap is to visualize project dependencies, a discussion document for risk management, communication document across development sites, and for high level resource allocation. There are different roadmaps: technology road maps ('what technology to use, what technology will probably become the industry standard') and business roadmaps ('future customer needs'). Finally, modular product development should not only be seen in relation to the development project but also in relation to its impact on production, together with the life time and end of life processes. An example of a forward looking roadmap is provided in Appendix 3.

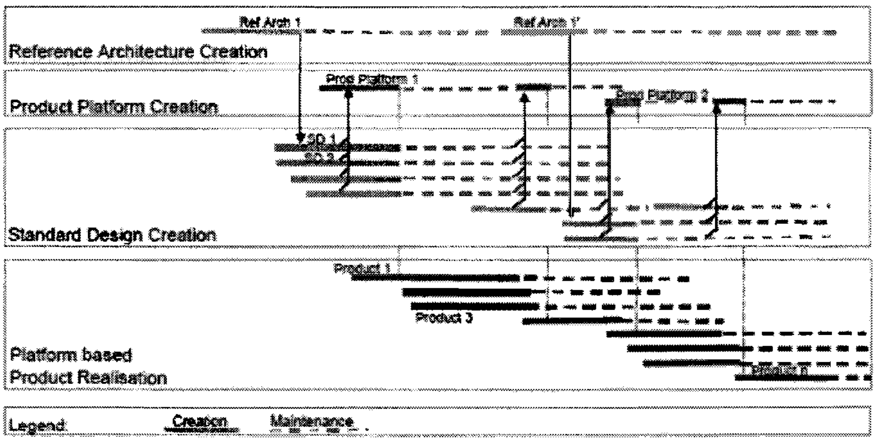

Figure 7 Roadmap

1.4.3 Objectives of the Product Line Approach

The A&SD process is part of the modular approach that is called the Product Line Approach (PLA) within Company A. PLA is an optimized development process that allows organizations to decrease effort and improve quality by systematically utilizing the similarities of their products. It works best when number of products is large enough, variation is well understood, and future evolution can be planned

Formally, a successful PLA should lead to a faster throughput in terms of product introductions, higher performance and reliability, and improved project schedule accuracy. This can be achieved by separating SD development (and Innovation Projects) from product development. The SDs, 'small' advanced development projects are there to prove feasibility and are meant to be re-used or for multiple use; technical risks are solved in mini projects. On the other hand product development's objective is to converge to a specific product, while Innovation Projects may be studies on new technology. The PLA approach is an investment in maintained Reference Architectures and SDs and stimulating commodity (re-use) over cost penalties in product. This should pay off in terms of the throughput, accuracy, and quality. Company A assumed that the domain- and technology know-how is allowing them to do so.

1.4.4 The innovation process

Useful new ideas for the Innovation Projects are filtered out via the Innovation Pipeline. This pipeline is a funnel (focused tunnel) which produces only few, but high-potential ideas. The mouth of the funnel is wide: this should represent the access to new ideas. The neck of the funnel is narrow, screening out only the feasible ideas into development projects (Burgelman et al., 2004). At the start or end of each phase of an Innovation Project there are Innovation Gates (IGs). Each IG involves a milestone 'go', 'no go' (stop) or 're-do' (defer, park, or transfer) decision. Breaking up the process in phases can decrease the uncertainty and create commitment and responsibility. The structure of the Innovation Projects is presented in Table 3 and has two functions in general: first, Idea Management: the finding, generation, filtering, and evaluation of ideas. Second, it is an Innovation and Feasibility Process (IFP): it includes feasibility investigation and feasibility realization.

Table 3 Innovation Projects

IG	Phase	Description
IG0	Phase 1: idea generation, collection, & verification	Create an open, stimulating atmosphere, allowing idea generation. Idea collection can be systematic goal-oriented (top-down) or non-systematic (bottom-up). Indications on the business case and technical feasibility.
IG1	Phase 2: pre study	Evaluation of ideas along the core competences and longer term vision
IG2	Phase 3: concept study, Innovation Project	The goal of the concept study is to get a detailed estimate on the business case and the technical feasibility. Select, plan, and execute Innovation Projects resulting in prototypes.
IG3	Phase 4: demonstrate idea, product engineering	Prototype demonstration, resulting project idea description that can be used as input for project definition.

1.4.5 The practical gap

Company A introduced the PLA (a modular approach) with the main goal in mind: 'developing a broader range of products with relatively less effort'. The further objectives that were set for this approach are stated in section 1.4.3. On the one hand, the potential benefits of this modular approach to act on the industry trends were clear when it was introduced. It seemed to be logic to take the investments up-front and develop products more concurrently. Some valuable lessons could be learned now, early in the development process. On the other hand however, in practice few gains were experienced. The starting-up, the implementation, and execution costs may be higher than expected. Also, a number of complexities and issues came to the light.

The practical gap involved that there was not enough insight in the real gains and costs of the modular development approach. The challenge was to evaluate the PLA approach from different perspectives, analyze the data, explore improvement areas, and provide practical recommendations that could be applied to Company A's organization.

2. Theoretical findings and research directions

In this chapter first the theory of the thesis' subject is further explained in the theoretical model. The concept of modularity is defined and the differences between the integral 'traditional product development' approach and the modular approach are treated. Furthermore, an overview of theoretical benefits together with best-practice examples is given. Also potential risks involved in modular NPD are showed based on the risk classifications technical, commercial / market, and organizational. The theoretical gap found in the literature and the modular approach is further explained. In the second part of this chapter there is focused on the research assignment with the research question and the project deliverables. In the third part the planning of the preparation and execution phases of the thesis can be found. In the final part of the chapter, the methodology for data collection (product training courses, information and documentation study, the questionnaire, interviews, meetings, and diverse data from development) and the process methodology (software tools used for modeling, calculation, and (graphical) presentation) is explored.

2.1 Theoretical model

2.1.1 Modularity

But what is modular NPD actually? Modular NPD is seen as being broader than platform development. Platforms and modularity are concepts that have proved to be useful in a large number of fields that deal with (complex) technological systems. With a focus on technology, a platform is defined as 'a relatively large set of product components (modules) that are physically connected as a stable sub-assembly and is common to different final models' (Muffatto, 1998, p. 489). Ericsson and Erixon (1999) defined a module as 'a standardized unit, a combinable, changeable part or component, a class of numbers, any in a series of standardized units for use together, a usually packaged functional assembly of electronic components for use with other such assemblies'. Most simply, a module is a building block with defined interfaces. When using a modular approach, many variations of final products could be built while controlling the internal complexity that often besets manufacturing companies as the increase customer choices of product design features (Ericsson and Erixon, 1999, p. 17). Thus, a better suitable definition of modularization is: 'decomposition of a product into building blocks (modules) with specified interfaces, driven by company-specific strategies' (Ericsson and Erixon, 1999, p. 19). For this thesis the definition of the modular approach is: *a set of subsystems and interfaces intentionally planned and developed to form a common structure from which a stream of derivative products can be efficiently and effectively developed, marketed and produced* (Muffatto and Roveda, 2000, p. 619) adapted from Meyer and Lehnerd (1997).

2.1.2 Integral versus modular development

There should always be a trade-off made between the two opposing concepts modularity and integration. Choosing more modularity means higher initial cost, while choosing to integrate more leads to higher operational costs. Modularity is better in situations with network externalities, physical network, increasing the installed base, increasing the availability of complementary goods, a dominant design, protect proprietary technology, and open standards. It should be avoided in cases of a powerful asset or position or if the company possesses a unique and powerful advantage (Schilling, 2000). In Figure 8 the differences are illustrated between an integral and a modular product architecture (Eerens and Verhulst, 1997).

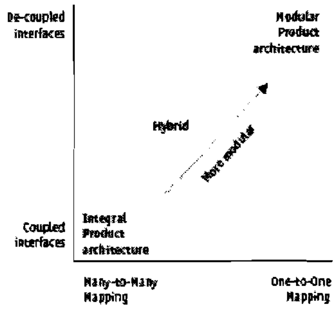

Figure 8 Integral versus modular

The PLA is based on modular product development and is an alternative for the 'traditional integral product development' methodology of Company A. The latter involves a search for a single 'constrained optimised' development solution for a product with specified performance objectives and cost constraints. An integral product has complex (N-to-M) mappings between functions and the building blocks, its interfaces are coupled, and a high degree of integration exists when a system achieves greater functionality by its components being specific to one another (Oosterman, 2001; Schilling, 2000).

The objective of modular product development is creation of a product design that can serve as the basis for a number of product variations and upgraded models with different performance and cost characteristics. The specified (standardized) component interfaces in a product design define the product architecture. These interfaces create a loosely coupled system of components (Sanchez, 2000). Modular products have a one-to-one mapping between functions and building blocks. A high degree of modularity exists when the components can be disaggregated and recombined into new configurations, possible with new components, with little loss of functionality (Schilling and Steensma, 2001). Modularity does thus three basic things (Baldwin and Clark, 2000): first, it increases the range of "manageable" complexity. It does this by limiting the scope of interaction between elements of tasks, thereby reducing the amount and range of cycling that occurs in a design or production process. Second, it allows different parts of a large design to be worked on concurrently. Third, modularity accommodates uncertainty.

2.1.3 Reasons for using the modular approach

Why should a modular approach be used? As already seen in the section above, in the literature a high number of potential benefits are mentioned. There are also plenty examples of best-practises of companies or in industries (Muffatto and Roveda, 2000). The ideal modular situation was reflected in the following phrase about successful modular NPD: 'the ready substitution of component variations into a modular product design achieves economies of substitution that allow product variations to be leveraged quickly and at low incremental costs per product variation, greatly increasing the flexibility of product designs' (Sanchez, 1995, p. 142). The main potential benefits of the modular approach in a high-tech sector were divided in the six categories: quality, time, functionality, profitability, coordination, and standardization. An overview of these theoretical benefits is provided in Table 4:

Table 4 Benefits from theory

(Product) quality
Easier product diagnosis and simpler control (e.g. easier to learn for users), easier installation, after sales / easier maintenance and repair, better (independent, parallel) testing (modules tested before final assembly have shorter feedback links, allowing easier adjustments), disposability (e.g. recycling, end of product life cycle), and re-use (e.g. 'proven' technology). *Best-practice example: Sony Walkman.*
Reduction in product development time
Shorter product life cycles through incremental improvements such as upgrade add-ons and adaptations, reduced development time (parallel development are possible once the interfaces between modules have been defined), shorter time-to-market (product development plans can be translated into production plans for each module / parallel manufacturing activities), reduced order lead time, and faster product evolution. *Best-practice example: Philips Electronics.*
Customization and upgrades
Economies of scale in component commonality, increased interchange-ability of products / component, increased number of product variants (diversity), and increasing responsiveness to customer needs. *Best-practice example: Black & Decker*
Cost efficiencies
Lower life cycle costs through easy maintenance, cost savings in inventory and logistics (work-in-progress is reduced due to shortened lead times, less stock maintenance of ready-made products), less R&D and manufacturing costs, lower capital costs, reduced material and purchase costs, economies of scale, lower costs through re-use of components, and decreased switching costs. *Best-practice example: automotive industry.*
Higher flexibility
Product changes, due to market or new technology, can be made more easily since they will only influence limited parts of the product, flexibility in component re-use (component flexibility), flexibility in architecture re-use (platform flexibility), strategic flexibility, increased number of product variants, decoupled risks (lower risks), reduced systemic complexity, and purchasing from multiple sources (e.g. suppliers / in-sourcing). *Best-practice example: Compaq.*
Design standardization
Task specialization, decoupling tasks (e.g. independent product development), more design freedom, better learning across projects, outsourcing, and easier administration (quoting, planning, and designing customized products can be done more efficiently). *Best-practice example: telecom industry.*
References: *Ericsson and Erixon (1999), Kamrani and Salhieh (2002), Kusiak (2002), Mikkola and Gassmann (2003), Muffatto (1998), O'Grady (1999), Oosterman (2001), Oshri and Newell (2005), and Schilling (2000).*

2.1.4 Risks in modular NPD

Besides advantages, there are of course also certain risks involved that can lead to issues related to modular NPD. This can also be the other way around: certain issues can have a risk that they grow or lead to other issues. Thinking in terms of platforms or families of products rather than individual products is one of the key drivers behind the success of short-cycle-time companies. However, also significant costs are associated with product platform development (Krishnan and Gupta, 2001). Modular product development risk can be classified in three main categories: technical risks, commercial risks, and risks that have to do with the managing of the organization and NPD-personnel (Riek, 2001). For each category examples are provided in Table 5:

Table 5 Risks of modular NPD

Technical risks
Design risk, over-specifying (balance between commonality and distinctiveness), being locked-in in a chosen technology path, products that look too much alike (overly similar), over-design of low-end variants in a firm's product family to enable subsystem sharing with high-end products, limited by the technology available, reducing of performance, difficult for new products (simpler in later stages of product life cycle).
Commercial risks
Developing the initial platform in most cases requires more investments and development time than developing a single product, delaying the time-to-market of the first product and affecting the return on investment time, competitors that are copying the design (reverse-engineering), and lower barriers to entry for competitors.
Organizational risks
Issues in defining modules and organising these choices so as to solve the issue of integrating parts, depend on the capabilities of available designers within the company, continuing innovation and renewal required (creating barriers to breakthrough innovations though rather incremental innovations), issues with cross-functional teams (e.g. different time frames, jargon, goals and assumptions), and one perspective can dominate the debate in the organization (engineers: efficiency by commonalities, marketing: effectiveness by distinct products).
References: *Henderson and Clark (1990), Krishnan and Gupta (2001), Meyer and Lehnerd (1997), Mohr et al. (2005), Muffatto (1999), Oosterman (2001), Pine (1993), and Smith and Reinertsen (1998).*

2.1.5 The theoretical gap

There is much written in the literature and known in practise about (modular) architecture and platform development. Many engineering studies, management journals, books and other literature specify a variety of reasons as to why and how product building blocks interact, and stress the implications of product architecture for the company (Oosterman, 2001). From a technical perspective, product architecture has been defined by Ulrich (1995) as the arrangement of functional elements, the mapping from the functional elements to physical components, and the specification of the interfaces among interacting physical components. A key issue in the design of the architecture is the ease in which the technical design of the architecture allows changes to be made to a product range, product, or component level (Ericsson and Erixon, 1999). Products with integral architectures require changes to several components in order to implement changes to the product's function. For products with a modular architecture on the other hand, desired changes to a functional element can be localized to one component. A modular product design therefore increases the likelihood to use standard components and also enables component interfaces to be identical across several products.

But an established architecture is strongly embedded within the organization and the organization's **way-of-working** and even the entire '**knowledge**' of a company is strongly shaped by this architecture (Henderson and Clark, 1990; Sanchez, 1999). Effective management of modular knowledge architectures enables greater clarity in identifying an organization's knowledge assets and greater precision in targeting strategically useful **organizational learning** (Sanchez, 2000). Further, Muffatto (1998) mentioned that architecture is heavily influenced by the **company's (development) culture**. For example, the high degree of autonomy at Honda and the powerful project managers at Toyota made it difficult to fully adopt a platform approach. These examples show that there is often a destructive resistance to change, also denoted as inertia. Organization must overcome this inertia (Hoetker, 2002). When the architecture is made more modular, also the organization needs to change in order to improve the critical interaction across different functions (Smith and Reinertsen, 1998). According to Oosterman (2001), the organization should reflect the (modular) architecture of the product, as illustrated in Figure 9. Tasks should be structured in semiautonomous groups of tasks in order to minimise the overall coordination effort and increase speed.

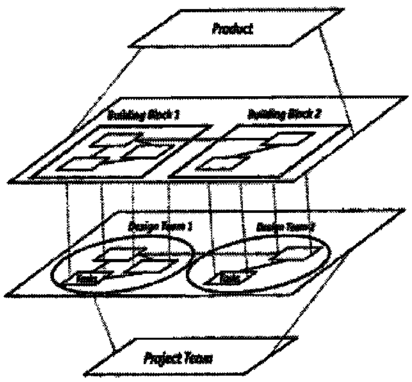

Figure 9 Architecture

The studies about platform development and modular NPD are highly detailed and very useful, but generally very technically oriented. There is a lack of clear definitions and consensus: the concept of modular NPD is predominantly associated with product technology and in a limited way with customer needs and the organization. Modular NPD is more than just adopting new design rules and creating the new resources required by a technical system. Managers must guide the values and norms in the cultural change process (Sanchez, 2000). There is too little emphasis placed on the detailed consequences of modular product architectures with respect to organizational aspects. Most of the relevant literature is less revealing when it comes to discussing problems related to implementing and managing modular architectures and successive platforms (Vuuren and Halman, 2001). A company must be clear what advantages it is seeking when it begins to invest in increasing the modularity of its products. Companies do not always perceive that the benefits of using a modular approach may outweigh the costs and risks (Hoetker, 2002). While nowadays products are built up more modular to make the managing of company processes less complex, this sometimes seems to have an adverse effect. The analysing of interactions between modules of a product leads to insight into the dependencies between developers that design modules. In practise there is little insight into those dependencies, and that results in bad management (Oosterman, 2001). Modular NPD is a great concept, but often the advantages are idealized, there is insufficient attention for (especially management) strategies to cope with the issues and complexities, and there is not enough anticipation on the risks. Modularity is not only about re-use of physical modules (technology), but also about offering variety to the market, creating a proactive organization, and showing the importance to the stakeholder that are involved. Modularization does not mean standardization in the sense of reducing the customer's choice, but managing and controlling variance by establishing an intelligently shaped product structure.

2.1.6 The modular approach

To take into account other factors than only technical and to make the development process more effective and efficient, the modular NPD approach is proposed (see Figure 10): with the use existing products (technology development for improvement in products and processes) and creation of new product ideas (to act on innovation), following the company strategy (organization) and listen to the customer demands (market versus technical power), a successful modularized product platform and product platform development plan can be created. Also the flexibility in the coordinating of the company's (human) resources (with the help of ICT or Knowledge Management) should be considered in this process. The funnel concept, explained in Section 1.4.4, is used for screening out only useful ideas. The most effort is taken up-front, as early as possible: 'thinking before acting' is the motto. The model of the modular approach is adjusted from the Modular Function Deployment (MFD) process by Ericsson and Erixon (1999) and serves as the thinking pattern for this thesis.

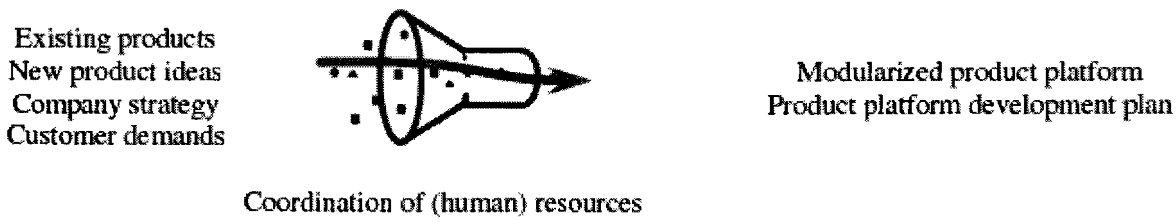

Figure 10 Modular approach

2.2 Assignment

2.2.1 Research question

Most of the issues described in the theoretical gap (Section 2.1.5) are also experienced in Company A's organization. The modular PLA is already implemented and the potential benefits were known beforehand in the organization. But besides technical issues, also commercial / market and organizational issues arose. There are insufficient recommendations from both theory and practise to cope with especially these market and organizational complexities and risks. This resulted in the following main research question:

What are recommendations for effectively and efficiently managing the issues and anticipating on the risks related to the process, the implementation and innovation of modular New Product Development (by making use of the benefits of modularity)?

One should not have the illusion that a real optimal solution can be found. There should be taken into account that there is always a balance required between resources for Product Management, Project Management, and Innovation Management objectives. Also the roadmap should be balanced between the short term (operational level) and long term (visionary / strategically level), see Figure 11.

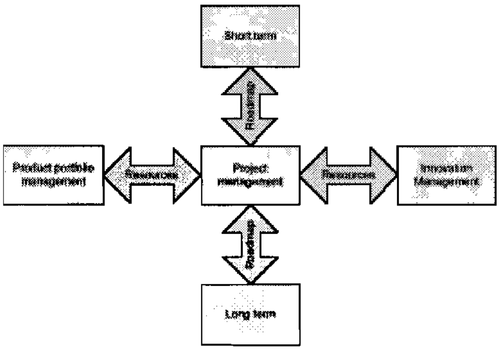

Figure 11 Balancing roadmap and resources

2.2.2 Deliverables

The research question should be answered from both Company A's perspective (with specific, practical know-how) as from the academic perspective (with general, theoretical knowledge). The deliverables stated what relevant information this research should provide. The aim of this thesis was design-oriented research. This means besides an analysis, also recommendations and redesign options will be given. This includes the implementation of the recommendations to Company A's organization. The main deliverables for the thesis were:

- Internal analysis: insight in the objectives, issues and potential risks of the company's development process.
- Recommendations for improvements: the tools and methods to improve the main issues or risks areas.
- Implementation: application of the redesigns option to the organization and defining the different roles that are involved.

2.3 Planning

The process of creating the Master thesis consisted of two phases: the front part and the execution part. First, the front part is the preparation on the Master thesis and included the university courses 'Literature Study (1ML05)' and 'Research Proposal (1MR05)'. In Figure 12 the global planning of the Master thesis preparation is given with the successive steps that were performed. The first two steps of the preparation involved an orientation. Step one, the selection of the thesis subject, was very straightforward. The (management) complexities and issues surrounding the 'great' concept of modularity already caught my attention when working on the final Bachelor of Science project. In this project the relation of modular NPD and the product life cycle was investigated. Step two in the preparation of the Master thesis was the selection and reading of relevant literature. Although there was much material available the main issue was to keep the focus as concise as possible. In the third step, the literature review, the theory of modular NPD is extensively described. The fourth and fifth steps were performed concurrently. Together with the introduction to the company also the link with the practise would be defined in the research design. Together with a planning and a description of the methodology this provided input for the last step of the front part: the research proposal. This was the start point for the execution part.

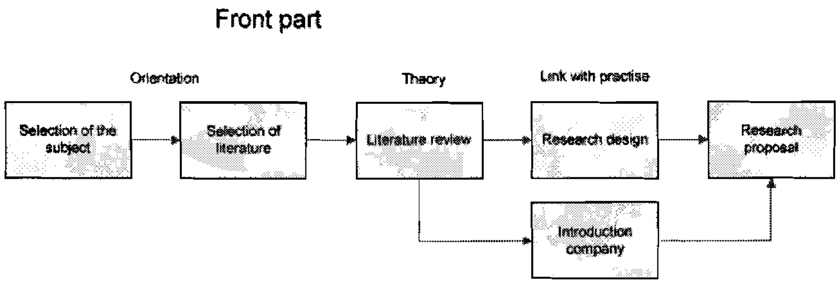

Figure 12 Front part of the planning

In the execution part (Figure 13), the following successive steps were performed (related to the deliverables):

- <u>*Internal analysis (Section 3.1):*</u> *description and analyzing the current situation (issues and risks with the strategy, the NPD processes, or structure)*
- <u>*Exploring of improvement options (Section 3.2):*</u> *capturing the goals and setting objectives following the strategic vision for by comparing the desirable situation with the current situation*
- <u>*Redesign options (Chapter 4):*</u> *presenting (re)design options for long term benefit and innovation when using a modular NPD approach*
- <u>*Implementation (Chapter 5):*</u> *application of the recommendations to the organization and a description of the (functional) roles in a modular NPD approach*

For a detailed overview of the execution part, see Appendix 4; taking into account the stated, the information needed, the source, and the methodology.

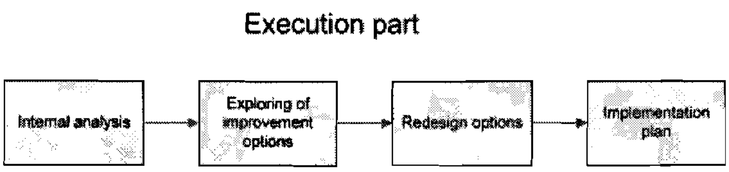

Figure 13 Execution part of the planning

2.4 Methodology for data collection and process

In this section the methodology for collecting data and processing the data is explained. Effective and efficient data collection is indispensable in an empirical case study. For applying the theory to the practise, some assumptions need to be checked in the specific company. Also new information should be gathered to confirm, extent, or replace the knowledge about the subject. In this thesis the following data collection methods were used:

2.4.1 Introduction / preparation events

A good start can make the difference. That is why a good introduction into Company A was very valuable. It helped to get a feeling with the security systems business and electronics industry. A company profile of the Corporate Group and Company A was build not only for introducing the company, but also to show the characteristics of the sector. Besides introduction meetings, there were meetings about the camera development and innovation processes that gave a closer look into the business processes. Furthermore, an extensive literature review was written on the subject and desk work was performed by studying information that was available. Also the research proposal was written with the aim to focus on a concise area for further study. In the mean time, product training provided more technical insights and knowledge, related to the company and the products.

2.4.2 Product training

Technical and market knowledge and underlying physics about the products, especially the surveillance cameras, were very useful for mutual understanding between Company A's people and me. In particular technology developers could be very specific and often used jargon. The following product courses were attended: CCTV Basic (concepts, characteristics, specifications, and applications of CCTV products and –systems), Cameras and objectives, IP Basic (applications of data networks in LAN and WAN environments), CCTV IP, IP cameras and modular domes, and VCA.

2.4.3 Information and documentation study

After the literature study, the level of knowledge about modular NPD was kept up-to-date and even increased by still studying books, articles, magazines, brochures, presentations, company reports and management procedures. This theory, practical guidelines, and contextual information gave valuable insights in the issues that are involved.

2.4.4 Questionnaire

Questionnaires are simple and low cost and time consuming methods for data collection. The results are easy to quantify over a bigger population and can be expressed statistically. A questionnaire was used to describe and analyze the current situation, to get insight in the goals, and to compare the present situation with a desirable ('should-be') state. The questionnaire had four main subjects that reflected the criteria for analysis:

- The definition of modular NPD and current way-of-working
- The reasons and drivers for using a modular NPD approach
- Trade-offs and choices in relation to modularity
- Factors that influence modular NPD

2.4.5 Interviews and meetings

The interviews provided an opportunity to get a deeper understanding of the issues and how they should be resolved. By asking and asking further there could be better focussed on some subjects. Also the most interesting or striking answers given in the questionnaire could be reviewed. Interviews are particularly suitable for evaluating the experiences of the people, in this case with platform development. Higher involvement for the thesis' objectives could be created. The following subjects were addressed in those meetings:

- The ideas behind chosen answers of the questionnaire
- Deeper insights in the subject of modular NPD
- The development process (technology and business innovation roadmaps) of Company A with a focus on modularity / SDs
- Possible risks and (organizational) strategies to overcome the challenges in modular NPD
- Own experiences in modular NPD, platform projects or SDs

2.4.6 Development data

With the help of Project Managers financial and scheduling data was made available. The development costs and throughput times were adjusted to come up with graphical results. To conform to the company policy, the project names and numbers showed in these results were not provided or were not exact. Only the proportions are provided to express the effects of the modular approach.

2.4.7 Process methodology

For the analysis and presentation of the data some software tools were used: for creating an active questionnaire (e.g. with checkboxes) the 'Forms'-option in Microsoft Word was used. Furthermore, most of the calculations and graphical presentations were made in Microsoft Excel. Extended 'if-then'-constructions could be made in this tool with the option to illustrate the results in graphs and tables. Finally, Microsoft Visio enabled the creation of models, flowcharts, and Gantt-charts.

3. Analysis

In the third chapter, the analysis, the first part involved an internal analysis of the results of the questionnaires and interviews. The second part involved the exploring of potential improvement options. The five different perspectives (customer demands, existing products, coordination, new product ideas, and company strategy) of the modular approach were used to get an overview of the issues. When these issues were known, they were classified as potential risks in one of the three risk categories (technical, commercial / market, and organizational) and were prioritized. Finally, the general findings of the analysis were illustrated in a framework from which three improvement options were derived.

3.1 Internal analysis

In the first phase, a pre-study, an internal analysis was performed on the current situation of the company (issues with the strategy, the NPD processes, or the structure). The data collection methods that are used for this analysis included questionnaires and interviews. The ideas expressed in the questionnaires could be further explained and motivated by the respondents in the interviews.

3.1.1 The questionnaire

Potential respondents and interviewees were selected in consultation with the site's Program Manager. A diversity of functions from different organizational levels was chosen, to get an overview of the general organizational opinion towards modular NPD. The people that were approached were the CTO, two (Senior) Product Managers, a Project Manager, two Group Leaders Hardware, two Group Leaders Software, two System Architects, a Software Architect, and an Electrical Designer. The contact letter that was sent to the persons can be found in Appendix 5. Twelve of the seventeen persons that received the questionnaire completed it. This is a response rate of 71% that is satisfying for this kind of method. A rule of thumb is that the average response rate of questionnaires by email is about 5% - 30% (www.wikipedia.org). The sample population consisted only of males with a mean age of 40 years with a standard deviation of 8.4 years. The youngest respondent was 26 years and the oldest 54 years. Five respondents had a working experience of one to five years at Company A, five respondents five to ten years, and two even more than ten years. Besides all the questionnaire respondents, also the Development Manager, Program / Project Managers, and a Hardware Architect were interviewed. In Appendix 6 the complete questionnaire together with the answers is provided. In Appendices 8 – 10 the answers are graphically illustrated and extensively explained. In the sections below, the most interesting results are highlighted. There should be noted that the questions are all subjectively rated because they involved personal opinion. But this was used to capture the ideas and spirit toward modular NPD within the organization.

3.1.2 The interviews

The aim of the second phase was to capture the goals and setting objectives by following the strategic vision and comparing the desirable situation with the current situation. Interviews were planned with a duration of about 60 minutes. In many cases it took longer because the discussions were very intense and interesting. First, some feedback on the results of the questionnaire was provided to understand the motivation of the chosen answers. Then a deeper dive could be taken into the subject of the project. Furthermore, the goal of the research 'to define recommendations to manage the modular NPD of Company A more effectively and efficiently, by making use of the benefits and coping with the risks involved' was discussed. There was kept in mind that modular thinking can yield many advantages for a company. But besides the technical and commercial (market) issues, also the organization, the implementation, and execution of a modular approach may form 'bottlenecks'. Some interesting answers and opinions were gathered.

3.1.3 Results of the questionnaire and interviews

A. The definition of modular New Product Development (NPD) (Appendix 8)

The questionnaire consisted of four parts, as mentioned above. The first part (A) addressed questions about the definition of modular NPD. The different definitions of modular NPD the respondents provided are shown in Appendix 7. For the question illustrated in Figure 14, respondents could choose between the following possibilities: 'Very Integral' (1 point), 'Integral' (2 points), 'Modular' (3 points), and 'Very Modular' (4 points). The figure showed the main conclusion of this section: in general the organizational members thought that the way-of-working is still integral. Furthermore, modular NPD was often solely seen as a technical approach instead of a marketing or organizational approach.

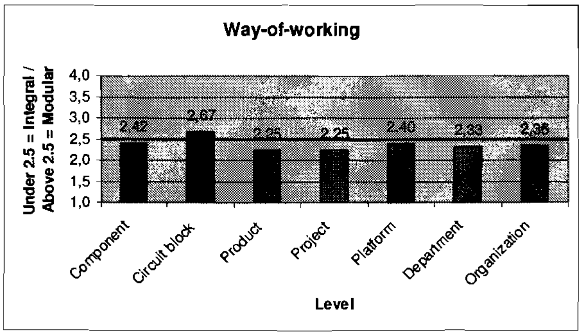

Figure 14 Way-of-working

B. The reasons and drivers for using a modular NPD approach (Appendix 9)

The second part of the questionnaire (B) tried to capture the most important reasons and drivers for using a modular NPD approach. The four most important reasons for Company A to use the modular approach were (Figure 15):

- 'a better optimal utilization of the innovative capacity'

- 'to generate a large range of products with just a few modular products using the resources of development, manufacturing, and purchasing efficiently'
- 'decrease the time-to-market because of the re-use of existing architectures'
- 'help to create integrated platforms with a better balance between departments.

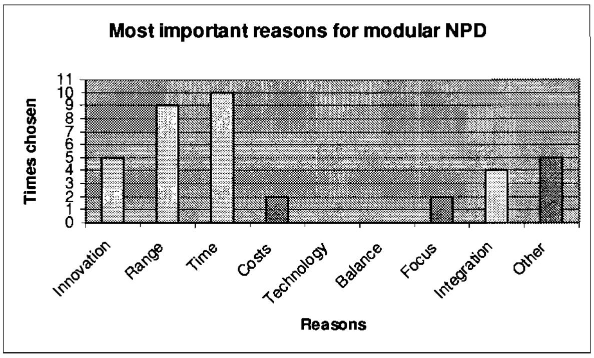

Figure 15 Most important reasons for modular NPD

C. Trade-offs in modularity

In part C some difficult trade-offs needed to be made between only two possibilities. These trade-offs that were partly derived from Vuuren and Halman (2001), were inspiring for further research. In real life the decision would not be so 'black and white' but more of a weighted balance. But it was still an indicator for which direction the company should head. In the interviews there was asked about the motivation of a chosen answer and this resulted in interesting pros and cons of a particular decision.

The first question was: 'should the platform be at the cutting edge of new technology development and risk high investments and development times which may not pay back in the end, or build further upon existing knowledge and risk inability of the platform to meet future customer demands?' Most people of Company A favoured 'developing new technology with risking high investments' (67%) over 'building on existing knowledge with risking not meeting customers demands' (33%). A reason (a pro) of the choice for the first option was that new technology and innovation is seriously important for company growth. Company A is sometimes not the first innovator in certain areas while the emphasis of the mission is on innovation. A clear con of this choice was that using a completely new technology path involves high uncertainty about the outcome. This leaded to the pro of the second choice, that a more evolutionary approach is safer. This means making smaller steps and using existing knowledge / technology that is already 'proven'. The danger of relying on existing knowledge is missing external development opportunities and potential breakthrough innovations.

The second trade-off involved the following question: 'should the platform allow a maximum of flexibility in product design and risk being too expensive in the end, or focus on efficiency in product design and risk not being able to meet future customer demands?' Now 'the focus on efficiency and risk not meeting demands' (58%) prevailed over 'the maximum flexibility and risk being too expensive' (42%). Eventually, the main advantage of the former, a focus on efficiency in product design, is the expected decrease in time-to-market by re-using elements. The comany should be better able to keep the costs within budgetary boundaries. For software development this choice is particularly suitable because about 80% of the software within Company A could be seen as common-based. But the other 20% is dedicated and consumes about 80% of the time. This is also known as the '80-20 rule' (referring to the Pareto principle, first applied by Juran (1964) to an industrial environment). But what is actually the big con of this choice is that it is initially more expensive to build a common base (platform). Furthermore, not all requirements can be defined as a standard. This pleaded for the other side of the trade-off, to aim for maximum flexibility. When there is more flexibility in the product design it should be easier to introduce more functionality in the different camera versions. But this creation of more functionality will come at a high expense; when requirements are not frozen, more freedom is kept, but of course this will cost a lot more.

The last trade-off was: 'aim for efficiency through high volumes in more than one market segment and risk low sales due to products that do not fully meet customer demands, or aim for effectiveness (i.e. meeting customer demands) in one market segment and risk low returns due to low volumes?' Here again 'the aiming for efficiency' (58%) was preferred over 'the aiming on effectiveness' (42%). The parallel was made with shooting on a target with a sniper rifle (one segment) or with a shotgun (multiple segments). The pro for the choice of effectiveness was that it is better to (intensively) aim on one or two market and do it right, than at multiple and do it wrong. The con is that the focus is just on a single segment, so chances are not spread. This is also the benefit to aim for efficiency through high volumes: the possibility to target multiple segments in parallel. Finally, a clear disadvantage of this latter choice is that most customers of Company A demand a broad range of products with multiple functionalities. Finnaly, product volumes are not as high as for example in the consumer electronics industry.

D. Factors that influence modular NPD (Appendix 10)

The question whether Company A is able to keep up with the five industry trends generally resulted in a 'yes' for 'the increasing product functionality and complexity', and 'the increasing customer demands on quality and reliability' but a 'no' for 'the strong cost erosion', 'the strong pressure on time-to-market', and 'the increasing business process complexity, globalization and outsourcing trend'. From the interviews it appeared that the control of the trends reflected the performance of the modular approach on the business drivers.

In the questionnaire and interviews the influence of the five different factors of the modular approach, described in Section 2.1.6, were explored, analyzed and clustered in the five perspectives: customer demands, existing products, coordination, new product ideas, and company strategy. These perspectives will be further elaborated on in the next section.

3.2 Exploring of improvement options

In the search for recommendations for improvement, first the results of the analysis were explored from the five different perspectives of the modular approach. With the information from the different perspectives, not only the issues and risk areas could be mapped but it also provided some direction for possible recommendations. The current situation, the possible risks, the approach, and objectives could be captured in a framework from which three improvement areas were selected.

3.2.1 Different perspectives of the modular approach

Customer demands perspective: this perspective's focus is on the effectiveness of the organization. From the marketing perspective as much variety (product variants) as possible should be created for better responsiveness to customer's needs. There should not be strived for full-customization (one product to one customer) but a fact is that Company A is a technology-driven company. This is in itself positive. However, customer insights may be better captured, which could lead to easier product diagnosis for users, simpler installation, easier maintenance and repair. Company A is operating in the business-to-business industry and is therefore often at a distance from the end-customer. There should be thought of how to target markets with platform segmentation strategies:

- horizontal leverage strategy: for application of technologies in other market segments
- vertical downscaling strategy: to cover the lower market tiers
- beachhead strategy: establish a 'beachhead' for totally new products

Existing products perspective: this operational perspective's focus is on using resources efficiently and creating as much commonality as possible. It should be possible to (physically) re-use product elements, like proven and tested modules or technology. This approach should decrease the time-to-market and increase the product quality level. Furthermore, the testing would be easier and could be performed more concurrently. When working with a platform, large investments will be up-front. This should enable the company to develop less costly derivative products. The performance of a platform could be measured by using platform-based performance indicators.

Coordination perspective: it should be able to increase the flexibility with respect to interchange-ability of components, architectures and products. In this way risks are decoupled and purchasing ('chopping') from multiple sources would be facilitated. Coordinating means taking care that resources are available and different (over-site) projects are tuned. It also involves knowledge sharing. ICT could play a role in this process.

New product ideas perspective: it appeared that the level of innovation can be fostered. The main question is not whether but how the organization should innovate. There is enough 'applied' knowledge with respect to operational activities on the roadmap but this could be better utilized. Maybe then more capacity could be made free for innovation. It is a good thing that Company A is acquiring companies with their knowledge. But Company A should not solely rely on acquisitions as the primary source for introducing innovation to the company. It should come from within the company and creativity is thereby very important for success.

Company strategy perspective: the company strategy should facilitate a modular way-of-working. Learning across projects is very important: proven architectures and ideas should be used in other parts of the organization. This does not mean the physical switching of components. It is more about the lessons that were learning in other projects. There is a lot of expertise and knowledge within Company A but it is difficult to integrate this. Task specialization and decoupling of tasks (an independent product development) could increase the performance, when it is rightly coordinated. Co-located, cross-functional teams, SD teams, and product development teams could provide diverse insights and increase the intensity of communication.

3.2.2 Current issues and possible risks

Table 6 Issues / risks in the technical, market, and organizational areas

Cat.	Issue / Risk	P	I	Rat.
Technical	Fast changing IT technologies (high uncertainty), easily locked-in in a chosen technology path	3	4	12
	Over-specifying of requirements (too much standardization)	3	3	9
	Too much camera functionality (high complexity)	4	3	12
	Technology is dedicated, specific, and embedded / Relatively small cameras (issues with the 'vormfactor')	4	4	[illegible]
	Testing takes longer than expected, double tests performed / High demands on quality and reliability testing	4	2	8
	Development issue EMC	4	5	[illegible]
	Development issue power supply	3	4	12
	Development issue heat	3	4	12
	Difficult to tune the SD's	3	3	9
	Coding standards are not always mutually agreed upon	3	4	12
	Chip dependability and debugging	3	4	12
	Not enough interaction between hardware and software	3	5	[illegible]
Commercial / market	High initial investments and time-consuming approach	4	5	[illegible]
	Universal interfaces require higher investments	3	4	12
	Uncertainty about outcome, not sure of market success (what is break-even?)	4	4	[illegible]
	Difficult to calculate the platform performance	4	4	[illegible]
	Difficult to calculate the integral costs of diversity	3	4	12
	Difficult to translate customer requirements into functional blocks but customer insights are indispensable	5	4	[illegible]
	Innovation often technology-driven instead of market-driven	4	3	12
	There is not enough diversity and relatively moderate product volumes	3	3	9
	Not enough economies of scale	2	3	6
	Outsourcing of parts is difficult because of the embedded nature	3	3	9
Organizational	Different abstraction levels, helicopter view required	3	3	9
	Resource availability (CCPM implementation)	4	5	[illegible]
	Complex coordination over projects	5	5	[illegible]
	Program Manager Officer (PMO) function important (leadership)	4	3	12
	Single-product focus instead of multi-product focus	3	4	12
	Quality of communication / not enough open climate	2	4	8
	Long term commitment and support (discipline) necessary by management and the whole organization	4	5	[illegible]
	'Not-invented-here' and 'doing it yourself' syndrome	4	3	12
	Knowledge Management: securing / re-using of knowledge (learning / evaluation)	4	5	[illegible]
	Role of ICT	5	5	[illegible]
	Acquisitions: technical, commercial, and organizational integration	3	5	[illegible]
	Not enough innovation capacity (is used), incremental rather than radical innovation	4	5	[illegible]
	Differences in release points between planning and execution / Requirements needed beforehand	3	3	9

From the internal analysis (the evaluation of the questionnaire and interview results) and the views of the different perspectives, the issues with the modular approach could be found. These issues were listed in Table 6, and could be seen as potential risks in a certain area: the technical area, the market area, and the organizational area. There can be directed to Appendix 11 for a more extensive description of the issues.

3.2.3 Rating of risks

In this step, the identified and classified obstacles / risks were rated based on the probability and impact. Probability means an estimation of how likely an issue is to occur or how often the issue occurs (frequency). The different classes of probability are illustrated in Table 7.

Table 7 Classes of probability

Probability				
5	Critical	Risk is certain to occur	(Almost) always	96% - 100%
4	High	Risk is highly likely to occur	Frequent	66% - 95%
3	Medium	Risks is somewhat likely to occur	Occasional	36% - 65%
2	Low	Risk is unlikely to occur	Uncommon	6% - 35%
1	Insignificant	Likelihood is insignificant	Remote	0% - 5%

Impact expressed the estimated severity of the issues. The different classes of impact are illustrated in Table 8.

Table 8 Classes of impact

Impact		
5	Catastrophic	Catastrophic impact on business drivers
4	Major	High impact on business drivers
3	Moderate	Moderate impact on business drivers
2	Minor	Low impact on business drivers
1	Insignificant	Impact is insignificant

A rating was derived by multiplying the probability (P) and the impact (I). The rating (rat.), probability, and impact could be found in the last three columns of Table 6. Based on this rating, insight was created in the priority of the risks (Table 9): red for high priority, yellow for medium priority, and green for no priority. Taken together it helped to make the decision which issues / risks should be further focused on for creating recommendations.

Table 9 Risk rating

Risk rating						
		Impact				
		5	4	3	2	1
Probability	5	25	[illegible]	[illegible]	10	5
	4	[illegible]	[illegible]	12	8	4
	3	[illegible]	12	9	6	3
	2	10	8	6	4	2
	1	5	4	3	2	1

3.2.4 Framework and the three improvement areas

From the results obtained in the analysis and exploring of improvement options above, a framework could be created, which is depicted in Figure 16. The current situation ('today's realities') are the strong cost erosion, strong pressure on time-to-market, the increasing business process complexity, increasing product functionality and complexity, and increasing customer demands on quality and reliability. Especially the former three trends are important for Company A to improve in relation to modular product development. The latter two were under control. Caution has to be taken to not 'fall in the chasm of uncertainty' and provide a fitting answer to the technical, commercial, and organizational issues and potential risks. 'Optimal utilization of the innovative capacity', 'generation of a large range of products with just a few modular products using the resources of development, manufacturing and purchasing effectively', 'decreasing the time-to-market with re-use of existing architectures', and 'the creation of integrated platforms with a better balance between departments' are the objectives ('tomorrow's desires') with the highest priority. To reach these objectives the thought architecture, the modular approach, should be used with the factors existing products, new product ideas, company strategy, customer demands, and coordination.

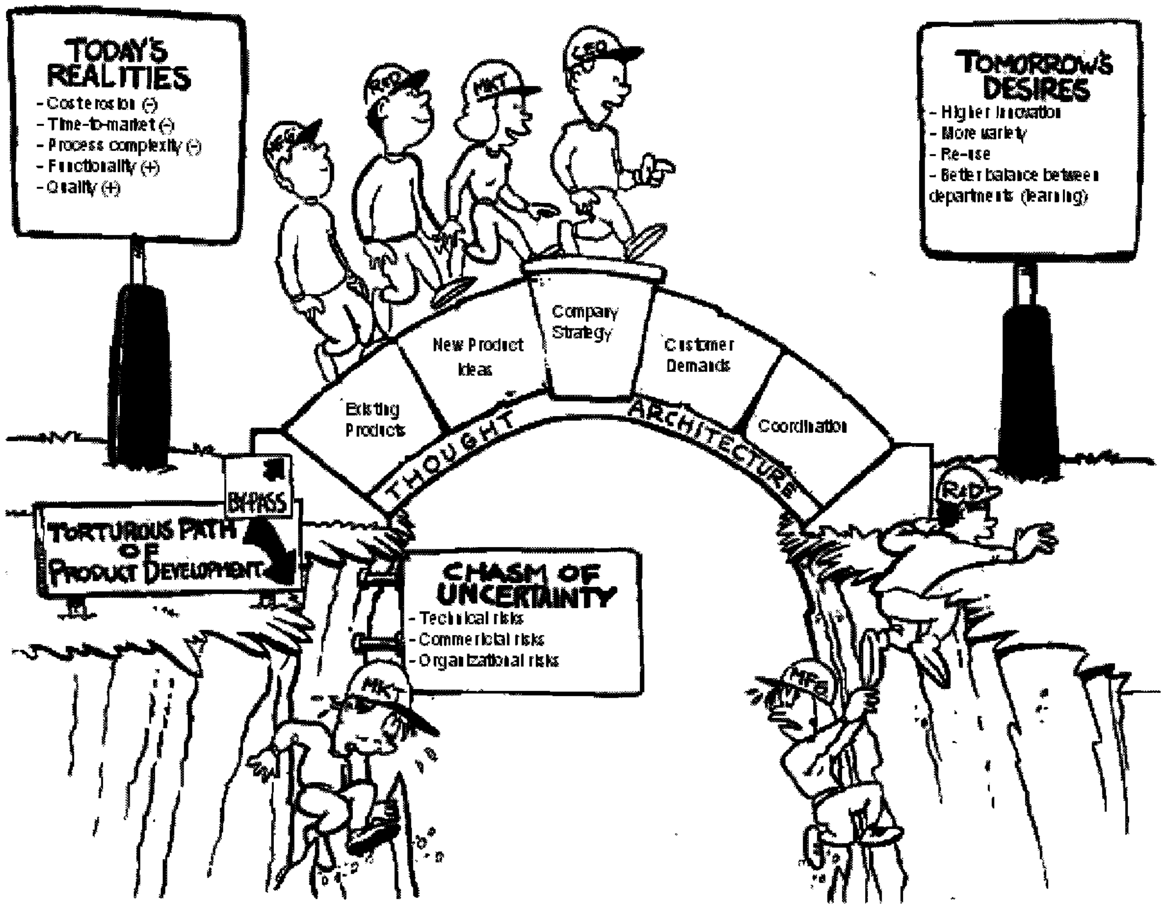

Figure 16 Framework

From the questionnaires and interviews it became clear that the performance of the modular development approach within Company A could be related to the business drivers of the five market trends that were described in Section 1.3: functionality, costs, time, quality, and business process complexity. Figure 17 illustrated these scores of the current situation and it appeared that two business drivers' development performance was sufficient and three business drivers' development performance was insufficient. Functionality for the customer and quality of the cameras are two areas that development has kept under control. The areas that required extra attention were the development costs, times, and business processes.

These potential areas for improvement were coupled to the stated objectives of the PLA and to the four most important reasons for using a modular approach from the analysis:

- **Insight in the development process business drivers' performance cost and time** (Figure 17): first, insight should be created in the complex business process, especially the development costs (cost per product and costs of spin-offs) and development times (throughput in terms of product introductions and project schedule accuracy). There was less emphasis on the business drivers functionality and quality (higher performance and reliability) because these were under control.

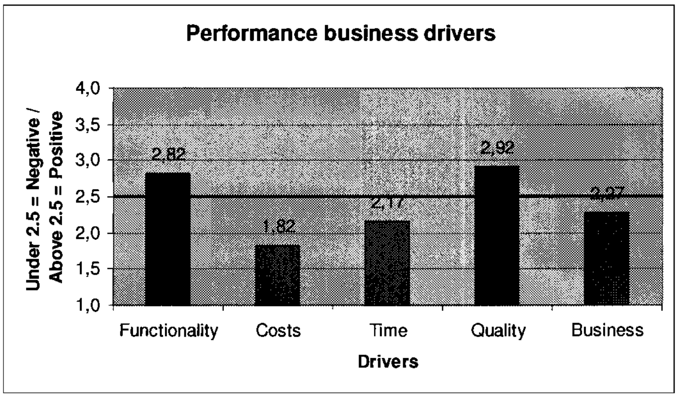

Figure 17 Performance on business drivers

- **Making the trade-offs in the scope:** this is related in the seemingly paradoxically important reasons for using a modular approach: on the one hand effectiveness; 'the generation of a large range of products with just a few modular products', and on the other hand efficiency; 'using the resources of development, manufacturing and purchasing effectively and decreasing the time-to-market with re-use of existing architectures'. The scope and quality of a SD will always be dependent on the choices made with regard to commonality and diversity
- **Structuring the organizational and innovation processes:** with the modular approach, the organizational structure is also under discussion. An important reason to use the modular approach was 'the creation of integrated platforms with a better balance between departments'. This also included 'optimal utilization of the innovative capacity'. The management (creation, securing, and sharing) of knowledge could be improved.

4. Redesign recommendations

The redesign areas consisted of 'insight in the development process business drivers' performance cost and time', 'making the trade-offs in the scope between commonality versus diversity', and 'structuring the organizational and innovation processes with regard to resources, coordination, ICT, functional areas, innovation, knowledge management, and learning'.

4.1 Insight in development process: cost and time

The first section provided insight in the development costs of the 'traditional product development' approach (± 2001 – 2007), the development costs of the modular approach, in this thesis called the PLA (platform and the SDs) (± 2006 – 2009), and the product development cost with the modular approach (± 2008 – 2009). The second section involved insight in the throughput times for these three phases. In the third section recommendations were made for the measurement of modular platform performance.

4.1.1 Insight in (product) development costs

Below, the relevant data that are required for the insight per phase was described:

- 'Traditional product development' costs: this data was available with a few exceptions. The data mainly consisted of the development costs per project (of the pre-platform period).
- Costs of the platform (PLA): in other words, the costs of creating commonalities. This data was also available and consists of two factors: first, there are the initial costs of defining and ongoing costs of maintaining the Reference Architecture. The costs of creating a platform were high but the updating and maintaining were even higher. Second, there are the development costs of the SDs. Because the SD projects were designed to be a complete and re-usable block, the scope was larger than in the 'traditional product development' approach. This required also extra test efforts; both scope and testing added more costs.
- Costs of product development with the PLA: this could be seen as the cost of creating diversity. Only data estimates by the Project Managers were available. This data involves two factors: less product development costs due to re-use of SDs and benefits in Bill-of-Materials (BoM). When SDs are re-used, the costs of (human) resources required in projects will be lower; when elements can be re-used, most resources are only needed for integration purposes. This effect should result in that people can direct their effort on other projects. Thereby, should the costs of introducing more product variation also be lower. From the common-base platform the standard building blocks (SDs) may be combined in new product variants. These 'proven SDs' should also result in higher quality and thus less quality related costs. The gains in lower costs of the BoM should be enabled by strategic purchasing processes. BoM is the term used to describe the parts list of components needed to complete a

SD or (saleable) item. There exists a BoM per SD, like the costs of components, Printed Circuit Boards (PCBs), coupling, ICs, and resistors. But there are also product BoM that also include the fabrication costs (overhead and product components) of the used SDs. When these required materials and components are known beforehand, this can be planned more precise and more can be purchased from a supplier at once. This results in higher economies of scale. There should be noted that no insight was provided in the costs of BoM. This complex calculation was not within the scope of the thesis.

Providing insight in the cost of development is of course a clear way to assess the modular way-of-working and process performance. In Figure 18 the development costs of three phases are graphically represented: the (pre-platform) 'traditional product development' projects (yellow bars), SD development projects (green bars), and product development with the PLA (blue bars). All costs were corrected with an average inflation of 2% per year (www.cbs.nl). The development costs of the platform IC were even five times higher than can be seen in the picture and are thus not in scale. Although these costs are huge; the choice was made to develop the IC in-house, so big investments were required. The assumption was made that the decision to develop the IC in-house resulted in higher costs and that these costs would also be there when the traditional approach was continued. Another assumption was that almost every project in the traditional approach resulted in a finished product (product development included).

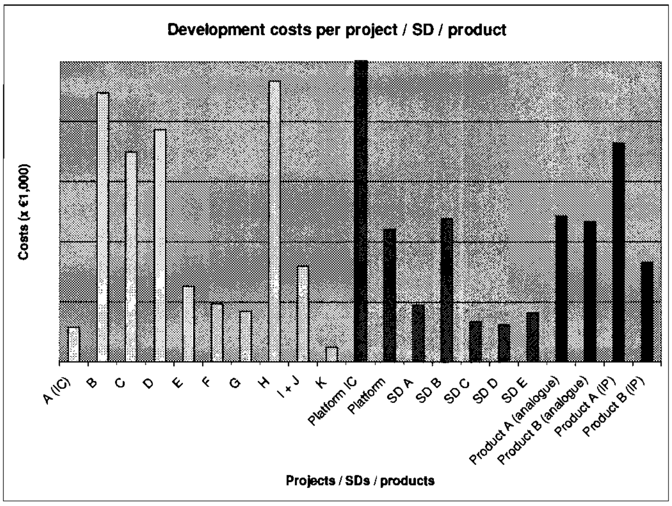

Figure 18 Development costs per project / SD / product

When roughly all the costs of the period ±2001 – 2009 are summed per phase, Figure 19 was derived. The yellow bar represented the development costs of the traditional approach, the green bar represented the development costs of the platform and SDs, and the blue bar the product development costs of the modular approach. The red bars on top of the first two bars showed the extra IC development costs per phase. The time span of the traditional approach and modular approach were not the same: the costs of traditional approach were collected over 7 year, while the modular approach involved only 4 year with estimates and projects in the pipeline. So, there should be looked at the average product costs to make a comparison between the development costs of the traditional approach and the modular approach. Under the assumption that every project in the 'traditional' approach delivered a product, and that there are only four products made in the PLA, the average product costs could be calculated from Figure 18 with the following equation: *'the average product development costs in the traditional approach'* (projects A(IC) till K) versus *'the costs of platform IC, SDs, and product development summed'* (Platform IC + Platform + SD A till SD E + Product A + B (analogue and IP)) and divided by *four* (Product A + B (analogue and IP)). This resulted in the average costs of a product in the PLA, at this moment, of more than **five** times the costs of the average product cost in the 'traditional' approach. The conclusion could be drawn that **the development costs per product, at this moment, have increased.** Of course there should be noted that this calculation is heavily influenced by the high IC development costs in the modular approach. Furthermore, expected gains in product development in the modular approach due to less resource, diversity, and quality costs and strategic purchasing processes can not be showed: there is not enough data at the moment.

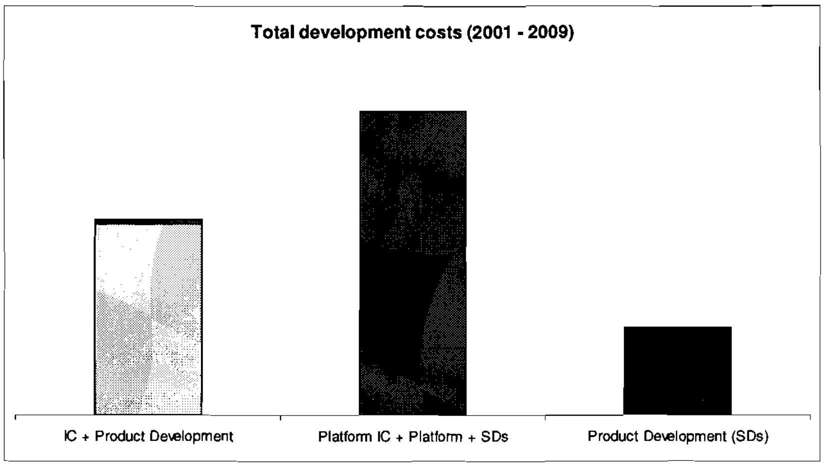

Figure 19 Total development costs (2001 - 2009)

The real benefits in cost should be gained in less cost for product introductions in product development with the PLA. In Figure 20 the product development costs with the modular approach of Product A were compared with those of Product B. Product B will benefit from the modular approach: the cost of the IP variant will actually be lower, a decrease of ±29% in costs compared to the analogue version. But for Product A the development costs for the IP variant will be much higher, even a rise of about ±49% compared to the analogue version of Product A. This was because the mechanical housing was unique and this had a significant impact on the project budget. Finally, there could be seen that, after a long while developing SDs, there are only four products planned. In the 'traditional approach' this was almost every year a new product. There seemed to be not significantly more diversity at the moment. Although the costs of the SDs may be spread over more products in the future (e.g. other domes and boxes, wireless variants, single board cameras, and other spin-offs), there could be concluded that **there is no trend visible that the spin-offs take less development costs** at the moment.

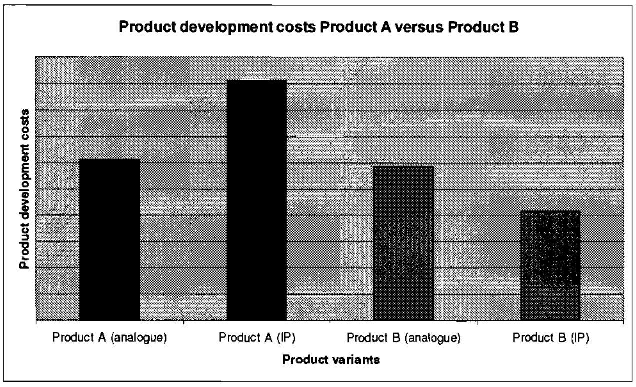

Figure 20 Product development costs Product A versus Product B

4.1.2 Insight into throughput times

For the insight in development times the comparison was the same as for the costs: the 'traditional' approach versus the PLA and platform and SD development versus product development. Below, the phases are further explained for time:

- 'Traditional product development' development times: this data was available with a few exceptions. The data mainly consisted of the throughput times per project (of the pre-platform period).
- Development times of the platform (PLA): in other words, the time for creating commonalities. This consists of the ongoing time consummation of defining and maintaining the Reference Architecture and the longer throughput times for SD projects due to the larger scope and higher testing efforts.
- Product development times with the PLA: only data estimates by the Project Managers were available. As for the costs, there are benefits to be gained in the re-use of SDs that should be translated in shorter development cycles. The PLA should results in a better planning and easier combination of parts to create diversity.

Figure 21 showed the development times of projects in the traditional approach. The time intervals are a rough illustration of the difference between the QA1 milestone (start point) and QA3 milestone (end point). The start and end points were not exact (more a range) because it is impossible to appoint a precise starting point. Either way the points could be used as good indicators for the model. At point QA1 there is known what product / feature should be made and how it is done. In QA3 products are ready to be shipped. This model showed that every year there was (/ were) one (or more) new products / features introduced to the market. Not every project involved a developed product. For example, project I was product development, while project J was the After Care of this product that took extra effort. The way-of-working of the traditional approach could be described as sequential with a sort of 'stage-gate' model. The development of the IC formed the backbone of this process and is a separate project in the model. Finally, there was calculated that the average throughput time of the projects was about 40 weeks.

Figure 21 Traditional product development times

Figure 22 below illustrated the development times of the modular approach (IC, platform, and SDs). These times are not precise but it indicates the modular way-of-working. In the platform development the SDs were defined and could be worked on in parallel. The picture showed a more 'concurrent' model instead of a sequential 'waterfall' model. The average development time of the SDs was about 55 weeks. Among other things, this was caused by more test time required, longer planned lead-times, ramp up, and a more rigid process. First, the increased focus on quality introduced more test time. Some of the tests can even be considered as redundant. Also the aimed preparation of factory testers during SD development is not achieved due to a lack of devoted engineering time. Second, the time-to-market predictability was responsible for introducing longer lead-times for model runs. Third, the QA3 (release date) in the PLA included ramp up. This means time was added for extra activities that should be performed. Finally, the on itself positive trend, the growing organization introduced a more rigid process.

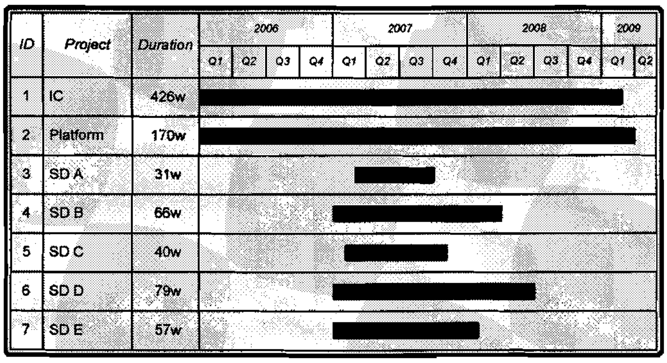

Figure 22 Development times of the PLA

The real benefits of working with SDs should be gained in the product development. Products should be able to be introduced faster to the market with less resources and easier combination. The development of two analogue and two IP products are planned by Company A. The estimated development runs and milestones for the two analogue products are illustrated in Figure 23. Upon the first introduction of the products with the modular approach it will really become clear whether the

PLA was more efficient and effective in time than the 'traditional product development' approach. The average estimated development time of the first two products will be about 54 weeks. The assumptions of the Master Plan were over-optimistic with regard to estimated development time reduction of the PLA. Although there will be two product introductions at once, there could be concluded that there was **no significant acceleration of product development time achieved by using the PLA,** there was no decrease in throughput time. The expected shorter development cycles were not visible; the minimum model run cycles remained three (B, C, and D). In the 'traditional' approach the average there was in general a product introduction once a year but in the modular approach there was already one or two year necessary to develop the platform and SDs. On the other hand **more projects were performed in parallel** (at the same time), so more output could be given. There was a better distribution of resources and effort.

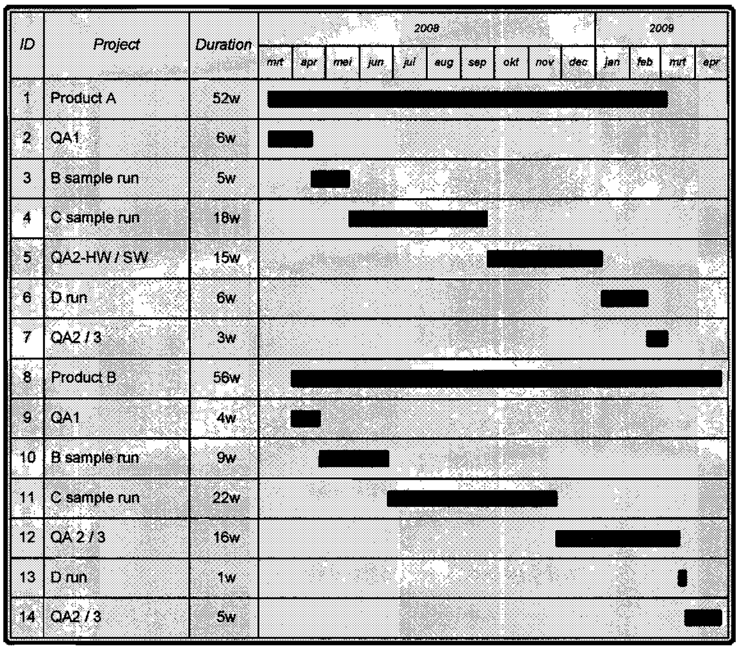

Figure 23 Estimated product development times (PLA)

4.1.3 Platform-based performance measurement

After the comparison between the 'traditional product development' and modular development approach, and trying to distillate the gains of the PLA in product development, there could be concluded: first, there is now insight in the costs and throughput times of the project of the traditional approach. There is also insight in the costs and throughput times of the PLA. But what is very important, the only things that not really can be expressed are the hard figures of the profits in product development when working with the PLA. A reason for this is that the first real product introductions will be in the future, so the real gains can not be experienced right now.

But beyond this reason Company A is recommended to create better insight in the platform performance. In the questionnaire 92% of the respondents answered negative on the question whether Company A made enough use of platform-based performance indicators. At any point in time in this ongoing dynamic process it should be apparent what the performance of a platform is. This will not only provide management support in decision making about issues related to a modular approach but will also give a better insight to the people who (have to) work with it. For the future it will be wise to take actions to get more insight in these kinds of factors.

Meyer and Lehnerd (1997) suggested a number of recommendations to measure the performance of platforms. The first recommendation was gathering the necessary data. This notion seems obvious but in practice it is often a difficult point. In Company A this information is not readily available. The idea is to develop spreadsheet in a database were these numbers can be stored. A condition for success is that the database must be regularly maintained and updated. A well-defined IT system can help in this challenge.

The second recommendation is to understand the efficiency of platforms for creating derivative products. Platform efficiency is defined as the (average) *'derivative products engineering costs'* divided by the *'platform engineering costs'*. For Company A this means the *'development costs of product variants'* divided by the *'costs of the platform and SD development'*.

The third recommendation is to understand the time-to-market consequences of platform development. The same kind of formula as above can be applied for development time. This is done with an indicator for calculating the efficiency of the cycle time which is defined as the (average) *'elapsed time to develop a derivative product'* divided by the *'elapsed time to develop the product platform'*. This is expressed in Company A's terms: *'the time to develop product variants'* divided by the *'development time of the platform and SDs'*.

The fourth recommendation is to understand the technological competitive responsiveness of the company. As can be seen in Figure 24, in this analysis the key product innovation and market introduction of an example company are compared with the competitors.

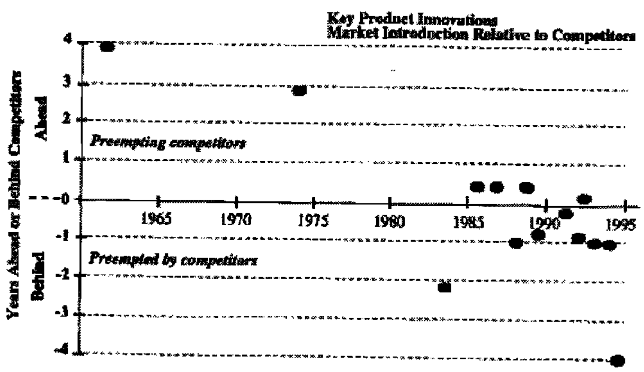

Figure 24 Example of a company's technological competitive responsiveness

The fifth recommendation takes the commercial effectiveness of platforms into account. This platform effectiveness is defined as the *'net sales of derivative products of a platform version'* divided by the *'development costs of derivative product of a platform version plus the platform development costs'*. This means: *'net sales of product variants'* divided by *'development costs of the PLA'*.

Finally, to understand the profit potential the Cost Price Ratio (CPR) can be calculated. This is defined as the *'costs of goods'* (material, labor, fixed and variable overhead) divided by the *'net sales'* (gross sales less transportation, returns, and discounts).

4.1.4 Recommendations for process improvements

The first recommendation for improving processes is the storing of data about the process and creating insight in the performance in cost and time. The bottlenecks can be explored and measures can be taken. Here are some practical recommendations for process improvement: try to allocate costs not solely to the platform development but to the related SD. In this way the platform development budget will not be a 'garbage bin' for costs. It will become more clear which costs are attributable to which SD. Roadmap changes also have a big impact on development efforts. The product roadmap and development roadmap should be aligned with less risk of full dependencies and protected by buffers. A good planning and back-up actions in case of change are very valuable. Furthermore, the roadmaps of different sites should be aligned in terms of SD releases and product development releases. This should results in a more synchronic program. Finally, start no parallel development of SD and product development. Management must support this for efficient resource utilization. It is recommended to take a broad view in this matter.

4.2 Making the trade-offs in the scope

This improvement area reflects two objectives: first, decrease the time-to-market and costs through finding commonalities and re-use (efficiency). Second, generate a larger range of product through better combining and creating diversity (effectiveness). A balance should be found between these seemingly opposing objectives. As could be seen in the trade-offs section (3.1.3 part C), this is never 'black and white'. With the modular approach both objectives can be achieved by making wise use of standardization. Too less standardization results in much freedom but also inefficiency. Too much standardization results in inflexibility. Meyer and Lehnerd (1997) stated that standardization for all components across a product portfolio can lead to rigidity in underlying platforms and inflexibility when it comes to advancing product designs in the future. Standardization by itself can also lead to nothing more than 'me-too' products that are easily copied.

4.2.1 Commonalities

The first objective was to find commonalities not only in the existing product portfolio but also in new products and markets guided by a sound company strategy and flexible coordination. Meyer and Lehnerd (1997) described a tool for finding commonalities in the company's product portfolio: the Power Tower. The Power Tower can provide insight into the synergies and commonalities on all organizational levels. In Appendix 12 an example is given of an adjusted Power Tower for the modular dome camera platform of Company A, the perfect example of a modular product platform.

There are three layers; the first layer represents the market application. The modular dome camera could be applied in the residential, commercial, and industry market segments. The product is mainly directed at the higher market tier. For these market segments different derivative products could be relevant: e.g. different analogue, IP, or wireless product variants. The second layer presented the different product platforms: dome camera platform, box camera platform, high resolution camera platform, and modular dome camera platform. The five different modules (CPU-, camera-, communication-, power-, and housings-modules) are shown for the modular dome platform. Finally, in the third layer, the common building blocks, the commonalities and synergies should be further explored for the five factors: existing products, new product ideas, company strategy, customer demands, and coordination.

4.2.2 Diversity

The second objective was creation of diversity. Company A should further exploit market diversification. There should be invested in making different versions of products by combining the modules; the SDs. It is not only more efficient to re-use modules in different product development projects; it also makes the process of creating variety more effective. This is what is called 'horizontal leverage'. Key subsystems and development processes can be re-used for other products. Existing technologies can be used for new markets but also for higher or lower tiers ('vertical scaling'). Company A is a technology-driven company, working in a business-to-business sector. There is not enough insight in what the real customer requirements actually are. When Company A invests more in market knowledge, commonalities and differences between customers will be more apparent and smart combination of standard building blocks will make it easier to develop different versions of products. With the planning of Innovation Projects, there can be thought beforehand about future versions and applications. Not only (technical) feasibility studies but market research (the need of a product) can contribute to creation of variety by re-use.

4.2.3 Recommendation for making the trade-offs

This aim of this section is to reflect on the direction the company should go. Company A should create a vision about the position in trade-offs and make this transparent in the whole organization. Looking at the three stated trade-offs of Section 3.1.3 part C, can help to create discussion.

It is highly recommended to invest in the exploration of new technology and applications, and accept more risks in this process. Company A is in certain areas a fast-follower but following the strategic vision, the company should be an innovator in the strategic areas. Company A should not solely make use of existing (technical) knowledge but should also be able to attack new, undiscovered markets. Only then breakthrough innovations could happen. Re-use standard elements like SDs as much as possible to be efficient but plan combinations beforehand. In other words: use internal standardization

in the processes but appear flexible to the market. Target multiple segments at once with products that are in essence the same, have a high level of functionality, but are different to a particular customer.
Another recommendation is to use SD development to reduce technical risk areas. A very successful element in the PLA was the risk mitigation strategy. The number of iterations needed in a particular SD to control the EMC (Electro Magnetic Compatibility) did not influence the product development start date. For the future less EMC issues are expected at this level during product development.
The most difficult thing in defining the scope of the platform and SDs is the definition and agreement on customer requirements. This is challenging for one product but this is even harder for a modular approach which involves more parties and has a wider scope of products. The scope of the platform and SDs should be clear and explicitly formulated and communicated. Only than customer requirements can be agreed on. To capture customer requirements, the scope of the platform should be clearly communicated throughout Company A's organization. The actions of people should be more based on a helicopter view instead of finding a local optimum. To effectively and efficiently use SDs, the scope should not be changed too much later on because of the high impact of those changes. The scope of the SDs was in some cases to large and too much focused on the camera development. This could be worked out smarter; SDs should have a minimum or none dependencies. They should be hands-offs with other SDs. Finally, re-define the scope of SDs to smaller activities; try to limit the duration to a half year development effort (in focus and scope), if possible.

4.3 Structuring the organizational and innovation processes

This section emphasized the points that need attention for better integration between organization parts and more utilization of innovative capacity. Recommendation for issues that were treated here were coordination and availability of resources (over projects and sites), the bridging of functional areas, the role of ICT, innovation, learning, knowledge re-use and securing.

4.3.1 Resource availability

Resource allocation worked out in a positive way with a high availability index. As a result of this, the project plan became more reliable. Also other actions to improve the availability of resources are already taken. Company A has implemented an approach called Critical Chain Project Management (CCPM). CCPM is a multi-project (Program Management) solution that uses shared resources to regulate the flow of work throughout the whole organization, whilst maximizing the throughput (Anderson, 2004). CCPM is compatible with some 'agile' methods and can be used to facilitate the 'early and continuous delivery'. It does this by treating project work as probabilistic rather than deterministic and defining the constraint for a project as the delivery date. If the delivery data is the inviolate constraint then all other decisions on the project must be subordinated to the decision to hit the delivery data. This is another approach than Company A used to work with: in CCPM, the milestones are based on a deadline instead of 'a level of feasibility'. The planning process becomes more precise but on other points there should be sacrificed.

4.3.2 Coordination over projects

The analysis showed that the (internal as well as over site) coordination needed improvement. The responsibility over the available resources has the highest priority. System Architects, Project Managers and especially the Program Manager Officers (PMOs) (or in the role of Master Schedulers / Program Managers) play a major role in this process. These roles are further explained in the implementation, discussed in Chapter 5. Coordination over project in relation to the role of PMO provides a good overall picture of planned developments within a product portfolio and allows to run different scenarios. Meyer and Lehnerd (1997) found three elements that should be present for successful coordination of projects: first, avoid a single-project / -product focus; manage the projects as a whole, a program. Second, the PMO should also function as a bridge between engineering and manufacturing and simultaneously redesign products and processes. Finally, there should be support of the senior management. They should use a long-term horizon and set the priorities expressed in resources and budget.

4.3.3 Role ICT

The performance of the ICT is not always experienced as supportive to the (modular) NPD processes. The role of ICT is defined as a facilitator. The fact is that 'technology should work for you, one should not have to work for the technology'. There are three issues that need attention: first, the infrastructure can be improved. The question rises how much the company should be willing to invest in the IT network and better data transmission. Maybe some constraining rules for data security purposes can be sacrificed for better network performance. The balance between data security and network performance should always be kept in mind. Second, the transparency of the internet- and intranet site can be improved. Although the intranet site is currently redesigned at some points, it should invite people to use these resources better and increase the find-ability of information. A final point is that the ICT systems should be better tuned with other organizational systems. For example: inter-site communication, merging of systems (like automation issues in implementing the BoM in the ICT system), integration of different CAD drawings, data storage locations, and how to control costs.

4.3.4 Bridging of functional areas

Within Company A, when using the modular approach, cross-functional teams are used for stimulating innovation. From Gebert et al. (2006) some theoretical recommendations could be given with regard to bringing the functional areas closer together. First, the quality of internal (within / between teams) and external (over sites, to customers) communication could often be increased to a higher level. This should be intervened by co-locating people, planning face-to-face meetings, more exchange of experiences, and even job-rotation. Second, an innovation-stimulating group climate should be created; not only build cohesiveness but also create task-related doubt for creativity. Finally, leadership skills are of outmost importance. Especially collaborative skills are useful. Persons should not only be assessed on individual performance but also on team performance.

4.3.5 Organizational innovation processes

The questionnaire respondents recognized that the company should not solely rely on acquisitions as the primary source for introducing innovation to the company. Innovation should come from within the organization and creativity is very important for the company's success. Meyer and Lehnerd (1997) comment on this point that a large company, like Company A, can only find growth-fuelling innovations outside its formal boundaries in skunk works projects and in smaller, less bureaucratic companies that it targets for acquisition. When this is not the case, innovation should come from within the organization.

But what is innovation actually? 'Innovation is the successful implementation of creative ideas by an organization' (Amabile, 2000, p. 332). Innovation consists thus of two parts: a creative, open part and a more structured, implementation parts. Both parts are important for successful renewing of a company. Within Company A this is translated into two separate activities: innovation studies and product development. These two different activities also have an overlap, as can be seen in Figure 25. Company A wants to separate these activities as much as possible.

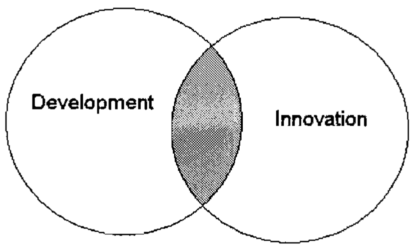

Figure 25 Development versus innovation

Innovation studies are directed at finding opportunities and are non-routine activities with a long term focus. New ideas are created and checked whether they are feasible. It also involves learning processes for being able doing it yourself. Innovative SD projects need more frequent technical evaluation from Architects to determine next steps or re-definition of the scope. On the other hand, product development is more of operational nature involving day-to-day activities focused on the short term. This often means putting efforts on getting projects on the right track, even with the help of external personnel.

4.3.6 Knowledge Management and organizational learning

Most knowledge that can be found within Company A is characterized as specific, embedded, and dedicated. Most of the technical knowledge is stored but there should be more emphasis on project evaluations; what did we learn? Furthermore, there are a lot of expertises and specialists present but the question is: how to make this information better accessible? This dependents for a large part on the interaction of people and creation of contacts and agreement between sites by (System) Architects and PMOs.

Another area that needs some improvement within Company A was the learning process. Not only individual and group level learning is important but also learning on the organizational level: organizational learning. Organizational learning is the embedding of individual- and group-level learning in organizational structures and processes, achieved through reflecting on and modifying norms and values embodied in established organizational processes and structures (Hislop, 2005, p. 143). So, a learning organization is an organization which supports the learning of its workers and allows them to express and utilize this learning to the advantage of the organization, through having an organizational environment which encourages experimentation, risk taking, and open dialogue (Hislop, 2005, p. 149). Management should stimulate a climate of experimentation, risk taking, and open dialogue. To improve the internal organizational learning in Company A, issues in relation to a phenomenon like 'technical perfectionism' needs to be managed. This has relation to the project's / SD's scope definition. Another point is that the internal innovation process should be further structured and communicated but this process is already in progress. Also the external organizational learning processes can be enhanced. The company culture is characterized by 'not-invented-here' in certain areas; this means the people are 'proud' on their way-of-working and do not consider other companies' ways-of-working enough. It is a form of inertia. More use should be made of external knowledge and in- and outsourcing, because this is often much cheaper. If possible create a network of contacts. Try to make use of cooperation with other organizations like alliances, universities, consultancy agencies, and government regulations (subsidies). The described characteristics should not always be seen as negative; recognition and awareness of the own company culture helps to learn and improve.

There are two strategies possible to enhance the organizational learning and Knowledge Management. These are compared in Table 10, adjusted from Hislop (2005). The first strategy that is from a technology perspective, involves an ICT system where knowledge can be stored and re-used. Company A developed a 'Wiki-system'. This is a free-content encyclopedia format, like Wikipedia, with clusters of knowledge. This codification strategy seems a suitable strategy for big companies with dispersed knowledge in certain areas. The main disadvantages of a system like this are the following: first, it takes much time, money and effort to develop and maintain this kind of ICT systems. With ICT processes that are already reaching their limits, it will become more difficult to offer an effective system. A second thing is that people should see the potential of the system and have the right skills to work with it. Finally, it is difficult to codify the 'tacit knowledge' (the knowledge that in one's head), document, and store it. More rules should be added with all the consequences.

The second strategy, the personalization strategy, is described from a more social perspective. People have and live in networks of people. The strengths of a network comes from knowing where to look for knowledge, instead of storing the exact knowledge. This can be internal (e.g. knowledge map) or external (e.g. consultancy companies). This will result in a 'helicopter view'; everything can be overseen, from a higher level. Often, in this sort of situations, the barrier will be lower to call someone for help or information instead of doing it yourself. Bureaucracy will eventually reduce. Meeting face-to-face with rich (and cross-functional) communication can facilitate knowledge transfer but costs a lot effort and is expensive. Also the people should be willing to share knowledge. System Architects and PMOs play a key role in this matter, over the different sites. Finally, a disadvantage of this strategy is that it is difficult to keep the persons within the organization. They will have a more extensive (external) network, so the risks of overturn will increase.

The advice is to make use of the advantages of both strategies, looking from both the technical and social side, and know the risks. An ICT strategy without a social view will not perform optimally. The same is true for networking without storing knowledge. The combination of ICT and networking will cover a large area for knowledge creation and re-use.

Table 10 Knowledge Management strategies

	Codification (technical view)	**Personalization (social view)**
Competitive advantage	Knowledge re-use	Knowledge creation
Knowledge process	Transferring knowledge from people to documents	Improving social processes to facilitate sharing of tacit knowledge between people
Motivate & reward	Codifying knowledge	Sharing knowledge with others
Training	ICT skills	Inter-personal skills
Advantages for Company A	'Wiki'-format already started	Know WHERE the knowledge is (internal and external)
	Complete overview	Networks of people ('helicopter view')
	Suitable for big, multi-site company	Overcoming bureaucracy
Disadvantages for Company A	High costs and effort for developing / maintaining system	High costs and effort for rich forms of communication (e.g. face-to-face)
	People should have the intention and skills to work with it	People should be willing to share the knowledge
	Difficult to codify tacit knowledge (more rules)	Difficult in case of high turnover of personnel

5. Implementation

In this chapter some of the recommendations of the previous chapter were applied to Company A's organization with a role description for related functions. First, an example is given of how to monitor the process costs. Thereby, a short sensitivity analysis was made. Second, a checklist for making better scope decisions was provided. Finally, some (functional) roles and tasks are described in the light of the modular approach.

5.1 Process monitoring

In this section the platform cost efficiency is further explored. This was only performed for the estimated development costs and not for the estimated throughput times: for the throughput times the only data that was available were the estimated development times of the first two analogue products. So no comparison was possible. However, predictions showed that the total product development time (without platform and SD development time) of Product A will be slightly less than for Product B. Nevertheless, the product development will still take about one extra year.

5.1.1 Platform cost efficiency

When the measure of platform efficiency will be implemented in the organization, this means that the following formula needs to be used: the *'costs of product variants'* divided by the *'costs of the platform and SD development'*. The cost of one product variant (the cost of product development with the PLA) is represented by one blue bar for Product A or one light blue bar for Product B in Figure 26. This is divided by the total cost of the platform and SDs (the IC development costs excluded), that is represented by the green bar in Figure 26. When the formula is filled in with the costs derived of Company A: the platform efficiency for Product A will be 0.32 for the analogue version and 0.47 for the IP version. A higher number means that the efficiency of that product platform is decreasing, so it will be more expensive to bring the IP version to the market. On the other hand the platform efficiency for Product B will be 0.31 for the analogue version and 0.22 for the IP version. This reflects an increased efficiency, so for Product B applies that introducing the next variant to the market will be cheaper. There was made more use of commonality between the variants. Of course these first conclusions may be premature and should be seen as just an example. For real statements more data points are necessary. Furthermore, there can not be stated that Product B will have a higher efficiency than Product A (0.31 versus 0.32) because the measure is not absolute but relative. The conclusion was drawn that the platform efficiency of the next product variant of Product B will increase in relation to the previous variant. For Product A applied that the platform will be less efficient for the next product variant in relation to the previous one.

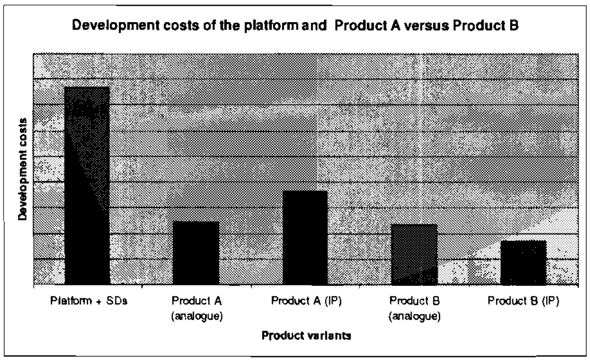

Figure 26 Development costs of the platform and Product A versus Product B

5.1.2 Cost sensitivity analysis

A sensitivity analysis on the efficiency can show the consequences in case of hypothetical positive and negative conditions. For both derived products (variants) A and B the effects are illustrated in relatively Figure 27 and Figure 28. The graphs provided an overview of the effect when in the development of a next product variant, for example a wireless product, the positive trend of Product B or the negative trend of Product A is going on. Obtained from Section 4.1.1, the costs of the IP variant of Product B decreased with 29% (rounded on tenths is -30%, illustrated with the light green bars) while the costs of the IP variant of Product A increased with 49% (rounded on tenths is +50%, illustrated with the orange bars). Although these are just rough predictions, it immediately becomes clear that Product A is more sensitive to the trends than Product B. It therefore needs extra caution and management attention.

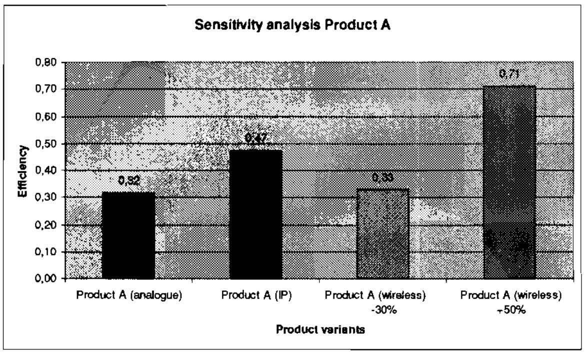

Figure 27 Platform efficiency of Product A

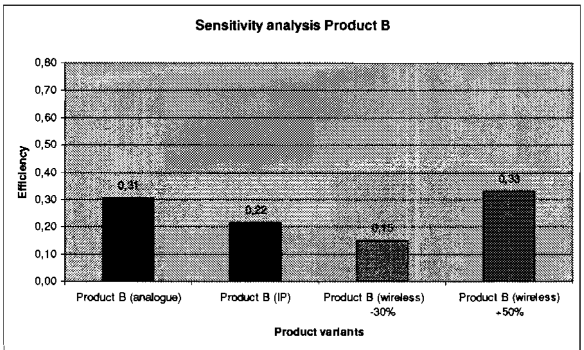

Figure 28 Platform efficiency of Product B

5.2 Definition of SD scope

For definition of the scope of SDs it was first important to define modular products in relation to the scope: modular products are products that fulfil various overall functions through the combination of distinct building blocks or modules, in the sense that the overall function performed by the product can be divided into sub-functions that can be implemented by different SDs, modules, or components (Kamrani and Salhieh, 2002). The scope of the core of the SDs should have sufficient capacity to cope with all expected variations in performance and usage. Components used in a modular product must have features that enable them to be coupled together to form a complex product. But how is the concept 'scope' defined within Company A?

5.2.1 Scope

Within Company A, the term scope means the requirements specified for the end result and the totality of work needed to complete a SD. Overall, the scope defines what the SD is supposed to accomplish and specifically defines what the end result should be. This can be for example a deadline or a certain level of feasibility. Testing plays a major role in checking whether the defined specifications are actually accomplished. The quality of a SD is dependent on the cost, time, and scope ('on budget, on time, and on specs'). Over the course of a large SD, quality can have a significant impact on cost, time, and scope (or vice versa). This is illustrated with the Project Management triangle in Figure 29 below.

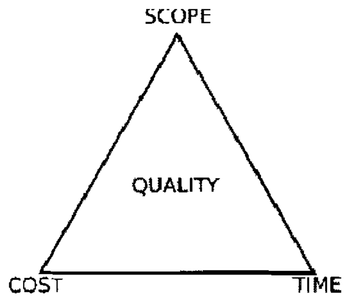

Figure 29 The Project Management triangle

5.2.2 Cost

The cost of the SD depends mainly on the used resources, as already explained in Section 4.1.1. Other factors that might have an influence on the costs are variables like: resource costs, labor rates, productivity, material rates, risk management, plant (buildings, machines, etc.), equipment, cost escalation, and indirect costs.

5.2.3 Time

For analytical purposes, the time required to develop a SD could be estimated by using several techniques. One method is to identify tasks needed to produce the deliverables documented in a Work

Breakdown Structure (WBS). A comparable method is used by Company A. The work effort for each task is estimated and those estimates are rolled up into the final deliverable estimate. The tasks are also prioritized, dependencies between tasks are identified, and this information is documented in a schedule. Time can be constrained due to dependencies and resources. Dependency-constrained means the dependencies between the task affect the length of the SD. Resource-constrained means the availability of resources is influencing the SD task length. Finally, also stories of users and feature lists could be used to make up a SD scope's length.

5.2.4 Scope creep

One of the phenomena that Company A should recognize is 'scope creep'. This term refers to the uncontrolled changes in a SD's scope. When the scope definition, documentation, or control of a SD is not optimal, the scope may grow; more tasks must be completed within the budget and schedule that was originally designed for a smaller set of tasks. This may result in overrunning the original budgets and schedules. Two different scope creeps could be found in an organization: the business scope creep and feature (technology) scope creep. A business scope is defined as decisions that are made with reference to a SD are designed to solve or meet the requirements and needs of the business. Business scope creep may be a result of less successful requirements definition early in development, or not including all the users of the product until the later stage of the systems development life cycle. Features (technology) scope creep can be introduced by (System) Architects adding features not originally contemplated. This may result in a 'gold-plating scope creep'. This can occur when (System) Architects augment the original requirements because of a bias toward 'technical perfectionism' or because the initial requirements were insufficiently clear or detailed. Furthermore, from a Product Management perspective a customer-pleasing scope creep may occur: when the desire to please the customer through additional product features adds more work to the current SD rather than to a new SD proposal.

5.2.5 Scope management plan

A scope management plan should be made for communication of the scope. The SD scope management plan documents how the SD scope will be defined, managed, controlled, verified and communicated to the SD development team and stakeholders. It also includes all work required to complete the SD. The documents should be used to control what is in and out of the scope of the SD by the use of a change management system. Items deemed out of scope go directly through the change control process and are not automatically added to the SD work items. The SD scope management plan should be included as one of the sections in the Program Management plan. It can be very detailed and formal or loosely framed and informal depending on the communication needs of the SD. In Appendix 13 a checklist for defining and maintaining the SD scopes is presented. Although the risk of an unclear SD scope is for a large part dependent on the size, complexity, and technology, the following factors should be taken into account:

- Scope (a general description of the SD)
- SD target (objectives of the SD)
- Resource allocation (what is dependency-constrained and what is resource-constrained?)
- Estimated duration (what are the estimated development times?)
- Estimated budget (what are the estimated development costs?)
- Deliverables (clear output criteria should be defined)
- Way-of-working (what are the methods to be used?)
- Process deliverables (what are the lessons learned?)

5.3 Implementation within the organizational structure (roles)

Although Company A already worked with platforms and SDs, the process can be improved on the points that were mentioned in the analysis and design. For the ones responsible for the evolution, maintenance or even creation of the platforms a substantial and long-lasting effort is required to work with the modular approach. Still being in the start-up phases of the modular approach, additional resources have to be invested and the 'normal' product development has to be maintained and supported. Company A must be open to the solutions of the modular approach but even so to the demands and limitations in both the short and the long term.

Interventions and organizational approaches to renewal will only have sense to execute when roles are defined with clear ownership of both the content and the process. Three factors are therefore extremely important for the right implementation (Meyer and Lehnerd, 1997): ownership, empowerment, and constancy. Ownership means control, that a charter is there to make decisions required by the task. Empowerment provides teams with the time and resources necessary to do the job. Constancy in granted ownership and empowerment for the full term of a project is required, from the start to the success or failure in the market.

5.3.1 Camera development planning and Program Management

Program Management offers advantages to overlook (a selection of related) projects. It must be continued but can be combined in the role as PMO manager / Master Scheduler.

All development activities should be included that can be allocated to dedicated group of resources. The descriptions of how different roles in Company A's organization should look like for making better use of the modular approach are given below (adjusted from Wit (2000)). The meaning of an implementation is not to appoint the persons to the task but to appoint roles to different functions. If roles are not conflicting, they can be combined into one person.

Teams

The teams should be characterized as multi-disciplinary project teams that structure the creation of a Reference Architecture. The Architecture is the responsibility of the System Architects, Electrical, Mechanical, and Software Architect, Function Managers and supported by the Purchasing Management, Quality Management, and Financial Control. To improve the quality of communication these persons should be co-located as much as possible, have regular face-to-face meetings and organize evaluation sessions (to exchange experiences). It is important that the team members can image oneself in another role. To keep track of the budget, schedule and resources a Project Manager's role is important in the project.

System Architects

One of the key roles is that of the System Architects. This heavyweight function requires different attitudes and skills to act within the boundaries of what it possible and what is not possible and to make those trade-offs. System Architects should be ahead of the troops. These persons should be identified, selected, and trained to do so.

They should have a broad, integrating view and knowledge and integral responsibility for the definition, validation, evolution, use, and maintenance (of the scope) of the Reference Architecture, Product Platforms and SDs. He does this by defining, coordinating and ensuring the evolution of functional partitioning and interfaces, and selection of key components in consultation with the Function Managers and Purchase Management (content definition and maintenance). He is responsible for the availability Product Platform and Architecture Roadmaps and should ensure benchmarking of the Reference Architecture(s). Other tasks are contributing to strategic supplier development, strategic purchasing (with the Purchase Manager) and recommending Innovation Projects related to future architectures.

A major function of the System Architect is to have intra- and inter-site communication. The quality of this communication depends on the way architecture, scope and priority are discussed; even though the interests of the multiple internal customers of Company A (different sites) are often different and opposing. The distribution of ownership should also be clear. Furthermore, platform renewing has to be included in the budget and the impact it has on the financials. Finally, an often underestimated function of the System Architect is the responsiveness to customer needs. Information flows to the System Architects should be created for better feedback from the market.

Software / Electronic / Mechanic / Industrial Architects

Architects often have specialist knowledge within one area of discipline. The role of the Architect corresponds to the role of the System Architect but is restricted to his own discipline. What is important is that this specialist knowledge of the Architects is secured with the help of an ICT system or social network.

Function Managers

Function Managers have multi-disciplinary technical and market knowledge within a functional domain. They ensure the availability, for his functional domain, of function / feature roadmaps and technology roadmaps. Commercial ambitions related to his functional domain are supported (e.g. 'best picture', 'best sound', and 'lowest consumption'). The Function Manager ensures the proper technical knowledge / competence is available to realize agreed plans and that roadmaps and competency are shared by setting up proper networking. He should, in case of renewal, initiate or, in case of a new architecture, detail tasks for new SDs and key-component developments related to his functional domain. The Field Call Rate (the percentage of products that failed in the market) and integral cost evolution should be managed and recommend Innovation Projects related to his functional domain. Finally, he should perform proper benchmarking and contribute to strategic supplier development.

Project Managers

The role of the Project Manager is to ensure successful realization of the Reference Architecture, Product Platform, or SD Creation project according to the task. The Reference Architecture, Product Platform or SD creation project should be managed and the whole project team should be motivated and stimulated. The agreed specifications, planning, budget, and quality of the SD projects is his ultimate responsibility.

Program Manager Officer (PMO)

The PMO is the actual owner of the Product Platform(s) and Master Plans that are developed, deployed, and maintained within his business. He should take responsibility to secure the scope. The role is to manage, plan and coordinate the portfolio of know-how-, Product Platform-, Architecture- and SD-projects. This includes ensuring that Platform Roadmaps are created and maintained, the platform budget is managed, and that proper standards and norms are applied to SDs (e.g. design rules). Tasks should include cost and quality targets. This also means performing high level risk management and presenting development scenarios. His main task is to continuously streamline and improve the platform processes and align development activities over the sites. As mentioned earlier, the characteristics of the PMO are: avoid a single-project / -product focus, manage the projects as a whole, a program. He is a sort of overall Project Managers with as highest priority optimalization of the throughput with fewer costs. The PMO should also functions as a bridge between engineering and manufacturing and simultaneously redesign products and processes. This means he is a coach for Function Managers and Project Managers. A social / organizational (knowledge) network (over sites) should be maintained by the PMO. The last element is the support of the senior management (Steering Committee / Management Team). They should use a long-term horizon and set the priorities expressed in the program's resources and budget allocations. The project scope should be SMART: Specific, Measurable, Acceptable, Realistic, and Timed.

6. Conclusion

In the conclusion there is first summarized whether the objectives of the modular approach (the PLA) had been met from the company's perspective. Furthermore, an overall conclusion is given. Finally, recommendations for future research were made.

6.1 Achievement of objectives

When there is focused on the practical gap and the company's stated objectives of the PLA in Section 1.4.3 are evaluated, it appeared that some goals were achieved and others had failed. First of all, the development times in terms of faster product introductions have not been improved. The development times of product variants are not expected to be shorter in relation to the traditional approach. Also the first spin-offs will not be more cost efficient. Although the cost of one product variant is predicted to be lower (more efficient) than the previous variant, there is no positive trend visible (yet). The average cost per product even increased. On the other hand, because of the modular approach, the process could provide more quality in terms of performance and reliability. Quality related issues could be better handled with the modular approach. Even though more projects (SDs) were performed in parallel, the project schedule accuracy increased. Resources were planned more precise (also due to CCPM) and the role of PMO is further extended, what will result in better (inter-site) coordination.
The ways in which this should be achieved also showed varying results. In general the SD development was separated from the product development. Although in many cases this distinction was not clear enough, a good SD scope definition should solve many of these issues in the future. The question remained whether the SDs, that are meant to be re-used or for multiple use, can actually be re-used in product variants. At the moment, this is difficult to say: some SDs can be re-used to a large extent. Other SDs will be more difficult to re-use. There was assumed that the domain- and technology know-how allows Company A to achieve the objectives of the PLA. There was recognized that there is enough knowledge and expertise present in the company but this knowledge can be better secured. In other words, there should be more emphasis on the creation, re-use, and management of knowledge. Think of technical (ICT) and social (network) solutions. Furthermore, the learning potential can be improved by separating Innovation Projects from product development projects, to study the feasibility of new ideas and features. Finally, the technical risk mitigation in mini projects was a success in Company A and was experienced as an important benefit of the modular approach. Some big technical issues were known beforehand and could be solved up-front. **The main conclusion after evaluating the modular approach was that it was still difficult to benefit from the re-use of standard building blocks but the idea of taking risks and feasibility studies up-front can offer gains.**

6.2 Overall conclusion

This section described the reflection on the closing of the theoretical gap and answering the research question. The findings from the analysis confirmed that the company was expecting many benefits in using the modular approach. Some of which did not come true (yet). The initial investments in costs and time were higher than predicted. But the main risks were found in the definition of the SD architecture scope. When the scope of a SD is clearly defined, this may result in an enhanced way-of-working. A suitable way-of-working can be facilitated by a sound organizational structure. The company's development culture has an influence on the way-of-working with a modular approach. Not only the modules have to physically interact and but also the organizational parts. That is why the importance of coordination, Knowledge Management, organizational learning, and Innovation Management will only increase. Modular thinking involves more than just technology. Structuring organizational processes can contribute in gaining benefits of this methodology.

In answering the research question some recommendation were made to manage three risk areas that are related to modular NPD, the implementation, and innovation. First, insight was created in the roadmap and development process and the associated times and costs. Platform performance indicators can support in the decision making process. Second, a clear SD scope definition contributes in setting the right objectives and completing these objectives. Third, the organizational structure should facilitate the innovative vision. By making tasks and responsibilities clear, the organization can better profit from a modular approach. **In general, the recommendation for Company A is to take the learned lessons into account, take a broad organizational view, and improve the processes on these points.**

6.3 Future research

Future studies are recommended to focus on making the modular approach fit better with Organization Science & Marketing perspectives. What is possible in terms of technology is known very well. But especially areas of research which involve coordination, organizational learning, Knowledge Management, and Innovation Management need attention in relation to modularity. The latter area of Innovation Management and modularity is under lighted in the literature but is the main source of discussions in practice. Questions arise like: should people (and other resources) be allocated in a roadmap and planned in processes with strict gates? Or should a small, independent innovation team work on an open assignment (within company working hours?) and include specialist of different functions to build, broaden, and deepen the knowledge? There will always be a tension field between different functional areas. Involve these organizational parts in a structured way and then a synergetic modular approach can really mean that *'the whole is more than the sum of the parts'*.

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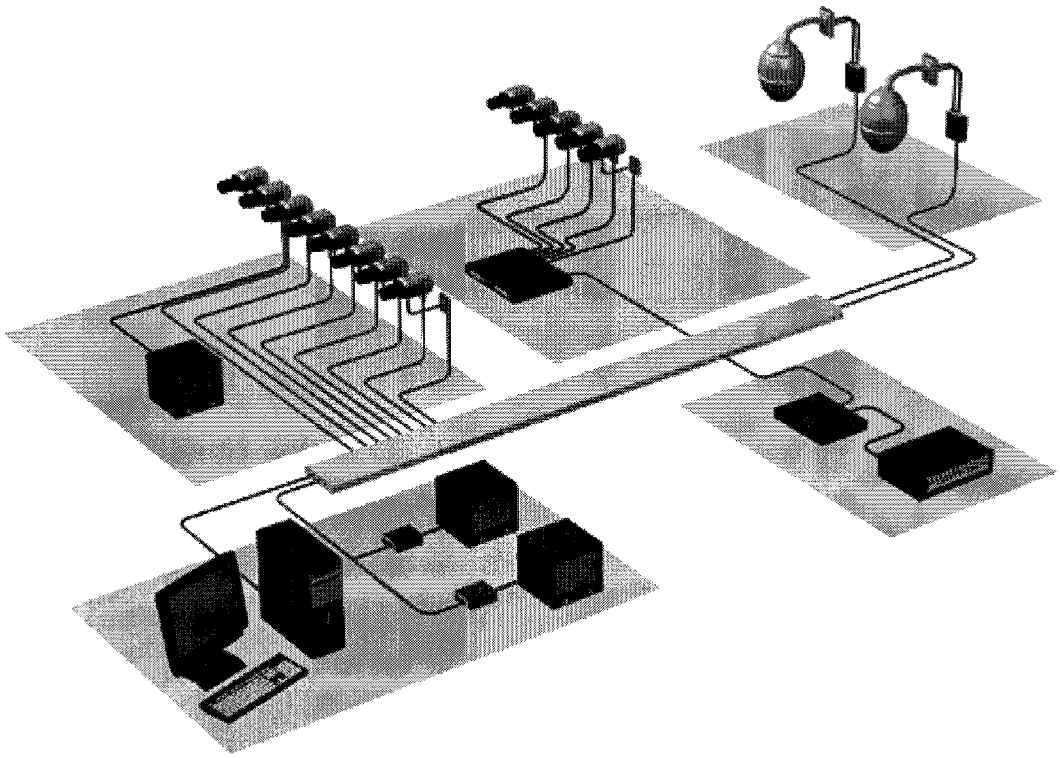
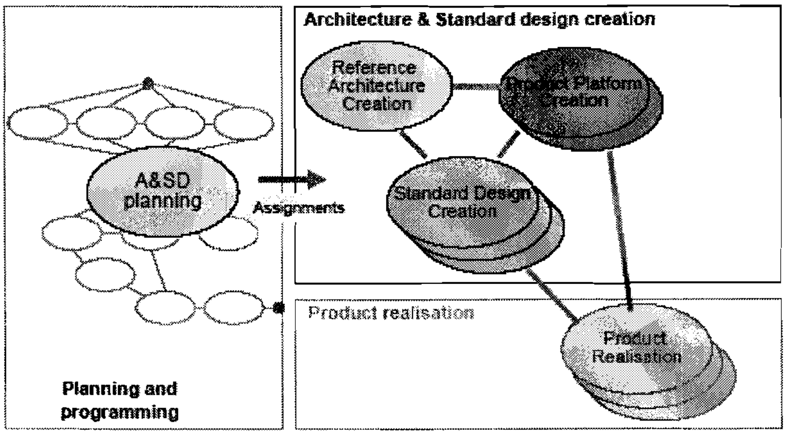
Appendix 1 Camera system's set-up



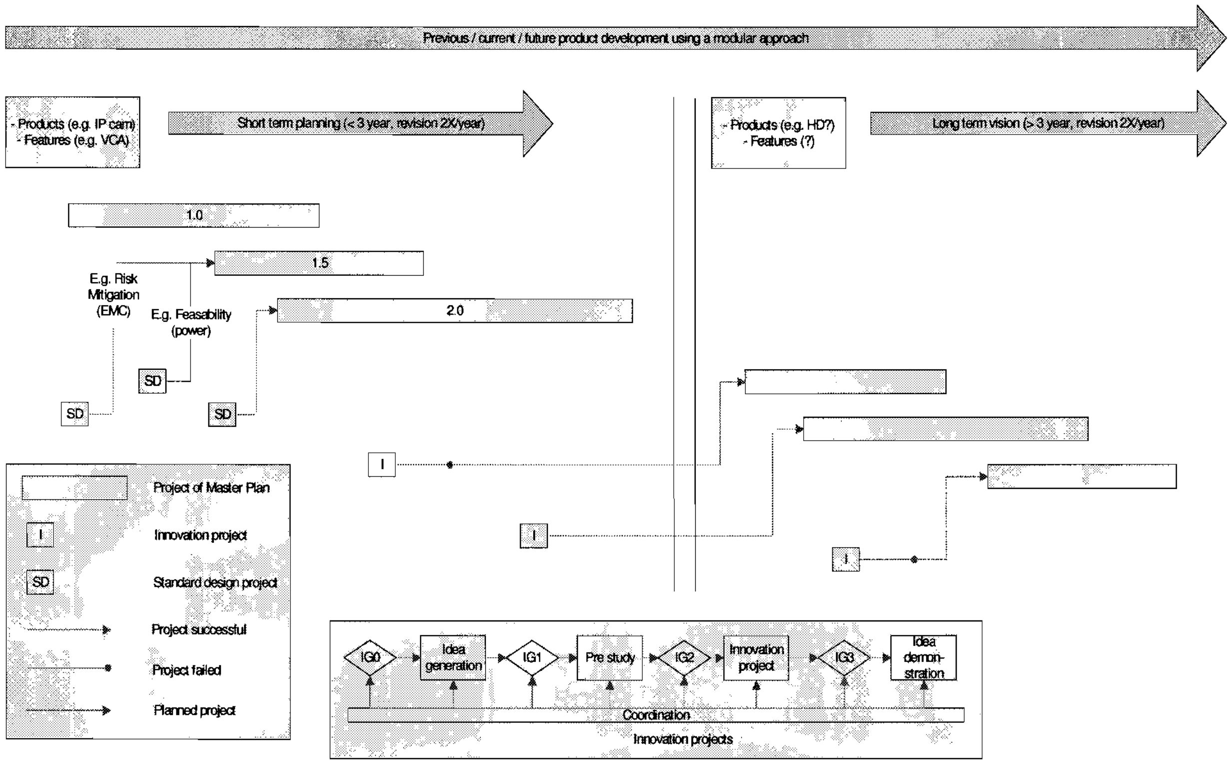
Appendix 2 Architecture & Standard Design phases



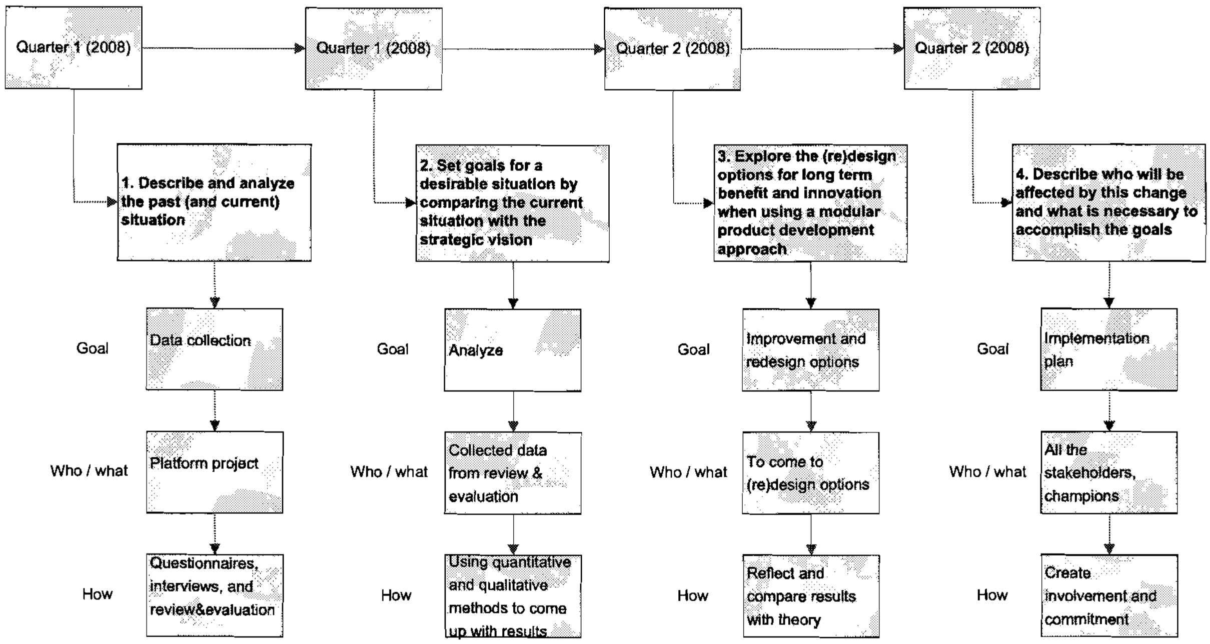
The main phases of the Architecture and Standard Design (A&SD) process are:

- Architecture and SD planning
    - Future direction of the business (roadmaps)
    - Priorities, resources, and budget
    - Assignments
- Reference Architecture Creation
    - Requirements of a product family
    - Partitioning into subsystems
    - Mapping of functionality to subsystems
    - Defining and documenting interfaces between subsystems
- SD Creation
    - Realization of subsystems
    - More specifically specification
    - Development
    - Testing
    - Documenting
- Product Platform Creation
    - Integration
    - Validation
    - Realize product families

Appendix 3 Example of forward-looking roadmap



Appendix 4 Detailed planning of the execution part



Appendix 5 Contact letter for the questionnaire

[English version below]

Geachte heer / mevrouw ....,

In de bijlage ziet u het document 'Questionnaire Modular New Product Development.doc' (Engelstalig). Hopelijk hebt u even de tijd deze in te vullen. Deze vragenlijst maakt deel uit van een afstudeerproject van de Technische Universiteit Eindhoven (TU/e) en Company A. Mijn begeleiders vanuit de TU/e zijn dr. Jimme Keizer en dr. ir. Peter Sonnemans. Binnen Company A zijn dhr. Frank Verschuren, M. Sc. en dhr. Frank Engelen mijn begeleiders. Het doel van het onderzoek is 'het definiëren van aanbevelingen om de issues and risico's van modulaire product ontwikkeling binnen Company A effectief en efficiënt te managen door gebruik te maken van de voordelen'. Ik ben er zeker van dat de academisch kennis and de praktische 'know-how' binnen Company A gecombineerd kunnen worden tot bruikbare aanbevelingen.

Stap 1: de huidige situatie en doelen (vragenlijst)
De eerste stap is het beschrijven en analyseren van de bestaande situatie, inzicht krijgen in de doelen en the huidige situatie te vergelijken met een gewenste ('should-be') situatie. De vragenlijst (ong. 25 min.) beslaat vier hoofdonderwerpen:

- De definitie van modulaire New Product Development (NPD)
- De redenen en 'drivers' om een modulaire aanpak te gebruiken
- Afwegingen binnen modulaire NPD
- Factoren die modulaire NPD beïnvloeden

Stap 2: modulaire NPD risico's en verbetermogelijkheden (interview)
Ik hoop dat we een keer kunnen afspreken voor een kort (ong. 30 – 60 min.) interview om kennis te delen en uw mening te horen betreffende de volgende onderwerpen:

- Het ontwikkelproces binnen Company A met een focus op de modulaire aanpak
- Mogelijke risico's en risicomanagementstrategieën bij een modulaire aanpak
- Het evalueren van de ervaringen met modulaire NPD, platform projecten en 'Standard Designs'

Ik ben er van overtuigd dat dit project waardevolle leermomenten kan opleveren voor zowel het bedrijf, als u en ik. Hopelijk kan ik binnenkort contact met u opnemen voor een afspraak te plannen.

Met vriendelijke groet,

Maarten Feskens, B. Sc.

Student Technisch Bedrijfskunde (TU/e)
Afstudeerproject voor de Master of Science in Innovation Management

Dear Sir / Madam ....,

In the attachment there you can find the document 'Questionnaire Modular New Product Development.doc' (in English). Hopefully you got some time to fill it in. This questionnaire is part of a graduation project of Eindhoven University of Technology (TU/e) and Company A. From the TU/e my supervisors are dr. Jimme Keizer and dr. ir. Peter Sonnemans. Within Company A my coaches are Frank Verschuren, M. Sc. and Frank Engelen. The goal of the research is to define recommendation to manage modular New Product Development within Company A more effectively and efficiently, by making use of the benefits and cooping with the risks involved. I am sure the academic knowledge and practical know-how about the subject can combined into some useful recommendations.

<u>Step 1: current situation and goals (questionnaire):</u>
The first step is to describe and analyze the current situation, to get insight in the goals, and to compare the present situation with a desirable ('should-be') state. The questionnaire (about 25 min.) has four main subjects:

- The definition of modular New Product Development (NPD)
- The reasons and drivers for using a modular NPD approach
- Trade-offs in modularity
- Factors that influence modular NPD

<u>Step 2: modular NPD risks and improvement options (interviews):</u>
I also hope that we can meet for a short (30 – 60 min.) interview to share some knowledge and discuss your opinion regarding the following subjects:

- The development process of Company A with a focus on modularity / Standard Designs
- Possible risks and risks management strategies in modular NPD
- Own experiences in modular NPD, platform projects or Standard Design

I am convinced that there are valuable learning opportunities for the company but also for you and me. I hope I can contact you to arrange an appointment.

Kind regards,

Maarten Feskens, B. Sc.

Student Industrial Engineering & Management Science (TU/e)
In partial fulfillment of the requirements for the degree of Master of Science in Innovation Management

Appendix 6 Questionnaire about modular NPD

Questionnaire about 'Organization of New Product Development and Innovation using a Modular Approach'

Directions

The questionnaire is in Microsoft Word format and has a diversity of questions:

- Open questions: grey shaded areas, which will expand so that there will always be enough space to answer (all letters, numbers, or symbols are allowed).
- 'Drop-down' multiple choice questions: there are a limited number of options available from which you can choose the (best suitable) answer.
- 'Check box' multiple choice questions: you can check the (best suitable) answer. The question states whether there will be one or more answers allowed.

When filling in the questionnaire keep in mind that the questions refer to Company A. Most questions concern your opinion and also some personal data is asked for. But the questionnaire is anonymously and confidentiality is assured.

It will take about 25 minutes to fill in the questionnaire. After the questionnaire is completed, please save this file and mail it to my email address. If you have any questions regarding the questionnaire or the subject in general, don't hesitate to contact me (on the same e-mail address).

Thank you in advance for taking the time to complete this questionnaire!

Kind regards,

Maarten Feskens, B. Sc.

Student Industrial Engineering & Management Science (TU/e)
In partial fulfillment of the requirements for the degree of
Master of Science in Innovation Management

Personal information

Date: - - *2008* (DD – MM)

Company:

Business Unit:

Department:

Function: *Senior Product Manager Imaging / Software Architect / Manager Electrical Engineering / Electrical Designer, System Architect / Team Leader / Group Leader development (mechanical, hardware test & approbation, CAD Layout) / CTO / Project Manager / Product Manager / Group Leader Software Development R&D / System Architect*

Gender: 12 *Male* 0 *Female*

Age: *26 / 31 / 33 / 34 / 37 / 38 / 40 / 42 / 45 / 46 / 52 / 54*

Years work experience at Company A:

0 *Less than 1/2 year* / 0 *Less than 1 year* / 5 *Less than 5 years* / 5 *Less than 10 years* /

2 *More than 10 years*

A. Definition of modular New Product Development (NPD)

In this section we try to capture what modular NPD actually means and to what degree it is used within Company A.

1. Can you define 'modular New Product Development (NPD)' in your own words?*

*Think of working with Standard Designs and Reference Architectures

2. Can the current way-of-working of Company A be classified it as modular* or integral**?

*Modular = one-to-one mapping between functions and building blocks and interfaces are de-coupled (3=Modular; 4=Very Modular, E = Empty, no answer)

**Integral = complex N-to-M mappings between functions and building blocks and interfaces are coupled (1=Very Integral; 2=Integral)

• On the component level	1, 3, 2, 3, 4, 2, 3, 3, 3, 2, 1, 2
• On the circuit block level (block diagram)	1, 3, 2, 3, 4, 2, 3, 4, 3, 3, 2, 2
• On the product level	1, 3, 3, 2, 3, 2, 3, 3, 1, 1, 2, 3
• On the project level	1, 2, 3, 3, 3, 3, 3, 2, 2, 1, 1, 3
• On the platform level	1, 3, 3, 2, 3, E, 3, 2, 1, 3, E, 3
• On the departmental level	2, 2, 3, 2, 2, 2, 3, 3, 2, 2, 2, 3
• On the organizational level	3, 2, 3, 2, 1, E, 3, 3, 2, 2, 2, 3

3. Can the current mind-set of the following parts of Company A's organization be characterized as modular* or integral**?

*Modular = when the system's components can be disaggregated and recombined into new configurations, possible substituting various new components into the configuration, with little loss of functionality

**Integral = the degree to which a system achieves greater functionality by its components being specific to one another

• In innovation management / opportunities	2, 3, 3, E, 3, 3, 3, 3, 4, 2, 1, 3
• In purchasing	1, 2, 2, E, 3, 2, 3, 3, 1, 1, 1, E
• In development	1, 3, 3, 3, 3, 3, 3, 1, 2, 3, 1, 3
• In production / manufacturing	2, 2, 1, 2, 2, 2, 3, 3, 1, 1, 1, 2
• In product portfolio	2, 3, 3, 2, 3, E, 3, 3, 1, 3, 2, 3
• In market needs / sales	2, 3, 3, 2, 3, E, 3, 3, 1, 3, 1, 3
• In logistics	1, 3, 3, 2, 1, E, 3, 3, 1, 2, 1, E
• In company strategy	3, 3, 3, 2, 3, E, 3, 3, 3, 3, 1, 3
• In the roadmap process	2, 3, 3, 2, 3, E, 3, 3, 2, 3, 1, 3

B. Reasons for using modular new product development

In this section we want to know what the most important reasons and drivers behind modular NPD is for Company A.

4. What are the main reasons for using modular New Product Development within Company A?
- Assess **ALL** individual statements whether you (strongly) disagree or (strongly) agree (1 = strongly disagree; 2 = disagree; 3 = agree; 4 = strongly agree)
- Check the boxes of the **THREE** most important reasons for Company A

- Modular NPD makes a optimal utilization of the innovative capacity better possible 3, 3, 3, 2, E, 2, 3, 3, E, 3, E, 4 4
- Modular NPD helps to generate a large range of products with just a few modular products using the resources of development manufacturing and purchasing efficiently 4, 3, 4, 2, E, 4, 3, 4, E, 4, 2, 3 9
- Modular NPD decreases the time-to-market because of the re-use of existing architectures 4, 3, 3, 3, E, 3, 2, 4, E, 3, 2, 2 9
- Modular NPD decreases the cost of the product due to maximum commonality in (electrical and mechanical) components or modules 2, 2, 2, 3, E, 2, 4, 3, E, 2, 1, 2 3
- With modular NPD, technology can be effectively used by leveraging it into new markets 2, 3, 2, 3, E, 3, 3, 3, E, 3, E, 2 0
- Modular NPD helps to find a better balance between short and long term 3, 2, 2, E, E, E, 3, 2, E, 3, E, 2 0
- Modular NPD helps to focus the attention of the management on those few projects, which have a significant impact on the costs and performance of a whole range of products 3, 3, 2, E, E, 3, 3, 3, E, 4, E, 2 2
- Modular NPD helps to create integrated platforms with a better balance between departments 4, 3, 3, E, E, E, 4, 4, E, 4, E, 2 2

Other reasons for modular NPD (*optional*): Lowering risks within product development projects / Integration into system-architectures outside competence or business activity of Company A / Commonality between products helps also customers to easily use and install the products /
Risk mitigation during product realisation /
Better, more predictable quality, more predictable time-to-market (5)

5. What are the main drivers of modular NPD and how important are they for Company A?

- Assess **ALL** modular NPD advantages whether they are (very) unimportant or (very) important for Company A: agree (1 = very unimportant; 2 = unimportant; 3 = important; 4 = very important)
- For each category, check **ONE** box of which you think it is the most important driver of that category

5.1 (Product) quality:

- Easier product diagnosis and simpler control (e.g. easier to learn for users) 4, 3, 2, 3, E, 2, 3, 4, E, 4, E, 2 0
- Better (independent, parallel) testing 4, 4, 2, 3, E, 3, 3, 4, E, 2, 3, 3 2
- Higher quality through re-use ('proven technology') 4, 3, 4, 4, E, 4, 4, 4, E, 3, E, 4 8
- Simpler installation 4, 3, 3, 2, E, 2, 3, 3, E, 4, E, 3 2
- Easier maintenance and repair 3, 3, 2, 2, E, 3, 3, 3, E, 3, E, 2 0
- Better disposability (e.g. recycling, end of product life cycle) 3, 2, 1, 2, E, 3, 4, 2, E, 3, E, 2 0
- Other (*optional*) Lowering costs of non quality (hidden costs) and keeping customers satisfaction at a high level (1)

5.2 Reduction in product development time:

- Shorter product life cycles through incremental improvements such as upgrade add-ons and adaptations 4, 2, 4, 2, E, 2, 4, 3, E, 4, E, 3 1
- Faster product evolution (e.g. make the product better in a shorter time frame) 4, 3, 4, 3, E, 3, 4, 3, E, 4, E, 3 4
- Reduced development time, shorter time-to-market, and reduced order lead time through re-use 4, 4, 4, 3, E, 3, 3, 3, E, 3, 3, 3 5
- Other (*optional*) Reduction of development time is reached by focussing on knowledge and development processing in terms of quality (increase maturity of organization; first walk, then run) /
  Better manageriability, with more reliable planning (2)

5.3 Customization, upgrades and functionality:

- Economies of scale in component commonality 3, 2, 4, 3, E, E, 3, 4, E, 3, E, 3 1
- Increased interchange-ability of products / components 3, 3, 3, 2, E, E, 3, 3, E, 3, E, 2 1
- Increasing responsiveness to customer needs 4, 3, 3, 2, E, E, 4, 3, E, 4, E, 2 3
- Increased number of product variants (diversity) 3, 3, 3, 3, E, E, 2, 4, E, 4, 4, 3 6
- Other (*optional*) In many cases product customization approach is faster and equally in cost as modular NPD. Modular development could hamper implementation of product improvements and even implementation of new technologies (1)

5.4 Cost efficiencies and profitability:

- Lower life cycle costs through easy maintenance 3, 3, 3, 2, E, E, 2, 3, E, 4, E, 2 0
- Cost savings in inventory and logistics 3, 3, 4, 3, E, 3, 3, 3, E, 3, E, 2 1
- Less R&D and manufacturing costs 4, 3, 4, 3, E, 2, 3, 3, E, 4, E, 3 6
- Lower capital costs 3, 3, 3, 2, E, E, 3, 3, E, 3, E, 2 0
- Reduced material and purchase costs 3, 3, 3, 3, E, E, 3, 3, E, 3, E, 2 0
- Economies of scale 3, 3, 3, 3, E, E, 4, 3, E, 4, E, 2 1
- Decreased switching costs 3, 3, 2, 2, E, 3, 3, 3, E, 4, E, 2 0
- Lower costs through re-use of components 3, 3, 4, 3, E, 3, 3, 3, E, 3, 3, 2 2
- Other *(optional)* Optimize the supplier-management by increasing the number of technical buyers and improve or structurize the communication with suppliers. Focus on combined development rather then on component delivery only /
  All of the above (2)

5.5 Higher flexibility and better coordination:

- Higher flexibility in component reuse (component flexibility)2, 3, 3, 3, E, 3, 2, 3, E, 3, E, 2 0
- Higher flexibility in architecture re-use (platform flexibility) 3, 4, 4, 4, E, 3, 4, 3, E, 4, E, 3 3
- Decoupled risks (lower risk) 4, 4, 4, E, E, 4, 4, 4, E, 3, 3, 3 7
- Reduced systemic complexity 4, 3, 3, E, E, 3, 4, 4, E, 3, E, 3 2
- Purchasing from multiple sources (e.g. suppliers, in-sourcing)4, 3, 3, E, E, 3, 4, 3, E, 3, E, 2 0
- Other *(optional)* Think more in terms of re-use of architectures and technologies then in re-use of final components /
  NPD does not necessarily give you higher flexibility (2)

5.6 Design standardization:

- Task specialization 2, 3, 2, E, E, E, 2, 3, E, 4, E, 3 0
- Decoupling of tasks (e.g. independent product development)4, 3, 3, E, E, 3, 3, 4, E, 3, 2, 3 7
- More design freedom 2, 2, 2, E, E, E, 3, 3, E, 4, E, 2 0
- Better learning across projects 4, 3, 3, E, E, 3, 4, 4, E, 4, E, 2 3
- More outsourcing 2, 2, 2, E, E, E, 3, 3, E, 3, E, 2 0
- Easier administration 2, 2, 2, E, E, E, 3, 3, E, 3, E, 2 0
- Other *(optional)* The process of building up a knowledge database (like QRG, = Quick Reference Guide database) is more important then the database itself (1)

5.7 Other drivers *(optional)*:

- *Systhematic approach*
- *Defining a Company A wide (combined) development plan*
- *Capability of high quality development*

C. Trade-offs

In this section three difficult trade-offs need to be made. There are only two possibilities.

6. Should the platform be at the cutting edge of new technology development and risk high investments and development times which may not pay back in the end, or build further upon existing knowledge and risk inability of the platform to meet future customer demands?

8 New technology / Risk high investments - 4 Existing knowledge / Risk not meet demands

7. Should the platform allow a maximum of flexibility in product design and risk being too expensive in the end, or focus on efficiency in product design and risk not being able to meet future customer demands?

7 Focus on efficiency / Risk not meet demands - 5 Maximum flexibility / Risk being too expensive

8. Aim for efficiency through high volumes in more than one market segment and risk low sales due to products that do not fully meet customer demands, or aim for effectiveness (i.e. meeting customer demands) in one market segment and risk low returns due to low volumes?

7 Aim for efficiency / Risk low sales - 5 Aim on effectiveness / Risk low return, low volume

D. Factors that influence modular NPD

From the literature study there appeared to be some factors that are influencing modular NPD. What factors are actually influencing the modular NPD within Company A?

9. Security systems industry trends

- Company A is being able to keep up with the increasing product functionality* and complexity
  *Functionality = the product is able to fulfill its intended function3, 3, 3, 3, 4, E, 1, 2, 3, 3, 3, 3
- Company A is being able to keep up with the strong costs erosion*
  *Cost erosion =increasing competitive intensity, faster new products, less profit per product
  2, 2, 2, 2, 3, E, 1, 2, 1, 2, 1, 2
- Company A is being able to keep up with the strong pressure on time-to-market 1, 2, 2, 2, 3, 3, 2, 1, 3, 3, 2, 2
- Company A is being able to keep up with the increasing customer demands on quality* and reliability**
  *Quality = the product fulfills customer requirements at 'all' customers during operational life,
  **Reliability = the product fulfills its intended function within a time frame under given conditions
  3, 3, 3, 3, 3, 3, 2, 4, 3, 3, 3, 3
- Company A is being able to keep up with the increasing business process complexity, globalization and outsourcing trend 2, 3, 3, 3, E, 3, 1, 2, 2, 2, 2, 2

10. Innovation

- Company A should rely on acquisitions as the primary source for introducing innovation to the company 1, 2, 1, 2, 2, E, 1, 2, 3, 4, 1, 3
- Innovation should come from within the organization 3, 3, 3, 3, 4, 3, 4, 4, 4, 3, 3, 3
- Creativity is important for the company's success 4, 4, 4, 3, 4, 3, 4, 4, 4, 4, 4, 3

11. Organization

- Company A makes enough use of modular development* / component teams
  *Modular development team = cross-functional project team, lead by a platform manager
  1, 2, 4, 3, 3, 2, 1, 2, 2, 2, 2, 3
- Company A makes use of platform-based performance indicators*
  *Examples:
  Platform Efficiency = Cost of Product Variant / Cost of Platform Development
  Platform Effectiveness = Sales of Product Variant / Cost of Product Variant
  1, 2, 1, 2, 2, E, 2, 3, 2, 2, 1, 2

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/ department of technology management

12. Market / customers

- Company A should strive for full mass-customization*

  *Full modularity in product, process and value chain; so pure individualized products

  3, 2, 2, 1, 2, E, 3, 1, 3, 2, 3, 2

13. Which segmentation strategy / strategies fit(s) with the goals of Company A?

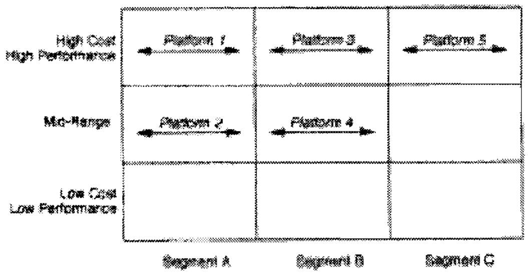
- The four segmentation strategies are described below.
- Check the boxes of the strategies that are used at the moment (multiple answers possible)
- Check the boxes of the strategies that should be used (multiple answers possible)

	Are used:	Should be used:
• Strategy 1: niche-specific	*1*	*2*
• Strategy 2: horizontal leverage	*11*	*8*
• Strategy 3: vertical (up or down) scaling	*9*	*8*
• Strategy 4: beachhead	*5*	*6*

Explanation segmentation strategies:

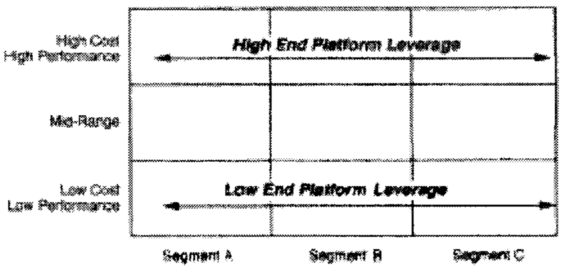
- Strategy 1: niche-specific platforms with little sharing of subsystems or manufacturing processes

  The company is totally focused and dedicated to serving the needs of a very specific niche, but this may be very expensive.



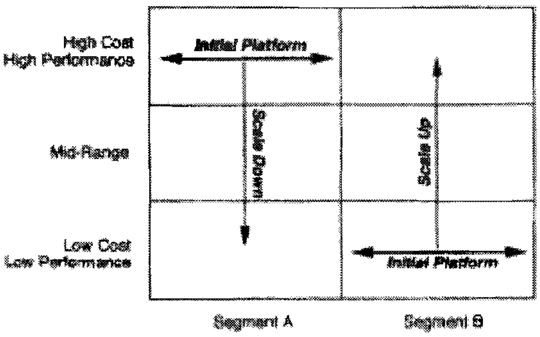
- Strategy 2: horizontal leverage of key subsystems or manufacturing processes

  The company introduces streams of new products across a series of related customer groups without having to 'reinvent the wheel' for each.



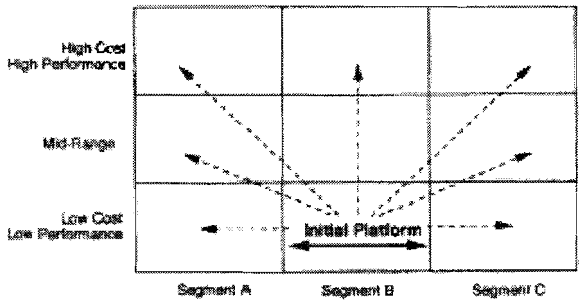
- Strategy 3: vertical scaling of key platform subsystems

  The company is able to leverage its knowledge of any particular segment, and to do so through product development that will be less costly than if an entirely new platform has to be developed for each tier of price or performance. The risk may be that a weak common platform or common subsystem will undermine the competitiveness of the entire product line.



- Strategy 4: the beachhead strategy

  From an initial market foothold, the company scales up (or scales down) the performance characteristics of the platform and add (or leave) other features designed to appeal to the needs of other segments.



14. Coordination / flexibility

- Within Company A there is enough flexibility in resource availability

  2, 2, 2, 3, 2, E, 1, 1, 2, 2, 1, 2
- Within Company A there enough flexibility possible in coordination of projects

  2, 3, 3, 3, 3, E, 1, 3, 2, 2, 2, 2
- ICT actually facilitates the modular NPD processes within Company A

  1, 2, 2, 3, 2, E, 1, 1, 2, 1, 1, 1
- Company A makes enough use of Knowledge Management

  1, 2, 1, 2, 2, E, 1, 2, 2, 1, 1, 2

15. Other comments about things not mentioned in questionnaire (*optional*): *Company A needs an integral development plan in order to fully utilize the expertise available. In addition to that an innovation plan is needed in order to 'be ready in time'. These plans need to be mapped upon the present and near future market needs. Only in this way Company A will be able to deliver the right products at the right time at the right cost level. High attention is needed to the technical purchasing organisation in terms of technical capabilities in order to be able to expand, choose, evaluate, develop and manage the supplier-base. In addition to that attention is needed for the quality part of Company A's organisation. Quality engineers need to be highly integrated into the development processing in order to optimize processes like Failure Mode and Effects Analysis, component releases, defect analysis etc. /*
Making use of platform development is often overrated and underestimated. For re-use you really need to do extra work but at this moment we think that e.g. software from other sites can be re-used without putting real effort in it. Next to that, platform development often creates components which are too complex because they have to anticipate on future needs. A recommended approach is an evolutionary one rather than an revolotionary one. Just make smalle modifications to products that work. A nice example is Toyota that makes small steps, keeping a high quality and reliable product.

Appendix 7 Company A's definitions of modular NPD

Chief Technology Officer
Modular NPD is a method of structuring development of new products using a modular approach. One can see this as modular approach as consisting of multiple layers. The first layer being a Reference Architecture, this architecture is the anchor point for platforms consistent with that Reference Architecture. A platform is typically an instantiation of a Reference Architecture for a certain application area, within a certain time span. A Reference Architecture consist of a structure of a multitude of SDs (hence the name 'modular'), which have an identified and described interface definition, have an unambiguous specification, and follow their own life-cycle.
Product Manager
Take building blocks from development to create new products or variations on existing products. Hopefully this approach reduces development time and / or re-work / errors to make the project delivery time more predictable because the risks are reduced.
Senior Product Manager
Definition and creation of methods and design elements to enable quick development of products with low (or controlled) risks. Re-use of these elements should enable even faster creation of derivatives or next generation products (based on a common platform).
Project Manager
Development of building blocks to review technical feasibility, risk mitigation during product realization. These building blocks should be re-usable in various products
Team Leader development
Lowering risks within the product development projects by starting with feasibility / SDs
Manager Electrical Engineering
Developing technical solutions in such a way, they can be re-used as much as possible.
Group Leader development (mechanical, hardware test & approbation, CAD Layout)
Standardized (new) technology and standard defined development building blocks rather then SDs as in standard components / materials. The capability to define product- / platform- / Reference Architectures. The capability to understand and translate platform / product / process requirements from the market needs. The ability optimize development processes with the customer in mind. The ability to excite customers with innovative solutions of product platforms / architectures.
Group Leader Software development R&D
Modular new product development is making new products partial from standard building blocks and partial from new development. Note that the work needed for new product development is under-estimated and over-rated. For re-use of building blocks extra effort is needed which normally is not invested. Practice shows that making new products in a fast way form standard building blocks is often not feasible because blocks are over-specified (need to be prepared for all kind of future extensions).
System Architect
It starts with the roadmap process to define the development of key components and technologies. The roadmap also contains the future product families, and he necessary underlying technologies are proven in SDs
System Architect (2)
Optimal re-use of functional blocks / software modules in all camera products and optimal re-use of physical implementations of these functions (panels, housings etc) in product families (e.g. the IP products). All questions below answered for the platform projects, not for older projects.
Software Architect
NPD is developing a product-range by developing independent components (SDs) based on a single Reference Architecture.
Electrical Designer
Design of Standard blocks that later can be used to make a product.

Appendix 8 Definition of modular NPD

The questionnaire existed of four parts, as mentioned above. The first part (A) addressed three main questions about the definition of modular NPD. The first main question was an open question, while for the second and third question four answers could be chosen: 'Very Integral' (1 point), 'Integral' (2 points), 'Modular' (3 points), and 'Very Modular' (4 points).

The first question asked the respondents about their definition of modular NPD. An overview of these definitions is already provided in Appendix 7. It is interesting to note that most people in their definition only thought about re-use of physical blocks (parts of a product), while the scope of the thesis was much broader (also a focus on market and organizational concepts).

The second question addressed the level of modularity in the way-of-working of Company A (Figure A.1). It appeared that in general only the circuit block level was seen as modular. On all the other levels, thus on the component, product, project, platform, departmental, and organizational level, a more integral approach was used. When this question was verified in the interviews it appeared that most respondents (especially Product Management) rated the working approach as (too) integral because they want the organization to work more modular.

The third question showed that not all different departments or functions worked according a modular approach (Figure A.2): Innovation Management, product portfolio, the company strategy, and the roadmapping process are experienced as to be modular. On the other hand, purchasing, development, production, marketing, and logistics are seen as integral processes. Especially production and logistics were integral processes but respondents commented that they have less insight in these processes.

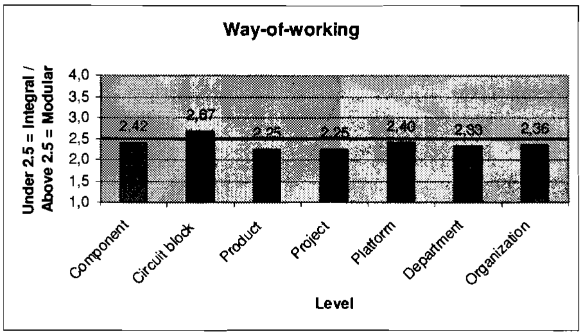


Figure A.1 Way-of-working (level)

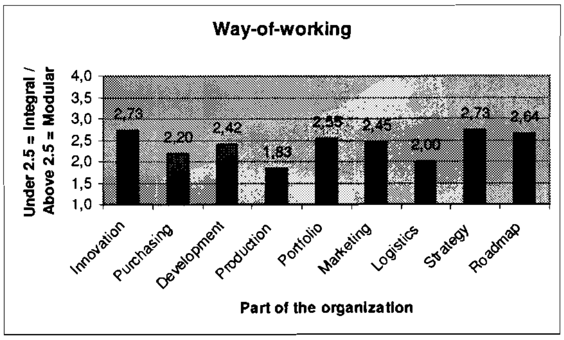


Figure A.2 Way-of-working (organization)

Appendix 9 Reasons and drivers for using modular NPD

The second part (B) of the questionnaire tried to capture the most important reasons and drivers for using a modular NPD approach. In main question statements about reasons for adopting modular NPD within Company A needed to be assessed with four possible answers (Figure A.3): 'Strongly Disagree' (1 point), 'Disagree' (2 points), 'Agree' (3 points), 'Strongly Agree' (4 points). There was also asked what Company A considered to be the three most important reasons of those statements (Figure A.4). Finally, there was the possibility to provide other reasons. Five other reasons were given, that were not included in the questionnaire: 'Lowering risks within product development projects', 'Integration into system-architectures outside competence or business activity of Company A', 'Commonality between products helps also customers to easily use and install the products', 'Risk mitigation during product realization', and 'Better, more predictable quality. Better predictable time-to-market'.

The most important reasons for Company A to use modular approach were 'to generate a large range of products with just a few modular products using the resources of development, manufacturing, and purchasing efficiently', 'decrease the time-to-market because of the re-use of existing architectures', 'help to create integrated platforms with a better balance between departments', and 'a better optimal utilization of the innovative capacity'. A broader range of products, more efficiency, shorter throughput times, and more innovation seemed to be the core reasons. 'Focus the attention of the management on those few projects, which have a significant impact on the costs and performance of a whole range of products', and 'technology can be effectively used by leveraging it into new markets' also scored positive. On the other hand, 'the decrease in cost of the product due to maximum commonality in (electrical and mechanical) components or modules' and 'the better balance between short and long term' were in general no valid reasons for modular NPD.

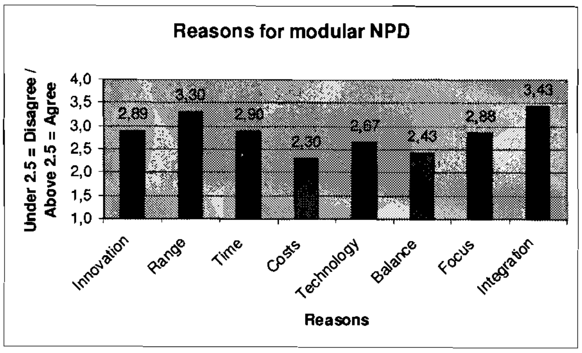


Figure A.3 Reasons for modular NPD

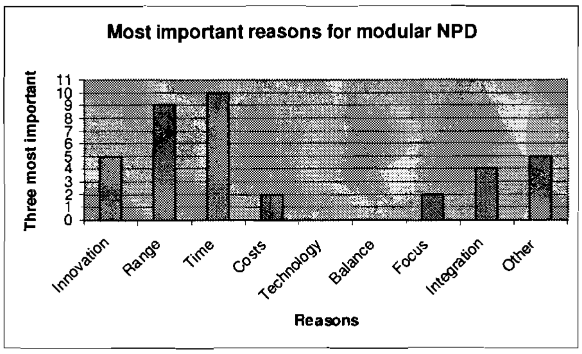


Figure A.4 Most important reasons for modular NPD

Question five addressed the main drivers of modular NPD, and how important they are for Company A. For each of the six advantage categories there was the option to think of another driver. Also drivers could be given drivers in general, not belonging to one of the categories. The importance is expressed in 'Very Unimportant' (1 point), 'Unimportant' (2 points), 'Important' (3 points), and 'Very Important' (4 points).

For the first category, (product) quality (Figure A.5), all the drivers were seen as beneficial for Company A, except the 'disposability'. On the average the respondent did not see the use of having better end-of-life processes although there was commented that there are government regulations which command to 'design for disposability'. 'High quality through re-use of proven technology' was rated as very important and is the main driver for modular NPD. 'Better testing', 'simpler installation', 'easier diagnosis', and 'simpler maintenance and repair' were also important drivers, especially for the Product Managers, which have naturally a more marketing-driven background. 'Lowering costs of non quality (hidden costs) and keeping customers' satisfaction at a high level' was an extra driver that was added.

All the drivers of the second category (Figure A.6) ('reduced development time', 'faster product evolution', and 'shorter product lifecycles through incremental improvement'), the reduction in product development time, were seen as important. The 'reduced development time was the most important driver of this category. Extra comments on this category were: 'Reduction of development time is reached by focusing on knowledge and development processing in terms of quality (increase maturity of organization (first walk, then run))' and 'Better manageriability, with more reliable planning'.

Customization, upgrades, and functionality was the third category (Figure A.7). All the drivers were seen as important. But the sequence of drivers from most important to least important was: 'number of product variants (diversity)', 'responsiveness to customer needs', 'economies of scale in component commonality', and 'interchange-ability of products / components'. Further, there was mentioned that 'In many cases product customization approach is faster and equally in cost as modular NPD. Modular development could hamper implementation of product improvements and even implementation of new technologies.'

For the fourth category about cost efficiencies and profitability (Figure A.8) all the drivers were seen as important, but the most important driver is 'the savings in R&D and manufacturing costs'. With a modular approach costs can be saved (later on) in development but also in production. Some comments were added that 'all the drivers are of equal importance', and 'Optimize the supplier-management by increasing the number of technical buyers and improve or structuralize the communication with suppliers. Focus on combined development rather then on component delivery only'.

The fifth category involved flexibility and coordination (Figure A.9). 'Reduced system complexity', 'purchasing from multiple sources', and 'higher flexibility in components re-use' are important, but 'architecture re-use' and 'decoupled risk' are even very important. Also the most important driver was the 'decoupled risk', with a second place for 'architecture re-use'. Further comments were added that there should be: 'thought more in terms of re-use of architectures and technologies then in re-use of final components'. Re-use of architectures appeared to be more important than re-use of components.

Design standardization was the sixth category (Figure A.10). 'Learning across projects' and 'decoupling of tasks' are the most important drivers here, but 'task specialization' and 'more design freedom' are also important. On average 'outsourcing' and 'administration' were not seen as a real driver of modular NPD. Learning and independent tasks are thus the core values. The organization of Company A can not really benefit from outsourcing. Here was the extra comment: 'the process of building up a knowledge database (like QRG, = Quick Reference Guide database) is more important then the database itself'.

Finally, there were also three other drivers added by a respondent that were not in the questionnaire: 'a systhematic approach', 'defining a Company A wide (combined) development plan', and 'the capability of high quality development'.

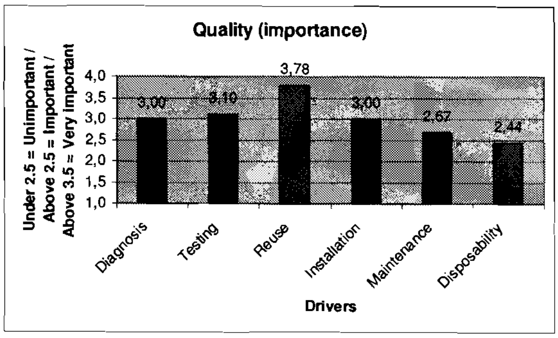


Figure A.5 Quality drivers

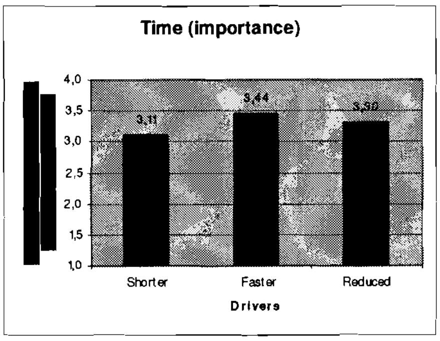


Figure A.6 Time drivers

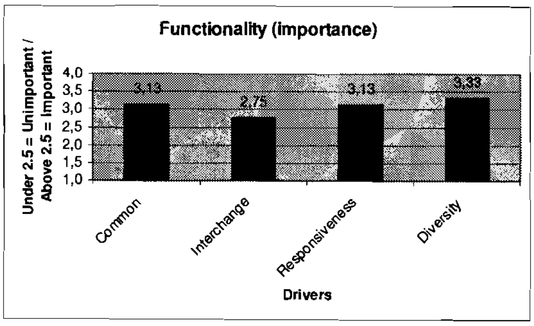


Figure A.7 Functionality drivers

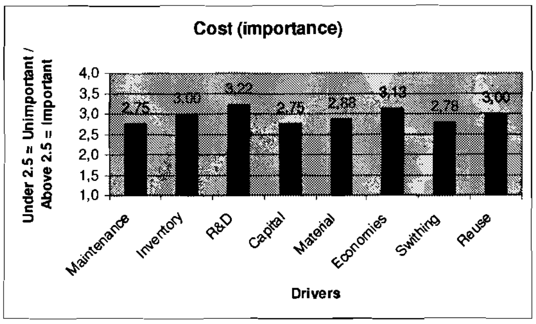


Figure A.8 Cost drivers

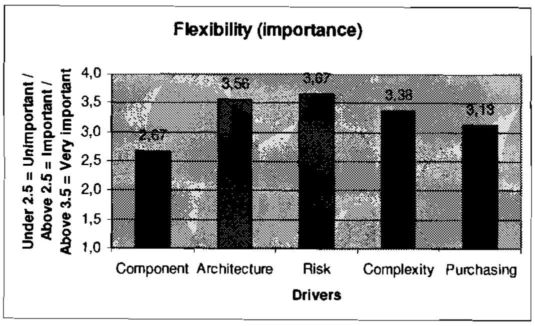


Figure A.9 Flexibility drivers

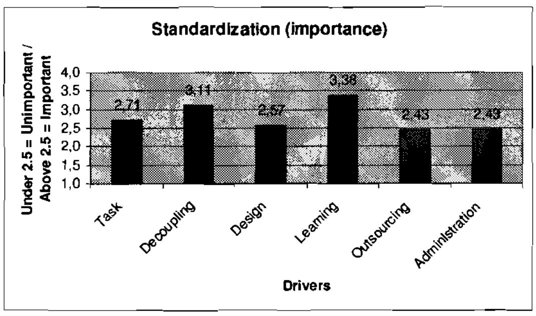


Figure A.10 Standardization drivers

Appendix 10 Factors that influence modular NPD

In part D of the questionnaire, the opinions about factors that are influencing modular NPD were investigated. Question nine captured whether Company A is able to keep up with the five industry trends (Figure A.11). It appeared that the people think that Company A is able to manage 'the increasing product functionality and complexity', and 'the increasing customer demands on quality and reliability', but not 'the strong cost erosion', 'the strong pressure on time-to-market', and 'the increasing business process complexity, globalization and outsourcing trend'. These results were explained in the interviews: Company A is known for the performance (functionality and complexity) and quality (and reliability) of its products. This confirms the image and included one of the elements of the mission: quality. But of course this quality has a price and is translated to the costs and throughput times that are not completely under control. The complex business processes also contribute to this trend. There can be concluded that especially the efficiency and the business process still can be improved.

Question ten involved the subject innovation (Figure A.12): it appeared that Company A should not solely rely on acquisitions as the primary source for introduction of innovation to the company. There was recognized that acquisitions are surely necessary for capturing knowledge and growth of the organization but most of the respondents agreed that innovation should come from within the organization. Most of them even strongly agreed that creativity is important for the company's success. The conclusion can be drawn that the innovation process can be improved.

Question eleven related to some organizational and marketing improvement points (Figure A.13): the broadly shared opinion was that Company A does not makes enough use of modular development teams and platform-based performance indicators. On the one hand, the modular approach can be better utilized by defining modular development teams. On the other hand, the results of using a modular approach are not enough visible in the organization. There should come more insight and transparency in the use of platform-based performance indicators.

Question twelve showed that Company A should not strive for full mass-customization. This illustrated that, at this moment, Company A should not aim for pure individualized ('custom-made') products.

Question thirteen referred to four segmentation strategies respondents could choose (Meyer and Lehnerd, 1997) (Figure A.14): strategy one involved a niche-specific platform with little sharing of subsystems or manufacturing processes. The advantage of this strategy is that it enables an organization to be very dedicated. The disadvantage is that it is a very expensive strategy. The second strategy was the horizontal leverage of key subsystems or manufacturing processes. The main benefit is that related customer segments can be targeted easily but that negative effects are also spread. Strategy three was vertical (up- or down-) scaling of key platform subsystems. This may decrease the costs but a weak platform can undermine the competitiveness. The last strategy, the beachhead strategy, was particularly suitable for penetrating new markets with new products. On the question which strategies Company A is using now, most respondents choose strategy 2, horizontal leverage. Also strategy 3, vertical scaling, and strategy 4, beachhead, are often used. Strategy 1, the niche-specific is almost never used. When the question was what strategies should be used by Company A, an equal number of respondents answered strategy 2 and 3. Also strategy 4 should be used. Strategy 1 did not fit Company A's strategy.

The last question was related to the coordination and flexibility of Company A (Figure A.15). Also here some major improvements could be made: there seems to be not enough resource and coordination flexibility. Actions are already set up but should be further worked out. ICT is not facilitating the modular NPD processes enough within Company A. Some said that it is even constraining. The last point was that Company A makes not enough use of Knowledge Management.

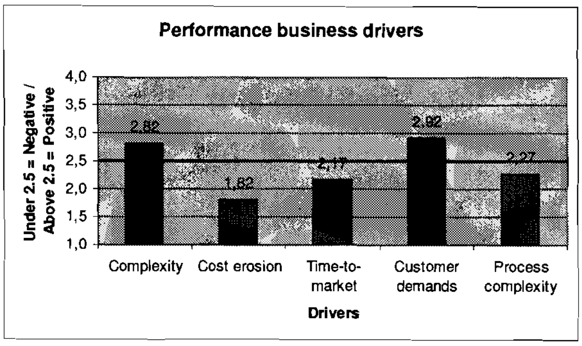


Figure A.11 Industry trends

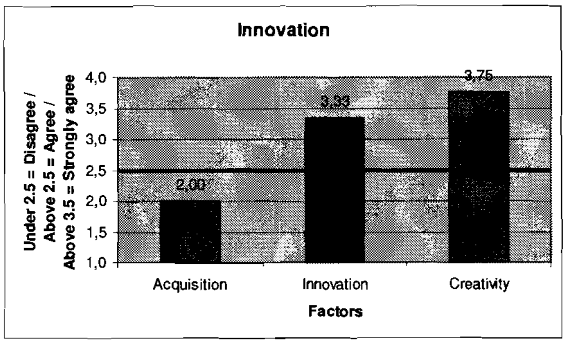


Figure A.12 Innovation

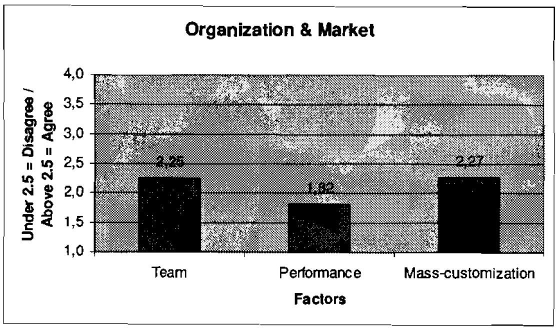


Figure A.13 Organization & market

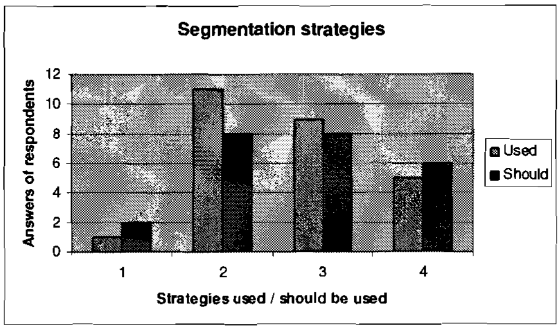


Figure A.14 Segmentation strategies

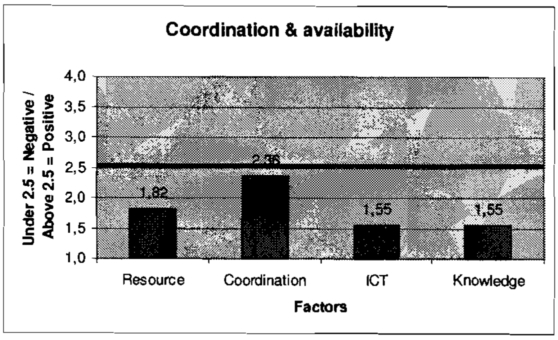


Figure A.15 Coordination & availability

Appendix 11 Detailed description of the issues

Technical issues

- The first issue is that the security systems industry was traditionally a rather slowly moving industry while now there is a high degree of uncertainty because the technology is changing: with the evolutionary switch from analogue to IP cameras (as described in Section 1.2.2), the security systems industry is adopting the characteristics of the IT industry.
- Flexibility is important in a professional high-tech market but when working with a modular approach, there needs to be some kind of fixed requirements for a period of time. That is why Company A can easily be locked-in in a chosen technology path.
- Over-specifying of requirements is trap that can be due to a modular approach. Too much standardization will make the development inflexible.
- Company A also has the tendency to develop too much functionality in one camera. The whole will become very complex and efficiency will be lost.
- The technical knowledge that Company A is working with is in general very dedicated, specific, and embedded in the camera. Because a security camera is relatively small, there is less design freedom. The 'vormfactor' plays also a major role when re-using parts for other applications.
- Quality is one of the three drivers of the mission statements. Therefore Company A has high demands on tests for quality and reliability. With the modular approach testing took often longer than expected, and also double tested were performed, which should have become redundant.
- There are also risks with regard to issues with EMC, power supply, and cooling. Especially the EMC issue plays a major role in the PLA. The magnetic effects appear to be more difficult to predict when parts are independently developed. An integral approach would probably solve these problems better.
- Furthermore, there are issues that are particular inherent to the software development. There is said that it is not so difficult to develop the basic software but the real challenge is in tuning the SDs. Another thing is that the coding standards are usually not mutually agreed upon. Agreement about standards helps to not 're-inventing the wheel' and easier re-use. Debugging the chip is also a major obstacle because almost everything is dependent on this. Finally, the intense interaction of hardware and software should always be taken into account.

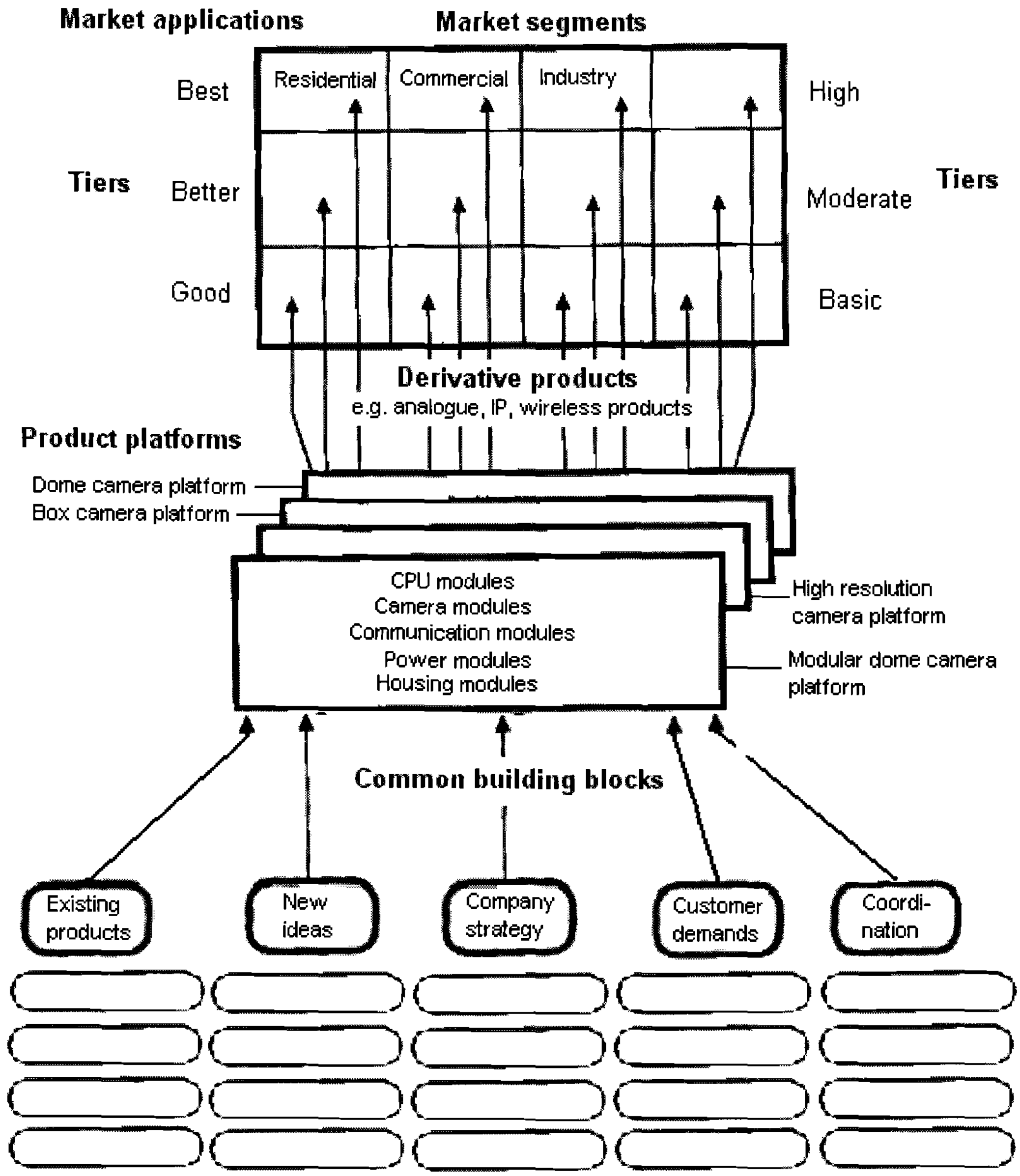
Commercial / market issues

- The first risk is that the developing and creation of a Reference Architecture, platforms, and SDs involves high costs up-front. Initially it also is time consuming because a larger common base should be developed. Of course, when interfaces must be universal this requires higher investments.
- The second risk is that there is a high uncertainty about the outcome. The question is whether / when you break-even? This is highly dependent on the market success, which is difficult to predict. Company A is not able to calculate the exact platform performance yet. For indicators like platform efficiency, effectiveness, competitive responsiveness, and profit potential the right data and definitions are necessary. These concepts are not practically defined and the information about products is not available yet. Another challenge is to calculate the integral costs of diversity. This means having an understanding of the relations of what changes / variations result in what cost differences
- From a marketing perspective is an obstacle that the company is more technology-driven instead of market-driven. Often there are technology innovations instead of market innovations. It is difficult for Company A to translate customer requirements into functional blocks. However, these customer insights are indispensable for being successful.
- On the one hand there is not enough diversity and on the other hand there are not enough economies of scale due to the relatively moderate product volumes. Also outsourcing of parts is difficult because of the embedded knowledge and nature of the camera.

Organizational / management issues

- The first issue is that for the architectures of the products, different abstraction levels are required. The inter-dependencies between these levels are not always there: a 'helicopter view' is missing.
- The resource availability is an issue especially for Project Management. There are multiple projects, which are worked on in parallel. In the case of resource distribution over sites and working with SDs, these issues only become more challenging. The Critical Chain Project Management (CCPM) method was implemented to keep the resource issues under control.
- A third organizational issue is the complex coordination within and especially over project. The network and leadership skills of a Program Manager Officer (PMO) are important for this issue. The coordination is also more challenging because a multi-product focus instead of a single-product focus should be adopted.
- A fourth obstacle is the quality of communication which can be improved. The people of Company A have often a very technical-specialistic background, so interaction and communication issues are likely to occur. Further, the company environment has some creativity- and innovation-constraining rules that hamper a real open environment.
- For the modular approach a long term commitment and support (discipline) is required. It is important for the management and for the whole organization to not act opportunistically but more strategically.
- There is a culture which can be described as 'not-invented-here' and 'doing it yourself' in certain areas. The 'not-invented-here' implicates this means the people are 'proud' on their way-of-working and do not consider other companies' ways-of-working enough.
- Another issue that can be improved is in the area of Knowledge Management. Learning and evaluation processes can contribute to the better securing and re-using of knowledge.
- The role of ICT is often under discussion because it is not really the facilitator it should be. To increase the performance there can be thought of improvements in infrastructure, transparency of the inter- / intranet, and better integration of systems.
- Company A is acquiring companies continuously. The success of an acquisition is dependent on the level of integration on the technical, commercial, and organizational area. Not only should the new products be added to the corporate products catalogue also the 'mind-set' of the acquired company should be mutually fitted.
- Furthermore, Company A does not utilize its innovation capacity enough. With the modular approach more capacity should be freed for innovation. Also most innovations of Company A are incremental rather than radical.
- Finally, there are also differences in release points between planning and execution. The requirements are needed beforehand but these are difficult to predict.

Appendix 12 The Power Tower of Company A



Appendix 13 The SD scope definition checklist

☐ SD project name:
....

Development area:
☐ Electric
☐ Lay-out
☐ PCB
☐ Mechanical
☐ Software
☐ Other:
....

☐ SD scope:
....
....

☐ Business scope:
....
....

☐ Technology scope:
....
....

☐ SD target:
....
....

☐ SD sub targets:
- ....
- ....
- ....

☐ Specification in SD scope:
1. ....
2. ....
3. ....
4. ....
5. ....
6. ....

☐ Owner of specification (resource allocation):
1. ....
2. ....
3. ....
4. ....
5. ....
6. ....

☐ Out-of-scope (optional):
1. ....
2. ....
3. ....

☐ Owner of optional specification:
1. ....
2. ....
3. ....

Estimated SD development time:
☐ < one month
☐ < two months
☐ < three months
☐ < four months
☐ < five months
☐ < six months
☐ > six months

Time constraints:
☐ Dependency constrains
....
....
☐ Resource constrains
....
....

Estimated SD budget:
☐ < € 50,000
☐ < € 100,000
☐ < € 250,000
☐ < € 500,000
☐ < € 750,000
☐ < € 1,000,000
☐ > € 1,000,000

Tools to be used:
☐ Work Breakdown Structure (WBS)
☐ User stories, feature lists and feature cards (deliverables)

☐ Deliverables (output criteria):
1. ....
2. ....
3. ....

☐ Way-of-working:
....
....

☐ Process deliverables:
....
....

SD success factors:

- Roadmap process:

☐ PLA roadmap
☐ Risk management: change control (the procedures to ensure that changes are introduced in a controlled and coordinated manner)
☐ Resource planning
☐ Stakeholder commitment & ownership

- SD project execution:

☐ Start & exit criteria
☐ Schedule & risk management (technical risk mitigation up-front)
☐ Make choices, take decisions, validate, improve, and do not keep all options open

- Requirements management:

☐ Relations & versions
☐ Inheritance & database

Check on other factors:

☐ Emphasis on well-defined requirements / motivation
☐ Initial identification with SD objectives but with advancing insights
☐ Separation SD development and product development
☐ Role of Project Manager
☐ Executive sponsorship: promote (re-)use of (existing) SDs
☐ Requirements in database for re-use
☐ Quality of communication / quality of information
☐ Prepare the right testing environment