



inventi

Early Involvement in Product Development

How to involve Inventi early in new product development processes of its customers

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Early Involvement in Product Development

*How to involve Inventi early in the new product
development processes of its customers*

Master Thesis

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Preface

With this master thesis I accomplish my study Business Administration. In January of 2009 I got in touch with Nedap and especially the innovative character of Nedap attracted me. I decided to apply for a master assignment at Nedap. The market group Retail Support formulated an interesting assignment and I started. After a few months, due to an internal reorganization, the assignment was not longer relevant. Fortunately, after a search within Nedap, I came into contact with Ton Scharenborg. Together we formulated a new assignment. In this case, Inventi, a subsidiary of Nedap, provided the assignment. I am grateful to Inventi and especially Ton Scharenborg for providing this assignment.

Although the new assignment was totally different, it was certainly not less interesting. Good ideas are needed for innovation. However, the transformation from an idea to a product, which can be produced in high volumes, is also essential. Without a good production process successful introduction of innovation is impossible. The research I conducted can contribute to the success of Nedap's future products. The practical character of the research attracted me and I hope Inventi will benefit from the results from now on.

It took me several years to complete my study at the University of Twente. Ten years ago I finished the 'MAVO' secondary school. Afterwards, I passed the 'HAVO', 'HBO' and finally the university. It was difficult to cope with the foreign languages, especially English. Never before I experienced the language difficulties so strong as during this final master thesis. Therefore, I am extra proud of the achieved result, in English. However this result was not possible without the support of Onno van der Kroft. I am thankful for all his comments on my English writing and his additional support as well.

I am very glad to have accomplished this thesis. In this period of my life I learnt to explore new areas and topics, which will be useful for my further career. My curiousness will always drive me to explore new areas and topics.

The research period was a very informative and enjoyable experience. Looking back I can say that the Inventi team consists of very dedicated and professional people. I would like to thank all employees of Inventi for their openness and patience. I especially appreciate their interest and cooperation in the interviews. I am grateful to Herbert, Johan and Miranda for being a sparring partner and the daily talks.

Furthermore, I would like to thank all interviewees of Nedap for the investment of their valuable time and energy. It was a unique experience to get a closer look in this innovative company. If I will have some troubles coping with a bureaucratic maze of procedures later on in my carrier, I will definitively think back to the period I spent at Nedap and its informal organizational structure.

During my graduation process, professional support was crucial. I am grateful to Ton Scharenborg, Waling Bandsma, Holger Schiele and Rick Middel for their valuable feedback and support during my master assignment. This thesis could not be accomplished without their advices. I wish Ton Scharenborg and Inventi all the best for the realization of the intended early involvement.

At last, but certainly not least, I am very grateful to Ilse and my family. They supported me in every possible way during my college years.

Management summary

The company Inventi is in charge of all kind of production orders for Nedap market groups. Inventi is responsible for its own performance. However, it has limited influence on its production process design and the selected components in the product designs. To get more influence on the product and production process designs, Inventi wishes to get earlier involved in the new product development processes of Nedap market groups. The involvement has to result in an increase of the product manufacturability, improvement of the production's quality performance and advantages of using preferred components.

A qualitative research has been executed in order to give an advice.

In the first place, literature has been explored to get a better understanding of the concepts of 'new product development' and 'early supplier involvement'. These insights have been used to investigate the possible involvement of Inventi in the product development projects of market groups. The new product development process has been divided into five steps: functional specifications, basic design, detailed engineering, production process design and start of production/ramp-up. During these development steps, Inventi can perform tasks. Furthermore, Inventi can provide resources, which are needed in development tasks. Moreover, the responsibilities of the development project can be distributed. The three dimensions of early supplier involvement are tasks, resources and responsibilities.

In the second place, the market groups' preferences have been collected. In order to investigate the wished involvement of Inventi among the market groups, three market groups have been selected. Agri, Energy Systems and Retail Support are good representatives of all market groups. These have been selected based on kind of products, organization of the market group and the current relationship with Inventi. Employees related to purchasing, engineering and market group management have been interviewed within each market group. A total number of eleven interviews have been conducted.

In the third place, Inventi's expectations regarding its involvement have been researched. Four employees of different functions have been interviewed. The three dimensions of supplier involvement took up the central position in the interviews.

The market groups' demand for Inventi's contributions is mainly related to component selection, design for manufacturability and test development. Inventi has to consult market groups in their development projects and has to provide its preferences.

Inventi's wished integration in the market groups' project teams will not be supported by the market groups. However, several instruments will be available for Inventi to get the intended influence in product design and component selection. Inventi will be involved on market groups demand. This results in a more informal way of cooperation, which is called the direct ad hoc contact approach.

Inventi has to perform the following tasks: (1) developing print layouts, (2) making prototypes and providing related feedback, (3) being involved in or performing test equipment development, (4) developing the (PCB) production process design and (5) performing a check before the start of production to control the results of previous NPD steps.

Moreover, Inventi has to allocate the following resources: (1) a preferred component manufacturer and distributor list, (2) a guideline with Inventi's design preferences with regard to the manufacturability of the products and (3) tools for test strategy determination.

In the last place, Inventi can form a technology-expert-team. It has to organize seminars or meetings to communicate technology, design for manufacturability and testing related knowledge. This knowledge can be transferred in between product development projects. The knowledge can be used in the early stages of product development processes. Furthermore, this two-way communication will support Inventi in developing its future strategy.

The responsibilities of the new product development processes have to be distributed. In general, the market groups will maintain their responsibilities for the product design. This includes the functional specification, the basic design and the detailed engineering steps. Inventi will be responsible for the production process. This consists of the elaboration of the production process design and the start of production/ramp-up step.

To a great extent, the realization of the above mentioned aspects will result in Inventi's wished influence in the market groups product development processes. In the future, more involvement might be possible. Good performance of Inventi will increase market groups' confidence in Inventi's capabilities. More confidence in Inventi's can convince market groups to involve Inventi for other development tasks, design for manufacturing analyses in the early stages of new product development.

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1 Inventi's organisation and activities

Inventi is a manufacturer of printed circuit boards and performs additional assembly tasks as well. Early involvement in product development processes of its customers is important to Inventi. Inventi expects significant cost reductions and quality improvements when product designs will be adjusted to its preferences. The adjustments entail both selection of components in product designs and adjustments of product design. These adjustments can be realized through involvement in the product development processes of Inventi's customers. However, Inventi does not know which involvement is possible, which involvement the customers prefer and how these involvement should be coordinated. The problem definition and research approach will be presented in chapter 2.

This chapter will give an introduction to Inventi, the company's strategy, the human resource policy and the organization characteristics will be presented. In the last paragraph, the specific relationship between Inventi and its customers will be discussed.

1.1 Introduction to Inventi

Inventi is a manufacturer located in Neede, The Netherlands. The production company was founded in 2007 by Nedap N.V. (Hereafter Nedap N.V. is denoted as "Nedap". See for more information Textbox 1). As a subsidiary, Inventi is charged with the production of several related products. Inventi is operating independently, which allows Inventi to produce both for Nedap and other companies. Currently Inventi is only producing for Nedap. Although Nedap is a single company, it can be subdivided by Inventi into several customers, based on the Nedap market groups (see appendix I). Inventi does not have an own product development team; it is producing on customers demand. Inventi produces a wide range of products, which varies from cow belts for activity measurement and identification for farmers to Electronic Control Units for convertible tops of cars (see for a quick view of the products; Figure 1). Although the purposes of the products are very divers, they have some characteristics in common. All products consist of one or more printed circuit boards on which electric components are attached. These printed circuit boards are assembled in some kind of casing and finally packed in boxes. The production series are medium sized ($\approx 100-5000$), but relatively constant.

Nedap N.V.

NV Nederlandsche Apparatenfabriek 'Nedap' is an internationally operating company with more than 600 employees and has its head quarters in Groenlo, the Netherlands. Nedap focuses on developing and supplying innovative and sustainable solutions in the fields of security and electronic control units as well as automation, management and information for organizations.

See for more information about Nedap N.V. and the founding of Inventi appendix I.

Textbox 1: Nedap N.V.



Impression of Inventi's order portfolio and the products purposes: Power supplies for printers and medical devices, battery chargers, electrical control units for convertible tops, and light controls for e.g. greenhouses or UV disinfection.

Figure 1: Produced products and its utilizations

1.2 Strategy of Inventi

The general aim of Inventi is: “ensuring that customers would like to outsource their production to Inventi” (Inventi, 2007). The strategy to achieve this is to “encourage employees to initiate bright ideas in order to maintain long-term relations with the customers.” Employees take up a central position in the strategy, because they should maintain the relationships and initiate ideas. More information about the employees will be provided in the next paragraph, 1.3. Important pillars of Inventi's market approach are price, good quality and delivery reliability. These criteria are order qualifiers, which are minimum screening criteria that allow a firm's products or services to be considered. The management emphasizes that Inventi needs to guarantee competitive prices, good quality and a high level delivery reliability, which is primordial for competing with the cheapest producers. The executives are aware that this is not realizable through simply hard working (if the wages in Romania are ten times lower, you cannot work ten times faster). Inventi can accomplish this, as the company's name suggests, in an *inventive* way through automation, tools and encouragement of employees.

Inventi's order winners, criteria that differentiate the products or services of one firm from another, are related to flexibility and maintaining close relationships with customers. These order winners represent Inventi's strategy to keep long-term relationships with the customers. Inventi wishes to be a partner, who is easily accessible to Nedap market groups and Inventi does not want to maintain a very formal supplier-buyer relationship. The specific relationship between Inventi and Nedap will be discussed in paragraph 1.5.

Hameland

Hameland is an organization engaged in sheltered work. The organization is responsible for carrying out the law “Wet Sociale Werkvoorzieningen” in the region Winterswijk, Aalten, Oost Gelre, Berkelland and Haaksbergen. Hameland employs about 2000 people. Hamelanders assemble and produce products in their own sheltered workshop, but sometimes they work at the customers' location, which also applies to Inventi. Hameland is the formal employer of the Hamelanders, but they act as real Inventi employees.

1.3 Inventi's human resources

Approximately fifty people are at work for Inventi, however none of them is formally working for Inventi. Inventi hires all the human resources it needs. Generally there are three different sources of employees, all for specific tasks. The first source is Nedap. Nedap is permanently seconding employees to Inventi. They manage the daily operations and determine tactical and strategic policy. The second

Textbox 2: Hameland

source is ‘Hamelanders’. This term refers to people, working for Hameland who need additional care in their work situation (see Textbox 2). The Hamelanders perform production tasks with a repetitive character. Temporary workers are the last source of labour. They are young people who had all kind of problems in education and other areas and form a flexible workforce to adjust to changes in production volumes. They are also charged with the more complex production tasks and some of them can even instruct Hamelanders. Although this group consists of temporary workers, many of them have worked for years at Inventi/Nedap. See below (Figure 2) for an overview of the employee groups.

The strategy focuses on maintaining long-term relationships with customers and low cost producing. This causes a dilemma for the employees. On the one hand they should maintain close contact with the customers and initiate bright ideas. On the other hand they should concentrate on producing cost efficiently.

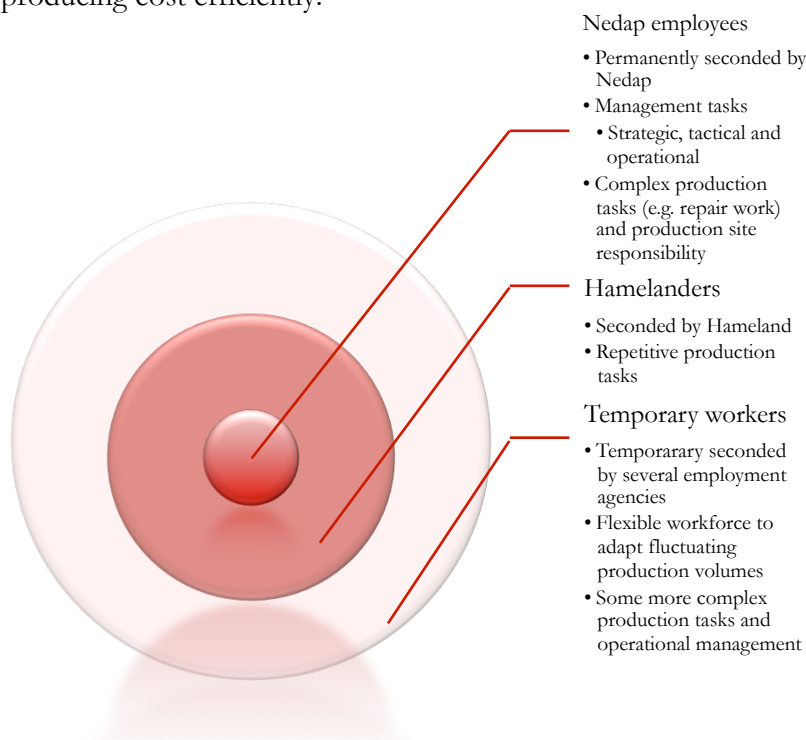


Figure 2: Three employee sources with corresponding tasks

The founders of Inventi chose an innovative approach by employing minimum wage earners, namely Hamelanders and temporary workers. Furthermore, Inventi encourages its employees to initiate bright and stimulating ideas to improve the product quality and the production process. This requires close contact with the customers and motivated employees. In the philosophy of Inventi, employees have to be stimulated to use their potential, which should not be underestimated. The motto is: “*challenges enrich life*”. Nedap employees may be expected to take more initiatives than Hamelanders or temporary workers. Nevertheless, these groups are also encouraged to initiate ideas. Finally this should result in a flexible production site, which produces quality products for reasonable prices.

1.4 Operations of Inventi

Currently, the production can be divided into several production methods. There are facilities for automatic and manual production. Because of the repetitive character of the manual tasks,

this work is suitable for Hamelanders. Instructions for all specific production processes are available to the Hamelanders. These instructions visualize for instance the exact position of components on the printed boards. The limited capabilities of the low wage workforces generally result in some extra guidelines to production processes. Therefore, organizing the production into small steps is necessary to ensure the required product quality. Furthermore, Inventi stresses the importance of automation. Customers are encouraged to take as much as possible advantage of the automated production facilities of Inventi.

The Inventi management had established some guidelines with regard to production orders. In the first place, a minimum production level of a product has to be realized ($\approx 1,000 - 100,000$ per year). In the second place, the manufacturing process should allow production in small, repetitive steps in order to facilitate production by Inventi's workforce. In the third place, Inventi aims to be entirely or partly involved in the selection of components. The customer's designers should be encouraged to select standard or familiar components in their design. This will result in a lower cost price. Inventi emphasizes that this is crucial to ensure its competitive market position.

1.5 Relationship between Inventi and Nedap

Although Inventi may operate as an independent company, the specific relationship with Nedap cannot be ignored. In the first place, the Nedap market groups and Inventi are both part of the Nedap corporation. This implies a common goal. All parties should aim at contributing in their own way to the corporate success. Therefore, there are less differences of interest as between two commercially independent companies. In the second place, the majority of employees with leading responsibilities have a history with Nedap. Before being employed at Inventi, they worked for a market group of Nedap. The results in a high level of familiarity among the employees of Nedap market groups and Inventi. In the third place, Inventi produces products for market groups, which were previously produced by the market groups itself. The employees of the market groups could feel this as a threat to their work. In the fourth place, Inventi is relatively closely located to the Nedap market groups, approximately 15km. This makes it easy to visit each other on location, but an unforeseen small talk at the coffee corner in the same building is not possible. Finally, the Nedap corporation has a vision towards the employees which results in high level of individual responsibility. An entrepreneurial attitude and an informal way of cooperation are encouraged. This open, innovative and creative culture is widely spread in both Inventi and the market groups.

2 The research and methodology

In this chapter Inventi’s current position as well as the problems it is facing will be discussed. After specifying the problem, the research questions and the research model will be presented.

2.1 Inventi’s situation

Inventi is producing all kind of production orders for Nedap market groups. As already mentioned in the previous chapter, Inventi management established requirements with regard to these new production orders. Production volumes, the kind of production processes and the selection of components should be taken into account.

Currently, new production orders do not meet all of these requirements. At the moment, Inventi is taking over production processes, which are already operational at Nedap. The production processes are simply transferred or copied from Nedap to Inventi, which impedes Inventi to transform the production processes completely. However, in the near future Inventi expect to start production of new products¹ as well. In order to make use of the specific production site efficiently, Inventi stresses the importance of taking the manufacturability into account during the development stage of the product. Furthermore Inventi has no equal say in the selection of components in the development stage of the products of its customers. The selection of components especially refers to electronic components. The core of the problem Inventi has been facing can be stated as follows:

Although Inventi is responsible for its own performance, it has limited influence on its production process design and the selected components in the product design.

In order to get more influence on its own performance, Inventi wishes to get more involved in the product development process of its customers. The intended involvement in this process can lead to more influence on production process design (e.g. making the production process suitable for Hamelanders) and on the component selection (standardized components). As a result the management expect more control over Inventi’s performance and a higher willingness of the customers to outsource production to Inventi, which is the general aim of Inventi. The

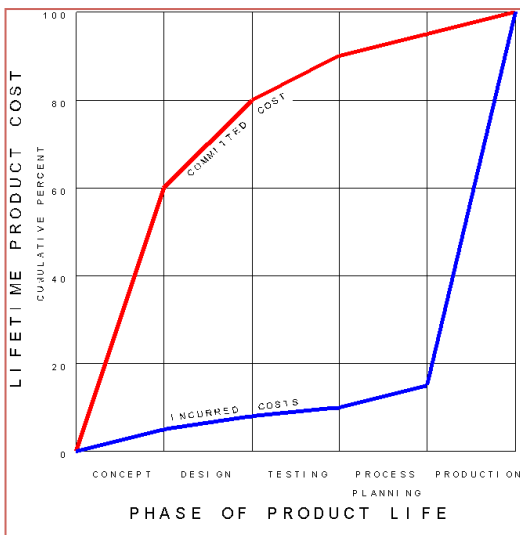


Figure 3: Incurred cost vs Committed cost (Anderson, 2004)

cost price of Inventi’s products and Inventi’s current influence on the cost price are discussed below.

The cost price of the product is almost completely determined in the product development process of Inventi’s customers. According to Anderson (2004), by the time a product has been designed, only 8% of the total product budget has been spent. By that time, the designer has determined 80% of the cost price of the product (see Figure 3). Inventi cannot influence this percentage, however it could contribute to the determination of the product’s cost in the development stage of the product. During the set up of production, Inventi spend a major part of the product’s budget. Specific tools (carriers) have to be made, the production site has to be adjusted for the production process and instructions have to be written. Furthermore, the chosen components in the development stage of the products

¹ The production of new products means that a specific product, developed by a Nedap market group, will be produced by Inventi. Between the development and production stage at Inventi, this product will not be produced somewhere else.

account for the main part of the cost price, approximately 70%. Most components can be substituted, which could have some advantages for Inventi. Inventi expect advantages like reducing purchasing costs and realizing a stronger bargain position, if the company manages to reduce the number of unique components in the product designs. Using familiar components² will result in higher purchasing volumes and will finally result in more purchasing power. However a developer should take these substitutes into account during the development process. When the design is finished a component cannot simply be replaced by a substitute of another brand.

As a result of these two points, Inventi can only influence the total cost price marginally. Nevertheless Nedap requires Inventi to minimize this cost price.

Inventi’s expected benefits of the early involvement are summarized in the following points:

- Increasing the manufacturability of the products.
- Improving the production’s quality performance.
- Benefiting from the use of familiar components.

The intended involvement and expected benefits only refers to cooperation with Nedap market groups. Inventi made a strategic choice to produce only for Nedap in the near future and is not willing to adjust its organization to the expectations of any other potential customer.

2.2 Research focus

Inventi considers realization of this early involvement as a challenge. Inventi should convince the customers of the benefits of the mentioned early involvement. Early involvement is primordial for enabling full control of production and purchasing processes and improving these processes and consequently its financial results. Early involvement can be realized through many ways, but which aspects are important for Inventi? What role can Inventi have in the product development processes? How could early involvement help to meet the expectations of both the customers and Inventi’s management and what are the preconditions?

The central question can be deduced from the above-mentioned situation.

What should Inventi do to be involved in early product development phases of its customers?

The core elements of the central research question are defined below.

Table 1: Definitions of core elements of the central question

Core element	Definition
Early involvement	Supplier involvement in new product development. The ability to influence the product design and production process design during the product development process.
Product development process	Process of improving existing products or developing new kinds of products.
Inventi’s customers	Nedap market groups

² Familiar components are components that are already used at the production site of Inventi. If a developer selects a familiar component, this component will be used in at least two products (one existing product and the new product).

2.3 Research questions

This research aims at answering the central question. To provide an answer, it has to be divided into sub-questions. In the first place, the concepts of ‘early supplier involvement’ and ‘new product development processes’ have to be explored. Literature will provide a framework to explore the expectations of both companies. Understanding of the important dimensions of successful involvement will lead to a comprehensive view of the situation, which will help to fulfil Inventi’s needs. Therefore it is needed to determine the important dimensions by exploring literature. This results in the first research question.

1. *How can suppliers contribute to new product development in general and how can the involvement be coordinated?*

In the second place, the possibilities of Inventi to participate in NPD processes of its customers, needs to be examined. Furthermore, the level of efforts Inventi is prepared to invest in early involvement needs to be determined. Also the prospected kind of support Inventi expects to deliver into the development processes of its customers has to be inventoried. This results in the second research question:

2. *Which aspects of early involvement in product development are important from Inventi’s perspective and how does Inventi wish to realize this involvement?*

In the third place, the characteristics and the expectations of Inventi’s customers have to be specified. To what extent will they accept Inventi to be involved in their NPD processes and which resources are they willing to share? Maybe, it is equally important to point out which elements are not suitable for collaboration and which conditions are required. This results in the third research question:

3. *Which aspects of early involvement in product development are important for Inventi’s customers and what are the preconditions for early involvement in their NPD processes?*

In this research only Nedap market groups will be taken into account as customers, because Inventi expects to produce in the near future only for Nedap and is not willing to adjust its organization to the expectations of any other potential customer. This decision will be further discussed in paragraph 2.5.

After the exploration of possibilities, impossibilities, intentions and preconditions of involving Inventi in product development of both Inventi and its customers, the results need to be compared. Causes of the differences should be discussed and the aspects where the companies’ intentions meet each other, need to be mentioned. This results in the fourth research question:

4. *What are the differences and similarities between Inventi and its customers regarding early involvement?*

An approach to implement the intended involvement can be formed when both perspectives are pointed out clearly and the differences and similarities are identified. The approach will support Inventi to get involved in its customers’ product development processes. This results in the fifth and last research question:

5. *How can the gaps between Inventi’s and the customers’ expectations be bridged in order to provide a satisfactory solution?*

These research questions are used to answer the central research question: *What should Inventi do to be involved in early product development phases of its customers?* The answer to the questions will lead to recommendations for Inventi to get successfully involved in the product development processes of its customers in the future.

In the next paragraph the approach to answer these questions will be presented.

2.4 Research approach

During the research the following approach will be used to answer the central question (see Figure 4).

This research consists of several steps. First, the problem and its settings will be defined as well as the methodology for the research. The second step comprises the development of a theoretical framework on supplier involvement in product development. This framework will form the basis for the following steps.

The situation will be explored by using the theoretical framework. It will be executed at Inventi and Nedap. The following step is analysing the differences between Inventi and Nedap and relating this to the theoretical framework. Eventually these steps will lead to recommendations, which will provide an answer to the central research question.

In order to give a professional and well-balanced advice, the first design ideas can be proposed to the customers and Inventi before realisation of the final advice.

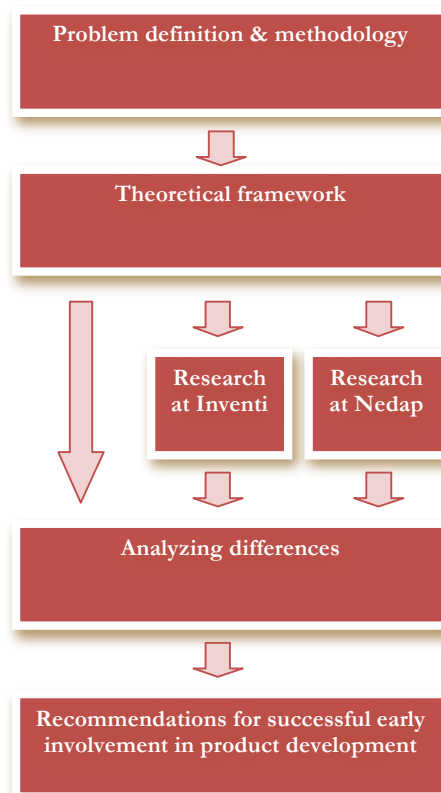


Figure 4: Research Approach

2.5 Research methodology

In the following paragraphs the used methodology of the research will be discussed. First, the reasons for a qualitative research are mentioned. Then, the units of analysis will be presented. The selection of the market groups will be motivated and a short introduction of these groups will be given. Furthermore, the selected employees of Inventi will be mentioned. Finally the methods of interviewing and data analyses are described.

2.5.1 Exploring literature

The research has a deductive character. This implies the use of a general theory, which can be applied to a more specific situation (Babbie, 2007). In this case, the specific situation will be the cooperation between Inventi and the Nedap Market groups. To use general theories, these have to be explored first. The theoretical research aims at answering the first research question:

How can suppliers contribute to new product development in general and how can the involvement be coordinated?

Theories are needed to explore Inventi's possibilities and impossibilities of involvement in product development. To find relevant theories the following key words or phrases are mainly used:

- Early Supplier Involvement
- Coordination of supplier involvement
- Success factors of ESI
- New product development
- Collaboration in product development
- Design for manufacturability

The collected literature is selected on relevance and appropriateness for Inventi's situation. The relevant theory will be provided in chapter 3.

Theories, which discuss supplier involvement from the supplier's perspective, are rare. Most literature is written from the buyer perspective. Therefore, the used literature will be selected and transformed to meet the supplier's needs and expectations.

2.5.2 Qualitative research

In order to explore the expectations of both Inventi and its customers, a qualitatively oriented research will be used to conduct the research. In this study the different customers should be explored. The research should result in a better insight in the customers' processes, expectations and Inventi's capabilities. Therefore the research has a descriptive character. Furthermore, the research will be prescriptive in the form of recommendations. The general aim of the research is advising the management of Inventi and providing a document to support Inventi's management in the communication of their vision on early involvement. Compared to a survey or an experiment, qualitative research has some advantages (Babbie, 2007). In the first place, a qualitative approach can be used for exploring social processes, like NPD processes. In the second place, the research is flexible. The research can be adjusted to a specific situation or new insights. In the third place, conducting a qualitative research is relatively cheap.

Conducting a qualitative field research generally results in a high internal validity, but the external validity is in general lower. The internal validity is more relevant for this research. Generalizing to other settings is not the central purpose of the research. Inventi aims to get more involved in the NPD processes of its current customers and is primarily not interested in willingness of companies in general to involve suppliers.

According to Yin (2003) there are six sources of evidence in case studies. These sources are: documentation, archival records, interviews, direct observations, participant observation and physical artefacts. Interviews will be the main source of input in this research, but it can be supported by documentation, for instance a formalized NPD process. The interviewees as well as the supporting documents are indicated in Table 2. The other sources of evidence are less applicable in this research and therefore not used. There is not any archival material available about previous projects, simply because of a lack of previous projects. Moreover, observations are not applicable because information is needed about expectations for the future. The selected sources will provide the information needed in this research.

Several functions within the market groups are related to supplier involvement. For example, purchasers, developers and group managers are involved in the cooperation. The different staff members may have different views on the cooperation. Interviewing one employee of a market group can easily result in a biased picture of the expectations of the market group. Using interviews as well as using formalized documents is a form of triangulation of data. Triangulation is defined as an observation from at least two different points. Data triangulation is collecting data from different sources, at different times, in different places or from different

people (Flick, 2004). The main purpose of triangulation in this research will be the enhancement of validation of data, which are obtained during the research of market groups and Inventi. Triangulation is used through interviewing different employees (collecting data from different people) and analysing the supporting documents (collecting data from different sources).

2.5.3 Selection of units

The second and third research question will be answered by analysing Inventi and its customers based on the insights from literature. However, first the cases for research should be selected properly to ensure the validity and reliability of the research. As already mentioned in this chapter, this study will consider the Nedap market groups as Inventi's customers. Although Inventi has the freedom to attract customers outside Nedap, in the near future it will only concentrate on Nedap market groups. Inventi is prepared to adjust its processes to the needs of Nedap market groups. However, for other possible customers the process will not be adjusted. Presently, Nedap divides its activities into over ten market groups. Inventi is not producing for all these market groups, but in principle Inventi can perform production tasks for all market groups. Although the market groups operate in completely different markets, they all need more or less, the kind of production facilities Inventi offers.

Considering the cases for analysis, it is relevant to explore both current customers and the market groups who outsource their production elsewhere. It is possible that the reasons to outsource elsewhere are related to the topic of this research; supplier involvement in NPD processes.

Preliminary Research

In order to determine the number of market groups to involve in this research and the related functions a preliminary research was needed. Three people were interviewed to get more insights in Inventi and the Nedap market groups. The interviews were semi-structured. Questions vary from what they expect from supplier involvement to how product development processes are currently managed. Afterwards all cases of analyses were determined. The respondents of this preliminary research were selected to get a broad view of the cooperation between Inventi and the market groups. The first case was Inventi. An employee responsible of one of Inventi's production sites was interviewed. The involved production site is the site where components are manually attached. The second case was the market group Retail Support. Recently Inventi has started to produce for Retail Support. The employee of Retail Support, who is charge of production, has been interviewed. The last case was the market group Energy Systems. Inventi maintains a long-term relationship with Energy Systems. A hardware engineer of Energy Systems was interviewed.

The results of these interviews are insights in the extent of differences between market groups and functions. Based on this information, the selection of units for interviewing with regard to Inventi and its customers will be discussed in the following two paragraphs.

Nedap market groups

After the first interviews it became clear that these market groups are operating in totally different markets and have a different NPD approach. However, the expectations about Inventi's input in their product development processes are comparable. This is the reason to limit the number of market groups to analyze. It is expected that analyzing more than three market groups will not lead to more useful information. The selected market groups will reflect all market groups. However, it is important to ensure that the selected market groups represent the whole spectrum of market groups. Aspects in the selection are:

- The kind of products or markets. Different kind of products may require different extents of involvement. Some products might need more complex production technologies and intensive cooperation than other products.

- The market group’s organization. Inventi’s involvement has to fit the market groups’ organizations. Each market group may have another way of organizing and structuring product development.
- The current relation with Inventi. Current customers of Inventi are familiar with Inventi’s capabilities. New customers might have other expectations of a supplier than the current customers.

The selected market groups for investigation and their basic characteristics are summarized in the following table:

Table 2: Selected market groups with characteristics

	Energy Systems	Retail Support	Agri
Market	Renewable energy and stand-alone energy islands	All kind of retail organizations	Farmers
Relationship with Inventi	Long-term relationship. Started in the early days of Inventi.	New relationship. Approximately a few months.	Inventi is production only a few products of Agri.
NPD organization	Formalized	Not formalized	Formalized
Interviewees	<ul style="list-style-type: none"> - Hardware Engineer - Business Controller - Market group Manager - Salesman 	<ul style="list-style-type: none"> - Manager Manufacturing - Hardware engineer - Engineer/ coordinator 	<ul style="list-style-type: none"> - Market group manager - Manager manufacturing - Manufacturing Contact person - R&D Coordinator
Supporting documents	NPD procedure	-	Project evaluation documents

Table 2 also provides the selected employees. These employees will be interviewed. The employees are selected because they are in charge of the market groups’ product development processes or they will be involved in the cooperation. Therefore, both strategic and operational cooperation aspects will be integrated in the research.

An overview of the interviewees and introductions to the selected market groups will be provided in appendix II.

Inventi

The methods for analyzing Inventi are comparable with the methods used for analyzing the three selected market groups. Interviews will be held with Inventi employees who are responsible for the cooperation with customers. The selected employees are:

Function	Selection reason
Overall manager Inventi	To establish Inventi’s vision on its involvement in NPD processes.
Manager production site (Protec)	To determine Inventi’s possibilities with regard to prototyping and production process development.
Manager production site I	To get insights in the communication possibilities and preferences of manufacturability aspects in product designs.
Purchaser Inventi	To get insights in the communication possibilities and preferences about purchase parts.

The interviews can be supported by documents, for example agreements between Inventi and market groups.

2.5.4 Interviewing employees of Inventi and market groups

The goal of the interviews is to get more insight in the preferences of the customers and the used processes. The interviews were semi-structured in order to answer some specific questions deducted from the theoretical framework (the theoretical framework will be provided in chapter 3. In order to obtain as much information as possible a semi-structured method is chosen. During the interviews the researcher does not only focus on the interview questions. In order to obtain as much relevant and useful information as possible, also additional information will be included. Moreover, the sequence of questions could be changed depending on the development of the interview.

In order to prepare the interviews, guidelines provided by Meulenberg (1990) are used. The questions are carefully selected and special attention is given to the aspect listening.

The interviews are used to answer the second and third research question:

Which aspects of early involvement in product development are important from Inventi's perspective and how does Inventi wish to realize this involvement?

Which aspects of early involvement in product development are important for Inventi's customers and what are the preconditions for early involvement in their NPD processes?

The order of answering the first two research questions is not critical. However, answering one question will influence the process of answering the second question. Important factors for Inventi can be integrated in the way of answering the second question. Answering the first two questions the other way around, will have comparable effects. In practice the research will be executed similarly. New knowledge or insights can directly be applied in answering the questions.

The interviews were held in a face-to-face setting in the natural environment of the interviewee. It is important to use a quiet location, which is not accessible to other employees. This resulted in a setting where the interviewee can speak freely. Before the interview, the protocol as well as the purpose of the interview was explained. As far as possible the confidentiality is guaranteed. However, the employees of Nedap and Inventi are familiar with each other. Names are not mentioned in the reports, but function names are unavoidable. Furthermore the interviewees were asked to agree with recording the interview. Two interviewees refused, but notes of important aspect were made.

The interview protocol can be found in appendix III. In total a number of fifteen interviews have been executed in which the length varied between forty minutes and hundred and twenty minutes. In each market group and in Inventi three or more interviews have been held.

The outcomes of these interviews are primordial in this research, thus analyzing the interviews in a uniform manner is needed. In order to analyze the interviews recordings were made as well as notes. The recordings made it possible to replay the interview afterwards, to achieve an even better view on the core of the conversation (Meulenberg, 1990). Furthermore, the recordings made it possible for the interviewer to focus on the conversation itself instead of writing down everything.

After the interviews, interviews reports are written. The structure of the report and methods of reporting are adopted from Meulenberg (1990). The following table present the structure of the interview reports (Table 3).

Table 3: Structure of interview reports (Meulenberg, 1990)

Part	Functions
Introduction	<ul style="list-style-type: none"> -Topic -Name interviewee -Function of interviewee -Date -Duration -Place
Core	<ul style="list-style-type: none"> -The conversation is written in the third person singular form. -Citations are only be made if relevant.
End	<ul style="list-style-type: none"> -The conversations have been characterized -Remarks are made -Possible further appointments

The reporting method of Meulenberg (1990) provides some advantages over writing the conversation literally. First of all, the method is quicker, and secondly, it leaves room for notes about atmosphere and non-verbal conversation.

2.5.5 Data analysis

An answer to the fourth research question can be given by comparing the results of the market groups and Inventi. After writing the interview reports, relevant phrases will be selected. For all three market groups and Inventi, these phrases are categorised into themes. For example, all phrases about the selection of unique components in the interviews with Agri employees were bundled into the theme ‘strategic components’. Analysis of these bundled phrases, resulted in the market groups’ and Inventi’s perspectives on the different aspects. The results of the interviews and analysis of supporting documents will be presented in the chapters 4,5 and 6.

The fourth research question is: *What are the differences and similarities between Inventi and its customers regarding early involvement?* This will also be discussed in chapters 4, 5 and 6. The bottlenecks for early involvement of Inventi will be reflected during this analysis.

Subsequently, an answer can be provided to the fifth and last research question. The last research question is: *How can the gaps between Inventi’s and the customers’ expectations be bridged in order to provide a satisfactory solution?*

Based on the analysis and theoretical aspects, advice will be given to the management of Inventi. This advice will provide Inventi information about the necessary actions to take. Furthermore, the central question will be answered. The central question is: *What should Inventi do to be involved in early product development phases of its customers?*

2.6 Conclusion and structure of report

Inventi wishes to get earlier involved in the product development processes of the Nedap market groups. The early involvement makes cost reduction and a higher manufacturability of the products possible.

In order to determine the ways of stimulation in early involvement in new product development processes, a research is required. In the first place, a theoretical framework is needed to conduct the research. The theoretical framework will be presented chapter 3. In the second place, the expectations of the market groups and Inventi regarding Inventi's early involvement have to be investigated. A qualitative oriented research will be performed. The main source of information will be interviews with several employees of market groups and Inventi. The results will be presented in chapters 4,5 and 6.

Based on the found similarities and differences between Inventi's and the market groups' expectations, an approach can be formulated to bridge the gaps. This approach will be presented in chapter 7.

Subsequently, the answer the central question as well as the recommendations can be given in chapter 8.

3 Theoretical framework

The theoretical framework aims at answering the first research question. This chapter is the result of a systematic and extensive exploration of existing theories, which are related to the research topic. The first research question is:

Q1 How can suppliers contribute to new product development in general and how can the involvement be coordinated?

Before investigating how suppliers can contribute to new product development processes, a better understanding of the concept new product development is needed. Furthermore, the importance of involving suppliers in this development needs to be discussed.

This theoretical framework will provide a foundation on which the research is based and the advice will be built. The framework consists of three parts. In the first place a general introduction on new product development will be presented. In the second place, supplier involvement in new product development processes will be broadly discussed. The concept of early supplier involvement will be introduced and the benefits will be discussed. Furthermore, three dimensions of supplier involvement will be introduced and cooperation approaches will be presented. By introducing the new product development process, the possible involvement per development stage will be discussed. Finally, three preconditions for successful involvement will be mentioned and an overview of all discussed aspects will be provided.

3.1 New product development

The economic success of a manufacturing company depends on its ability to translate market needs quickly into products that meet these needs. This is not only marketing related, not only design related or only manufacturing related. It is a common product development problem related to all these functions (Ulrich & Eppinger, 2000). Successful new product development can be seen as: *'the result of (a) careful planning of a superior product for an attractive market and (b) the execution of that plan by a competent and well-coordinated cross-functional team that operates with (c) the blessings of senior management'* (Brown & Eisenhardt, 1995).

The focus in this research will be on the execution of the physical development of the product, which is mentioned as *'b'* in the above citation.

The ultimate goal of new product development (NPD) in a for-profit organization is to develop commercially successful products. However, to make this more specific Ulrich & Eppinger (2000) argue for five commonly used dimensions to assess the performance of a product development effort:

- Product quality
- Product cost
- Development time
- Development cost
- Development capability

Developing a new product requires efforts of almost all functions within a company, however three functions are central in this process (Ulrich & Eppinger, 2000). The marketing function should identify the needs of a firm's customers and is responsible for launch of new products. The designers manage the transformation from the customers needs into a physical product. This process contains the engineering design (mechanical, electrical and software design) as well as the industrial design (aesthetics, ergonomics, user interfaces). The last key function is manufacturing. Manufacturing is responsible for the production system design. Purchasing and distribution are also related to the manufacturing.

In NPD projects often interdisciplinary project teams are formed. Figure 5 visualizes a typical product development team for an electromechanical product of modest complexity (Ulrich & Eppinger, 2000). Communication among project team members as well as communication with outsiders stimulates the performance of development teams. Thus, “the better members are connected with each other and with key outsiders, the more successful the development process will be” (Brown & Eisenhardt, 1995).

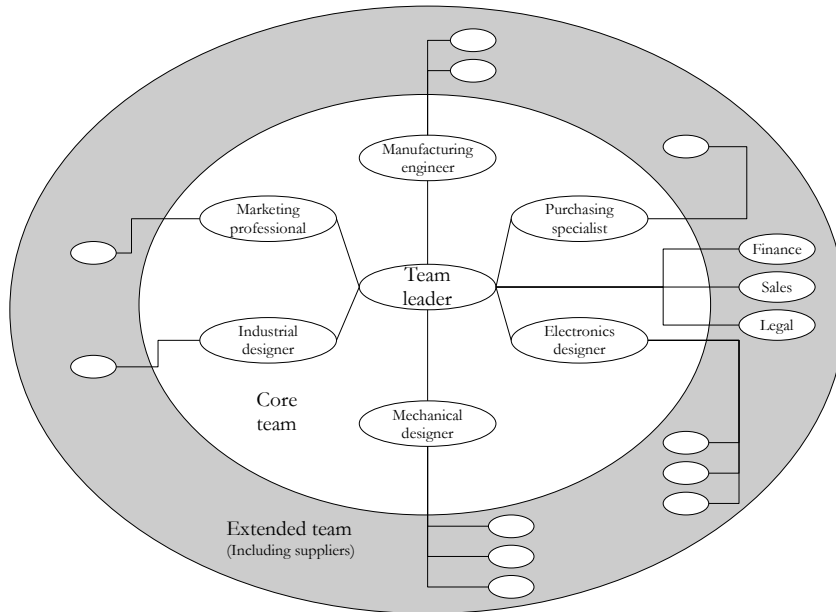


Figure 5: Example of composition of a product development team for an electromechanical product of modest complexity (adopted from Ulrich & Eppinger, 2000)

The core team members are representatives from the marketing function, the design function and the manufacturing function within a company. However, a company can decide to outsource its production tasks. This development automatically implies losing vital production knowledge from the development team. An underestimation of manufacturing aspects in the product design can result in a higher cost price or an insufficient product quality. The selected supplier can introduce knowledge of production processes in the project team to ensure the manufacturability of the product.

It is an old paradigm that companies must generate their own ideas and then develop, build, market, distribute, service, finance, and support them on their own (Chesbrough, 2004). The new *open innovation* paradigm assumes that firms can and should use external as well as internal ideas, as they wish to advance their technology (Chesbrough, 2004). According to this new paradigm, suppliers can be involved in the NPD processes of its customers.

The concepts of this involvement will be broadly discussed in the following paragraphs.

3.2 Supplier involvement in product development processes

Suppliers can participate in product development processes of its customers. The involvement can range from small design suggestions related to components selection or production methods to taking over the complete responsibility of the development of (a part of) a product. The involvement of suppliers in product development is defined by several authors as “Early Supplier Involvement”. Echtelt, Wynstra, van Weele, & Duysters, (2006) define Supplier Involvement as follows: “*Supplier involvement refers to the resources (capabilities, investments, information, knowledge, ideas) that suppliers provide, the tasks they carry out and the responsibilities they assume regarding the development of a part, process or service for the benefit of a buyer’s current and/or future product development projects.*” The term suppliers refer at suppliers outside the business unit who are involved in the

business or its technical processes. This participation or involvement may occur at any point in the new product development model (Handfield, Ragatz, Petersen, & Monczka, 1999). Early Supplier Involvement (ESI) refers to supplier involvement, which starts in the early stages of new product development.

Early supplier involvement enables the supplier to be involved in the product development process of its customers. This allows the supplier to inform the designers about specific production processes, which may result in significant cost reduction, simplified designs, reduction of duration of the design process and product improvement.

Benefits of early supplier involvement in new product development can be divided into short-term and long-term benefits.

Short-term benefits are realized within one new product development project, for instance better product designs and decreased material costs. These examples are related to an increased output of the cooperation, however a decrease of input is also beneficial (Wynstra, van Weelde, & Weggemann, 2001). For instance the total development costs of a product can be decreased. Realizing a decrease of input or an increase of output is beneficial for both companies. Cost reduction will lead to higher margins on sales and an increased output will lead to a better market position, which will result in higher sales figures for both companies.

Long-term benefits are more related to the whole supplier-buyer relationship, which result from common development projects. For example, this enables the supplier to plan its production facility investments, based on future demands. Key benefits are summarized in the table below.

In table 4, benefits of ESI are related to the commonly used NPD performance dimensions. Together, the ESI benefits have a positive impact on all the mentioned performance dimensions of Ulrich & Eppinger (2000), which justifies the popularity of ESI. The related NPD performance dimensions are mentioned in the third column of Table 4.

Table 4: Long-term and short-term benefits of supplier involvement

	Benefit	Related NPD performance indicator (Ulrich et al, 2000)	Author e.g.
Long-term	Possibility for supplier to plan		Ragatz et al. (1997), Handfield et al. (1999)
	Creation of time to develop the needed capabilities	Development capability	Ragatz et al. (1997)
	Access to technological knowledge	Development capability	Wynstra et al. (2001), Sobrero & Roberts (2002)
Short-term	Decrease of product cost	Product cost	(Ragatz et al. (1997), Clark (1989), Peterson et al. (2005)
	Decrease of development cost	Development cost	(Ragatz et al. (1997), Clark (1989), Peterson et al. (2005)
	Increase of product quality	Product quality	Peterson et al. (2005), Ragatz et al. (1997), Clark (1989)
	Reduction of development cycle time	Development time	Wynstra et al. (2001), Ragatz et al. (1997), Clark (1989)
	Increase of sales and profitability		Peterson et al. (2005)
	Standardization	Development cost / product costs	Wynstra et al. (2001)

3.3 Problems of supplier involvement in product development

The benefits of early involvement are widely acknowledged, but down sides should not be underestimated. Implementing early supplier involvement implies several aspects and challenges. Although supplier and buyer can benefit from ESI, some developers experience discomfort when external suppliers are included in the development team and sensitive information is discussed (Petersen, Handfield, & Ragatz, 2005).

Wynstra et al (2001) distinguished three types of problems in supplier involvement in new product development.

The first problem comprises relationship aspects. This problem can be caused by for example a lack of communication, a lack of trust or diverging expectation. The second problem of supplier involvement concerns the supplier, who can be incapable of cooperation. The third source of problems is related to the buying company. The buying company can have an unclear NPD process/strategy or its employees can impede successful involvement. Developers can experience the cooperation as a threat to their jobs and can initiate all kind of tricks to turn the cooperation into a failure.

3.4 Implementation of supplier involvement

The advantages of supplier involvement are made clear as well as the related problems. It is also necessary to explore the way of involving a supplier and making use of its know-how.

The involvement of a supplier in product development processes can be characterized by several dimensions. Supplier involvement is in literature viewed as '*the assets the supplier allocates*' (Ragatz, Handfield, & Scannell, 1997) or as '*the contributions suppliers provide*' (Lakemond, 2001) or as '*the information suppliers provide and their participation in decision making*' (Handfield, Ragatz, Petersen, & Monczka, 1999).

In the before mentioned definition of early supplier involvement Echtelt et al. (2006) made a distinction between the supplier's *provided resources, tasks* and *responsibilities*. These dimensions cover the views mentioned in this paragraph and indicate accurately the different aspects of supplier involvement. From both, supplier's and buyer-company's perspective, these dimensions are relevant. It excludes for example the selection of suppliers to involve, which is only relevant for the buying company (Wynstra, van Weelde, & Weggemann, 2001). The three dimensions and the reasons to choose them will be presented in paragraph 3.5.

The three dimensions show how a supplier can participate in a new product development project. However, what is the best way to coordinate the supplier's provided resources and the distribution of tasks? Lakemond, Berggren, & van Weele (2006) distinguish three coordination approaches, ranging from an integrated project team to a disconnected approach. Each coordination approach is suitable for specific situations. The allocation of resources, tasks and responsibilities can entail different situations. The three approaches will be presented in paragraph 3.6.

NPD projects are processes of several steps. The involvement of a supplier can differ during these steps. To explore at which stage involvement could be realized, the NPD process is divided into five steps. Important aspects related to the dimensions of involvement are discussed per product development step. This elaborated NPD process will be presented in paragraph 3.7.

3.5 Three dimensions of supplier involvement

The following three dimensions will be used to investigate the possible degree of involvement in each development stage:

- **NPD tasks** carried out by the supplier
- **Resources** allocated by the supplier to NPD projects
- **Responsibilities** of the supplier in the NPD process

After a short introduction of the three dimensions, the dimensions will be discussed in paragraph 3.5.1, 3.5.2 and 3.5.3.

The dimensions cover the extent of the possible involvement of the supplier. The transformation from a superior product idea into a product, which suits a high volume production process, consists of many tasks. In the first place, a supplier can perform a selection of these tasks. The allocation of tasks to a supplier can, for instance, contribute to the manufacturability of the product or ensure the procurement of selected components. The first dimension tasks is used to describe the tasks carried out by the supplier in the development process.

In the second place, some resources are needed in performing NPD tasks. Both capital and knowledge resources are essential. A supplier can provide some of these resources, which can be referred to as the second dimension resource allocation.

In the third place, if a supplier performs development tasks, the responsibilities of the supplier have to be specified, which is reflected in the third dimension responsibilities. The three dimensions used in this research are defined below.

3.5.1 Tasks in product development

The dimension tasks refers to the allocation of tasks to both supplier and buyer. A supplier can perform a selection of the total number of activities, which are needed in a product development process. Specific tasks are related to each step in the development process. In this study, only tasks, which can be performed by the supplier, will be taken into account. Specific tasks, which both companies assume to be performed by the buying company, will not be mentioned in the results.

The distribution of these tasks should be identified per NPD step. For example, a buyer can develop the basic design and perform the detailed engineering while the supplier carries out the subsequent tasks of designing the production process and production ramp-up. The supplier can also perform only specific tasks, like prototyping.

3.5.2 Resource allocation

The tasks mentioned in the previous paragraph can be linked to the variety of resources, which a supplier can allocate during product development. This is reflected in the second dimension of supplier involvement. A supplier can allocate several resources to NPD projects. These resources can be related to financial, knowledge, human or capital sources. The allocation of resources can be a critical condition for a successful involvement. The supplier can use its resources to support the NPD processes of its customers. For example, the supplier's prototyping capability, which the customer may not have, can be critical in achieving short test cycles and can therefore speed up the overall project cycle time (Echtelt, Wynstra, van Weele, & Duysters, 2006). Furthermore, a supplier can provide specific information, ideas and knowledge in order to align the functional performance of a product with its manufacturability

This research focuses on the knowledge and capital resources of the supplier. The special relationship between the companies, as presented in paragraph 1.5, results in less attention for other kinds of resources.

3.5.3 Responsibility distribution

The last dimension of supplier involvement is the distribution of responsibilities between buyer and supplier. The distribution of responsibilities can vary during the sequence of development steps. For instance, the buyer can be totally responsible for the basic design while the supplier can be responsible for specific test equipment related to the production process design step. Furthermore, the responsibilities can be distributed for a part of a product. For example, a buyer develops a camera while the supplier develops a specific lens for that camera. In this case, the supplier can have the full responsibility of the lens, without having any influence on the development of other parts.

The distribution of tasks and related responsibilities implies a varying degree of participation in the decision-making process. The supplier's responsibilities are related to the tasks and deliverables it has to account for.

3.6 New product development project coordination

In order to coordinate the cooperation during a project Lakemond, Berggren, & van Weele (2006) distinguish three coordination approaches. The cooperation can act like an *integrated project approach*, a more *ad hoc contact approach* or the supplier can execute a *disconnected sub project*.

The different approaches fulfil different coordination needs. They are suitable under different conditions and imply different levels of coordination costs. A driver of differentiated coordination approaches is the degree of task dependence. The dependence is usually higher when the allocated tasks to the supplier are more complex. The technological novelty also increases the dependence of the companies e.g. if the expected contributions of a supplier are related to knowledge about complex technologies. A high level of dependence requires a higher degree of inter-organizational coordination.

A higher degree of diverging expectations and long-term collaboration objectives are drivers for a more integrated coordination approach. The use of a more integrated coordination approach results in a solution for the relationship problem, diverging expectations in supplier involvement projects (Wynstra, van Weelde, & Weggemann, 2001).

The three approaches will be presented in the following sub-paragraphs. Moreover, the three approaches are visualized in Figure 6.

3.6.1 Project integration coordination

In the first place, the cooperating companies can form a joint product development team. Employees with different disciplines of both companies take position in the team. The product will be developed jointly. Development teams can be co-located, which facilitates activities with a strong need for knowledge-oriented exchange by ease of face-to-face communication. However, co-location is not a necessity, project integration can also be established by use of modern communication techniques.

A *project integration coordination* approach creates a basis for easily sharing resources. Tasks can be performed jointly and responsibilities can be shared.

3.6.2 Disconnected sub project coordination

In the second place, the companies can decide to disconnect parts of the project and to keep the developers apart. Each sub project team takes account for its own part of the development tasks. This is for example possible at a modular product design³, which results in a low level of architectural interfaces. The relatively little dependence between the task of the supplier and the

³ Modular design is an approach that subdivides a system into smaller parts (modules) that can be independently developed.

task of the developing company reduces the need for coordination during the project. Ideally, communication is only needed at the beginning and at the end of the supplier's task. The supplier performs its development efforts within the own company.

By using a *disconnected sub project coordination* approach, the resources of the supplier will only be available for the supplier's development part. The tasks as well as the responsibilities are strictly separated. The disconnected sub project coordination approach is only useful if the supplier tasks can be performed independently, like in a modular design.

3.6.3 Direct ad hoc coordination

Finally, the coordination can be facilitated by a direct ad hoc contact approach. Direct ad hoc contact mainly occurs on an incidental basis and can be initiated by certain questions that arise in the project. Communication only occurs when an employee of one of the cooperating companies directly contacts his or her counterpart of the other company. In contrast to this incidental way of communication, project integration coordination approach facilitates a more or less continuous interaction between buyer company and supplier.

The direct at hoc coordination approach can be related to the three dimensions of supplier involvement. Resources are primarily available within the own company. Buyer and supplier depend on each other for the availability of the other's resources. Tasks are allocated to the supplier or the buying company.

Direct ad hoc coordination must be seen as an informal solution to supplier involvement. Successful direct ad hoc coordination should be based on an on-going and well-established relationship between the cooperating companies.

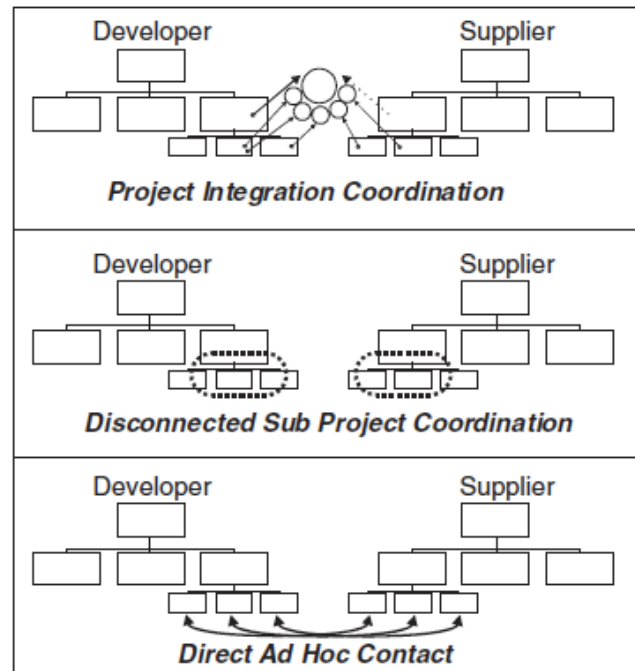


Figure 6: Coordination approaches for involvement in product development projects (Lakemond, Berggren, & van Weele, 2006)

3.7 New product development steps

Product development usually consists of the following four or five stages: Concept development → Basic design → Detailed engineering → Production/ramp-up. In this research, a NPD model is used, which is divided into five successive steps (based on Clark and Fujimoto (1991)). The role of the supplier can differ in all these steps.



Figure 7: NPD steps based on Clark and Fujimoto (1991), with added "process design"

In Figure 7, a generalized NPD procedure is presented. The presented process is slightly different from the product development stages of Clark and Fujimoto (1991). The production process design step is added in this process. This process will better reflect the processes of the researched company. For a production capacity supplier, the production process design is an important development step to be subject of cooperation. Therefore, the production process

development is separated and added as the fourth step in the NPD process. Other authors, like Griffin (1997), see process design as an additional development step as well.

This NPD process aims at developing a physical product. The “fuzzy front end” of product development is not part of the presented model. The “fuzzy front end” refers to the idea generation and contains activities like exploring market trends (Reid & de Brentani, 2004). The involved supplier in this research is a capacity supplier, which implies that it is delivering man-hours, logistic services and production capacity. The supplier is not involved in exploring the markets and business development. That is why the issue of the “fuzzy front end” is not included in this research.

The related supplier is also not concerned with commercialization of the product. Carrying out the marketing activities of the products is exclusively related to the buying company. Therefore, the commercialization is not included in this research as well.

During NPD steps a supplier can perform several tasks. It also allocates resources and has responsibilities. These aspects will be described per NPD step. Before describing the tasks and needed resources more precisely, the distribution of responsibilities will be discussed.

The responsibility of a supplier can be determined for a complete development project of a product. However, the distribution of responsibilities can also change during the different development steps. In case of a part supplier, the buying company can decide to give the supplier the full responsibility of the detailed engineering and the production process development steps. This is especially suitable for use of a modular design approach. In case of a production capacity supplier, it is likely that the buying company is responsible for the basic and detailed engineering steps. The supplier can be fully responsible for the production process design step. Two different responsibility distributions in a capacity supplier setting are visualized in Figure 8.

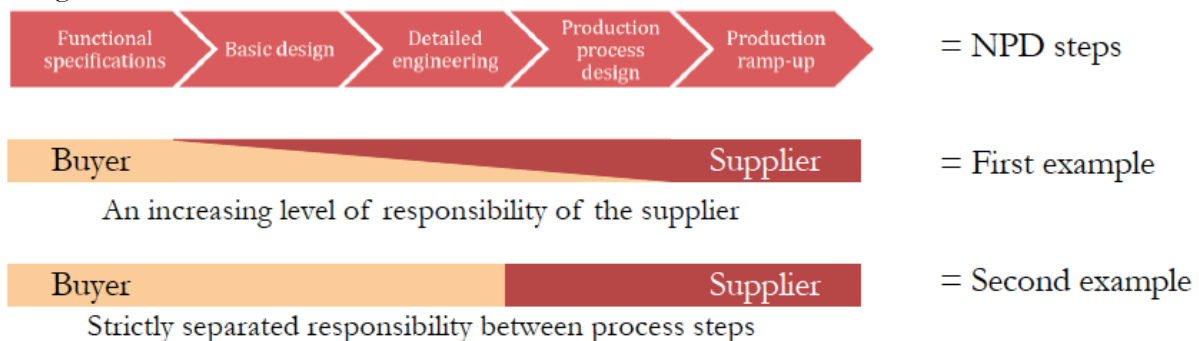


Figure 8: Possible distribution of responsibilities during NPD steps in a capacity supplier setting

In the first example, the supplier’s level of responsibility increases during the project. Ultimately, the supplier is fully responsible for the production process. Such a distribution is possible for use of a “project integration coordination” or “direct ad hoc contact” approach. In the second example, the buying company is fully responsible for the detailed engineering step and gives the responsibility to the supplier to design the production process. This is useful in a form of “disconnected sub project coordination” approach. The “disconnected sub project coordination” approach is often used in a modular product setting. However in this case, the supplier does not have the full responsibility of a part of a product, but the supplier has the full responsibility of a part of the development process of one product, namely the production process design step.

In the following paragraphs, each NPD step will be described. Furthermore, the possible involvement of suppliers will be discussed. Important aspects of the involvement of a capacity

supplier are related to component selection, design for manufacturability and the testability of the products. These aspects will be integrated in the following paragraphs as well.

3.7.1 Functional specifications

The first NPD step is the functional specifications step. The functional specification step entails the transformation of customer needs and innovative ideas into a number of functional specifications. The new product has to meet these functional specifications.

The functional specifications can be a result of two different paths. In the first place, internal idea generation and idea screening processes of the developing company can lead to a product idea. In the second place, the developing company can get a request to develop a product for a customer, which fulfils the prescribed customer’s functional specifications.

The contribution of the supplier is not substantial in the functional specifications step. The buying company has a vision with regard to the new product. It has to translate this vision into functional specifications to develop the product. The supplier’s contribution is limited to providing guidelines, which are needed to specify the intended function of a product. If a buying company asks a supplier to develop (a part of) a product, the supplier must fully understand the intended functions of a new product and other requirements related to the development of the product.

3.7.2 Basic design

The second step is a determination of technologies, which should fulfil the functional specifications of the product. Choices have to be made between for example electrical, mechanical and software solutions to solve design problems. Afterwards the cost price can be estimated.

A supplier can e.g. contribute to this step by identifying the most up-to-date technologies to be incorporated into a new product (Huang & Mak, 2000). Moreover, for a supplier of production capacity, it is very important that the developed products are easy to produce. Therefore, the concept of *design for manufacturability* will be introduced in the following section.

Design for Manufacturability

“Design for manufacturability (DFM) is the process of proactively designing products to: (a) optimize all the manufacturing functions: fabrication, assembly, test, procurement, shipping, delivery, service, and repair, and (b) assure the best cost, quality, reliability, regulatory compliance, safety, time-to-market, and customer satisfaction” (Anderson, 2004). DFM should be performed throughout the development process of a product (Anderson, 2004; Ulrich & Eppinger, 2000). This implies application of DFM in every step, but the concept of DFM will be discussed in this paragraph, basic design. The slogan in textbox 3 illustrates the importance of DFM.

*Functionality gets us into the game;
Quality and reliability keeps us in the game;
Manufacturability determines the profit.*

Textbox 3: Importance of DFM (Anderson, 2004)

DFM requires a cross-functional team, because it is one of the most integrative practices of product development (Ulrich & Eppinger, 2000). DFM involves information like (a) drawings and product specifications (b) understanding production and assembly processes, and (c) estimates of manufacturing costs, volumes and ramp-up times. This requires contributions of most members of a development team. When a supplier performs the production or assembly of (a part of) the product, it should contribute to ensure successful DFM. Throughout the NPD process a supplier can carry out DFM analysis as a kind of tasks (Huang & Mak, 2000). Related (supplier’s) employees should be early involved and be active within the project (Ulrich &

Eppinger, 2000). Supplier's resources are desired during these steps to estimate the different costs and to bring up suggestions for cost reductions. Anderson (2004) agrees to formulate a manufacturing strategy during the basic design step. A manufacturing strategy includes process selection, test strategy, and quality strategy.

3.7.3 Detailed engineering

Based on the basic design the product will be developed in detail. All development specialists will account for their own part of engineering. Related functions are mechanics, electricians and software engineers. Furthermore, purchasers, manufacturing specialists and industrial designers can be involved in the process. After finishing the detailed engineering, the final product will be available as prototype. However, more than one detailed engineering cycle may be required. After the first cycle the prototype will be examined. This examination is needed to check the functional specifications. If the design does not fit the specifications properly, another development cycle is needed until the specifications are met.

Important aspects of the detailed engineering step are component selection, DFM, and testability. These aspects will be described in the following three sub-paragraphs.

Component selection

The product developers select all kind of components to build the product. For example the components can be electronic components, connectors, wires, metal parts or plastic housings. The manufacturer, who assembles all these components, has to purchase these components when the product is in production. These purchase parts can be divided into four groups based on the profit impact and the supply risk (Kraljic, 1983).

- Leverage Items. Products that represent a high percentage of the profit of the buyer. There are many suppliers available.
- Strategic Items. Products that are crucial for the product of the buyer. They are characterized by a high supply risk caused by scarcity or difficult delivery.
- Non-critical Items. Products that are easy to buy and also have a relatively low impact on the financial results.
- Bottleneck Items. Products that can only be acquired from one supplier or their delivery are otherwise unreliable. The products have a relatively low impact on the product's cost price.

For each group a company might have different purchasing strategies. Eventually, the manufacturer has to cooperate with the component suppliers. Moreover, a supplier can support designers with the selection of most suitable materials and catalogue components (Huang & Mak, 2000).

Design for Manufacturability in detailed engineering

As already introduced in the paragraph "basic design" the detailed engineering step has a significant impact on the manufacturability of a product. A supplier can assist in or perform component selection tasks (see previous paragraph, "component selection") Furthermore the supplier can provide solutions to component and part designs (Huang & Mak, 2000). Moreover, a supplier can provide manufacturing and testing knowledge resources. In the last place, a capacity supplier can support the developers by, for example, controlling the output documents on ambiguousness.

Test development

To ensure a high quality, a test plan is needed. Theoretically, products need not be tested if all processes are 100% in control. However, few companies are so confident in their processes. At least many companies conduct a functional test at the end of the production process. Products

with an expected high first pass accept rate could avoid diagnostic test development and the expensive in-circuit “bed-of-nails” testers (Anderson, 2004). Production capacity suppliers need to contribute in the test selection process.

3.7.4 Production process design

During the production process design all production processes will be developed. This comprises the detailed process development. Choices for the main production methods have already been made in the previous steps. In this step programs for production machines as well as instructions for employees will be written. Furthermore a configuration to control the process should be developed. In this step the first products will be produced in order to verify the production process design. Like the previous step, this process may require more than one development cycle to develop the definitive design.

The production process design step is also related to some DFM tasks (Anderson, 2004). However, Anderson (2004) argues to perform these tasks concurrent with the previous step, detailed engineering. Examples of DFM tasks in the production process design are: designing versatile fixtures and designing special tooling. Moreover, a supplier can contribute in several ways, like assisting in make or buy decisions or providing the most capable tooling, fixturing and equipment (Huang & Mak, 2000).

3.7.5 Start of production and ramp-up

The last step is the start of production. The production employees take over the product plan from the development team and start the production. The production process will be improved while the production is operative. This fine-tuning results in a better-controlled process.

During the launch and ramp-up, the development team should stay involved. The team should help to launch the product and write all change orders until the production has stabilized (Anderson, 2004). The production is stabilized when all predetermined goals are reached. The goals can be production volumes, quality goals (measured by yield, defects per million or complaints) and productivity.

3.8 Preconditions for successful supplier involvement

In literature preconditions for successful supplier involvement are mentioned. For this research a selection has been made. The selected preconditions are applicable in the cooperation between the researched companies. Successful involvement will be impossible, if these conditions will not be met. After exploring the literature the following requirements are distinguished:

3.8.1 Information flow

Achieving successful supplier involvement depends on several factors, but the purpose is to exchange significant information. A good flow of information is primordial for successful supplier involvement. Important aspects of the information flow are for instance: content of information, moment of exchange, speed of response and the used medium.

Petersen, Handfield and Ragatz (2003) propose the following two critical points for successful supplier integration related to the information flow. The first point is ensuring that technology and cost information transfer between the design team and the supplier. This information flow can occur during all development steps like basic design, detailed engineering and production process design, but also in-between projects. For instance, regularly planned meetings between managers of the cooperating companies. The second point is ensuring that the supplier has an ongoing active role on the design team. The used cooperation approach influences the role of the supplier. Using a “project integration coordination” approach results more automatically in an ongoing active role of the supplier in the design team. Using a “disconnected sub project” or

“direct ad hoc contact” approach will increase the need for instruments to ensure the correct flow of information.

3.8.2 Level of trust

Relationships with a high level of trust can develop in a very satisfactory and friendly manner, and the technological success of the projects can exceed the average level of success. Relationships characterised by the absence of trust will likely break when conflicts arise (Klein Woolthuis, 1999). Inter-organizational trust is built upon trust between people working together. Past experiences and future expectations of the cooperating companies’ relationship can influence the level of trust. Three forms of trust can be distinguished: In the first place, cognitive trust, which is based on past experiences. In the second place, affective trust, which is based on personal relationships between individuals and finally, calculative trust, which is based on future perceptions or expectations (McAllister, 1995; Williamson, 1993).

With regard to early supplier involvement one important aspect of trust is the confidence of a buyer in its supplier’s capability. Understanding the focal supplier’s capabilities and design expertise is necessary for establishing successful supplier integration (Petersen, Handfield, & Ragatz, 2003).

Trust is not a static phenomenon; it develops and evolves as part of the process. Actions, events and incidents can have a positive or negative influence on the level of trust. In addition, co-located teams face fewer challenges related to the development of trust, interpersonal relationships and communication in the project team (McDonough III, Kahn, & Barczak, 2001).

3.8.3 Top management commitment

Top management commitment is necessary in order to stimulate employees to share information between the cooperating companies. Both the supplying firm’s top management and the buying firm’s top management have to be committed to supplier integration (Ragatz, Handfield, & Scannell, 1997). The buyer’s management should allow the supplier to be involved. The supplier’s management should encourage its employees to act pro-actively in the NPD processes of the customer. Top management commitment can also stimulate the willingness of NPD project members (Wynstra, van Weelde, & Weggemann, 2001). Without top management commitment, product developers may create barriers for supplier involvement when they feel their work is threatened. They may argue that the communication with suppliers adds too much complexity to their work or that the supplier is incapable. In order to make the tasks difficult for the supplier, they can provide insufficient information.

3.9 Framework from theory

This last paragraph of the theoretical chapter will summarize and combine the above-introduced theories. Furthermore it will indicate how this literature will be used in the research.

The research aims at getting Inventi earlier involved in NPD processes of its customers. The literature will be used to guide and structure the research. A distinction is made between five NPD steps:

1. Functional specification
2. Basic design
3. Detailed engineering
4. Production process development
5. Start of production and ramp-up

Each development step is related to specific subjects. The most important subjects for a production capacity supplier are related to: component selection, design for manufacturability and the testability of products

Use of the three dimensions in this research

In order to determine Inventi's contribution to the NPD process, three dimensions of early supplier involvement will be used: tasks distribution, resource allocation and responsibility distribution.

1. Within a capacity supplier setting the supplier's tasks will be related to the following NPD aspects: component selection, DFM analysis, test development, prototyping and production process development.
The intended allocation of these tasks to Inventi or the market groups needs to be investigated.
2. Regardless of the performer of NPD tasks, resources are needed. The allocation of resources depends on the customer's design demand.
It is important to determine the market groups' demand for Inventi's resources. This determination is needed for Inventi to allocate its resources to NPD processes of the market groups. Knowledge and capital resources will prevail.
3. When a supplier performs NPD tasks and allocates resources, a responsibility distribution is needed. The expectations of Inventi and the market groups need to be explored. Which responsibilities will be allocated to Inventi and how will this distribution change during the NPD project?

A note needs to be made regarding the time horizon of the allocated resources and tasks. Supplier involvement takes often place during different stages of a specific development project. However, a supplier might be contacted also in advance of, or parallel with, a development project. Exchanging technological possibilities of production processes is an example of knowledge allocation, which is possible in between projects. Therefore, supplier involvement cannot only be related to specific NPD steps. The research has to include other NPD related cooperation as well.

An investigation about the expectations of Inventi and the market groups with regard to the three ESI dimensions is needed. The expectations have to be investigated per NPD step. The results of this investigation will be presented in the following three chapters. In chapter 4 the results with regard to the distribution of tasks will be presented. Chapter 5 will provide the results regarding the allocation of resources. The expectation with regard to the distributions of responsibilities will be presented in chapter 6. Moreover, the differences between Inventi's and the market groups' expectations will be discussed in each chapter.

Based on the expectations found, approaches to bridge the gaps between the market groups' and Inventi's expectations have to be determined. These will be presented in chapter 7.

Selection of coordination approach

After the determination of the tasks, which Inventi will perform, the resources it will allocate and its responsibilities, a coordination approach that fits this involvement has to be chosen. The choice for an integrated, disconnected or ad hoc approach depends on the wished supplier-buyer cooperation. In turn, the chosen coordination approach influences the possibilities for responsibility and resource sharing. It also influences the possibilities of task distribution.

The intended coordination approaches of both the market groups and Inventi will be explored. The chosen coordination approach should fit the intended task allocation, resource sharing and the distribution of responsibilities. The consequences of a chosen approach for the three ESI dimensions are presented in Table 5. This table can be used to determine the needed coordination approach.

Table 5: Relations between the three ESI dimensions and cooperation approaches.

COORDINATION APPROACH				
ESI DIMENSION		Project integration approach	Disconnected sub project approach	Direct ad hoc contact approach
	Tasks	Tasks can be performed jointly or easily divided during the project	All NPD tasks will be allocated to the supplier or the buyer. Tasks will not be performed jointly	NPD tasks will be performed separated. On demand of one of the cooperating companies, tasks can be performed (partly) jointly
	Resources	The allocated resources of both companies are available for the whole development team	Resources are only available for the own development part	Resources are on demand available for the cooperating company
	Responsibilities	Responsibilities can be easily shared	Strictly separated. Responsibilities can be separated for a product part or between NPD steps	Possibility to separate responsibilities per NPD step or for a whole product part

Preconditions for successful involvement

The chosen coordination approach has an impact on the preconditions information flow and level of trust. A higher level of project integration will result in a higher level of information flow and trust. Moreover, a high level of trust is required to apply a disconnected sub project coordination approach. However, an extensive investigation of the preconditions is not part of this research. Nevertheless, the preconditions are important and the researcher will be aware of that during the research.

Conclusions and recommendations to Inventi’s management will be provided in chapter 8. The framework, which will be used in this research, is visualized in Figure 9:

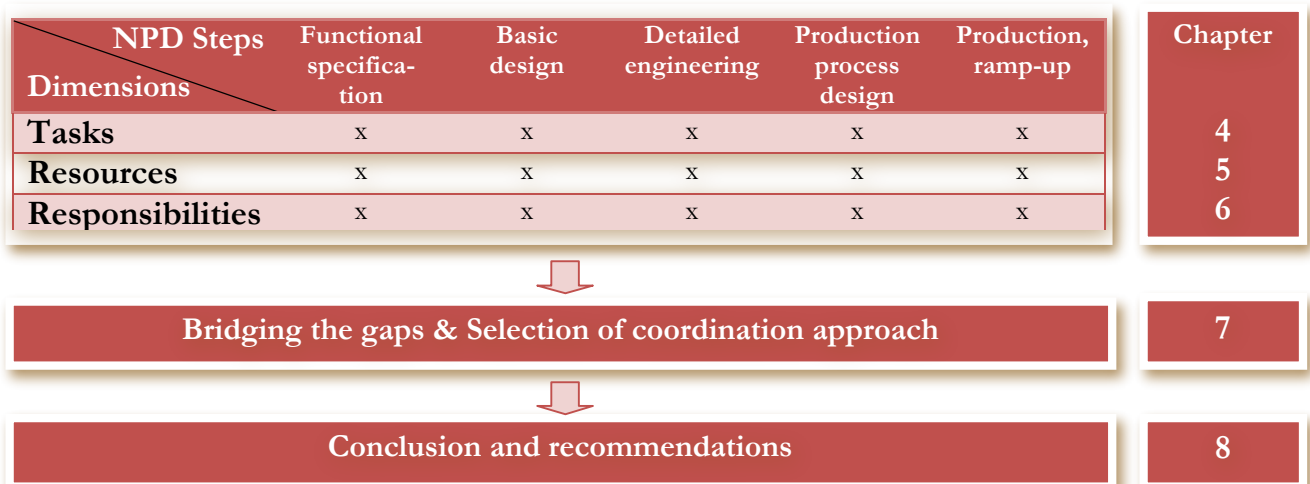


Figure 9: Framework and reading guide of this research

4 Research results of task distribution

Chapter 4, 5 and 6 will provide answers to the second, third and fourth research question. Each chapter will present the results of the three research questions with regard to one dimension of early supplier involvement. Early supplier involvement can be divided into the dimensions tasks, resources and responsibilities.

In this chapter the results of the research with regard to the ESI dimension ‘tasks’ will be presented. Both, Inventi and the market groups will be included in these results. Furthermore, the differences will be summarized per NPD step.

The research questions to be answered are:

Q2: Which aspects of early involvement in product development are important from Inventi’s perspective and how does Inventi wish to realize this involvement?

Q3: Which aspects of early involvement in product development are important for Inventi’s customers and what are the preconditions for early involvement in their NPD processes?

Q4: What are the differences and similarities between Inventi and its customers regarding early involvement?

An overview of the intended tasks distributions will be provided. Figure 11a will present the Inventi’s wished situation. Figure 11b will provide the market groups’ wished situation.

4.1 Functional specifications

Inventi

According to Inventi, involvement in this step is not necessary. Moreover, Inventi stresses the natural curiousness of the Inventi’s employees, which will ensure information sharing about new projects (IN1,4)⁴. However, influence in this step is not needed to ensure the manufacturability of the new product. This is not needed because no decisions will be made in this step with regard to component selection or production processes.

Market groups

The market groups do not expect involvement of Inventi in this step. The market groups stress that involvement of Inventi has to be related to Inventi’s core business. The market groups assume low-cost producing, high quality and flexibility as Inventi’s business focus (AG1,2,4, RS1, ES2). Therefore, involvement in functional specifications and product innovation does not correspond with Inventi’s focus on low cost producing. However, innovations in production process technologies are relevant. To benefit from these production process innovations, the market groups’ engineers have to be informed. Inventi has to inform market groups in between NPD projects about production process innovations (AG1,4, ES1). The allocation of this knowledge will be discussed in chapter 5.

Comparison

With regard to the functional specifications step, diverting expectations between Inventi and the market groups are not found. Both, the market groups and Inventi consider this step as a task for the market groups.

⁴ Abbreviations will be used to refer to a specific interview or market group. For instance ‘AG’ refers to the market group Agri. The list of abbreviations can be found in Appendix II Overview of interviews.

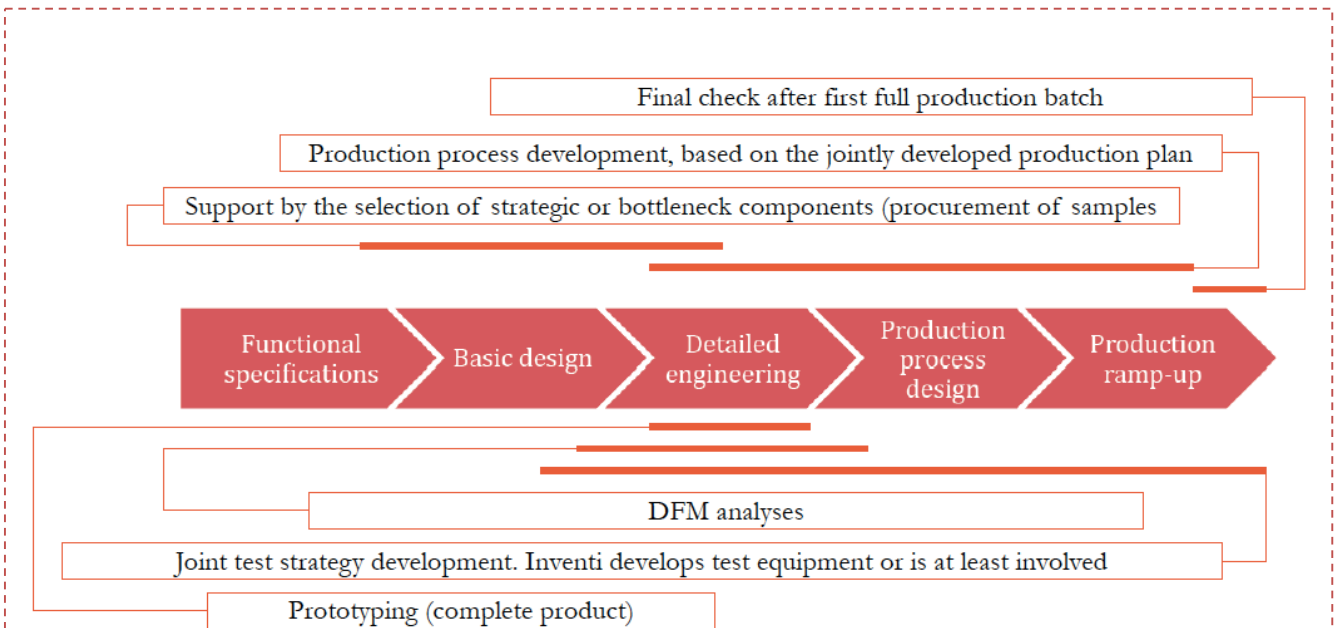
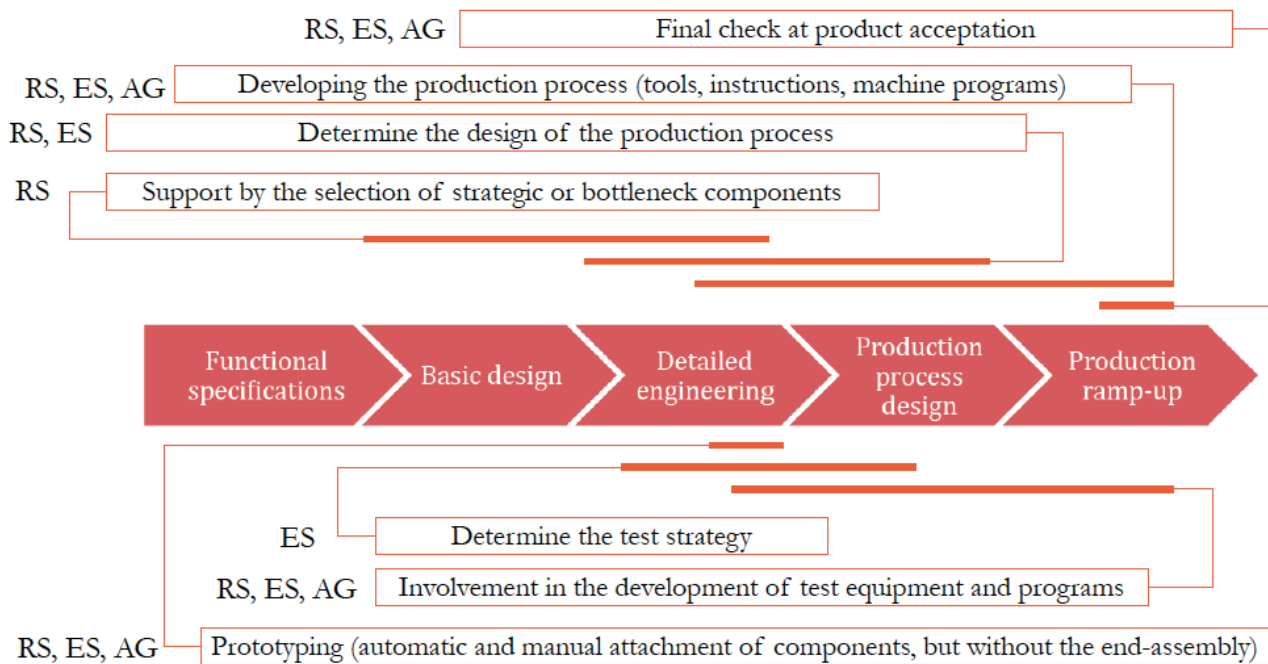


Figure 11a: Inventi's intended tasks related to NPD steps

The tasks, which Inventi wishes to execute in NPD processes, are mentioned in the textboxes. In the middle, a timeline is presented that consists of the five NPD steps. The lines parallel with the NPD steps, indicates which tasks are related to specific NPD step.



RS = Retail Support, ES = Energy Systems and AG = Agri

Figure 11b: Market groups' proposed tasks of Inventi related to NPD steps

The tasks, which are indicated by the market groups to allocate to Inventi, are mentioned in the textboxes of Figure 11b. Abbreviations are used to refer to specific market groups.

4.2 Basic design

The second step is a determination of technologies, which should fulfil the functional specifications of the product. This determination also implies choices for strategic components and production processes. During the research it turned out that several tasks could be allocated to Inventi. These tasks are related to component selection and design for manufacturing aspects. These two elements will be presented. In each section two aspects will be discussed: Inventi's intended tasks and the tasks allocated by the market groups.

4.2.1 Component selection tasks in basic design

In order to develop a new product, very specific or unique components are often needed. These components can be defined as strategic or bottleneck items (Kraljic, 1983). Because of the special function of these components, they will be selected in the basic design step.

Inventi

Inventi wishes to reduce the number of strategic and bottleneck components in product designs. However, these components cannot be totally eliminated. To select the remaining strategic and bottleneck components, Inventi has some preferences.

Inventi's purchasers would like to support market groups' engineers to find and select the strategic and bottleneck components for a new product (IN1,4). The market groups' engineers can focus on the functional and technical aspects of the component while Inventi's purchasers can focus on the price and availability of the component. To be able to support engineers, Inventi's purchaser needs to be technically skilled. The general manager acknowledges a lack of specific knowledge within Inventi. Furthermore the position of strategic purchaser is vacant.

Moreover, Inventi argues to perform the procurement of samples for new strategic or bottleneck items (IN1). This will prevent Inventi from having to deal with unknown component-suppliers and related agreements in the production stage of the new product.

For Inventi it is important to get involved early in the selection of strategic and bottleneck components. The electronic component market is to some extent protected and controlled by the component manufacturers. Component distributors will have the exclusive right to sell a component meant for a certain customer. An example will be provided in Figure 12. In this example, distributor Y suggests a component of brand A to fulfil a specific function in the product of a Nedap market group. The engineer is satisfied and decides to select that component for the product. In the production stage of the product, Inventi can only purchase that specific component from distributor Y. If Inventi asks distributor Z to supply this component, the component manufacturer will not supply this component to distributor Z. The manufacturer has registered that distributor Y recommended this component for the specific product. Manufacturers and distributors agreed in the registration of these exclusive sales rights. For this reason, purchasers of Inventi want to be involved in the selection of distributors to ensure a good price and a good relationship with a distributor.

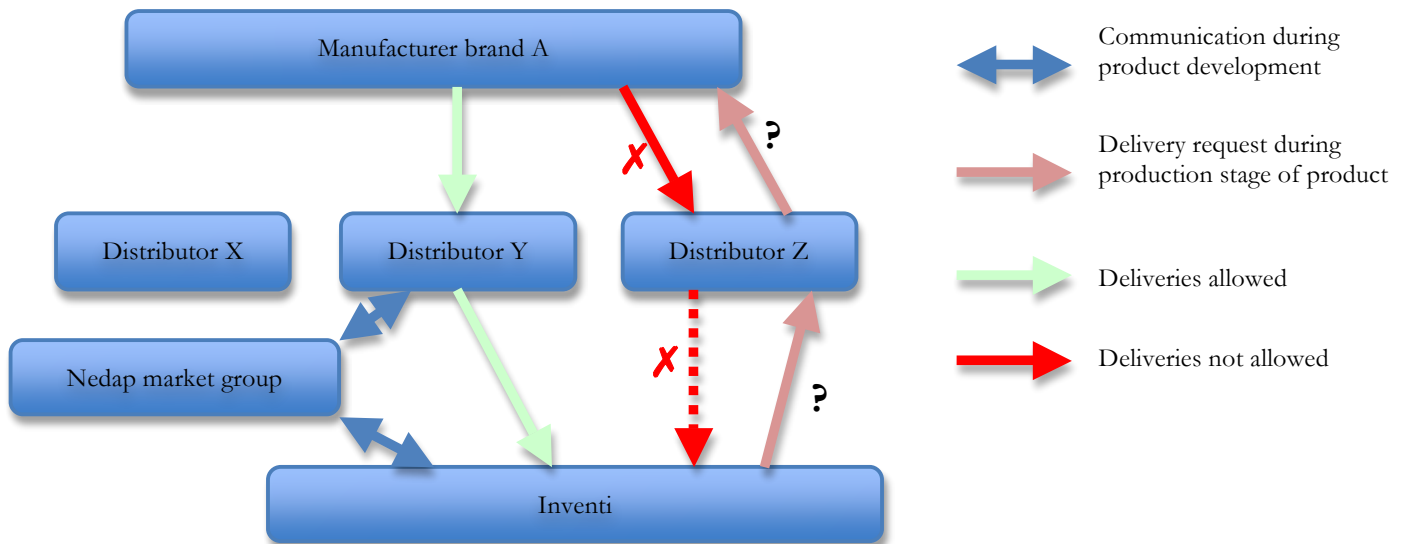


Figure 12: Current project registration in the electronic component market

Market groups

Sometimes it is difficult for a market group engineer to find the needed strategic or bottleneck component. Engineers of Retail Support ask Inventi for support to find these components (RS2,3). A technical purchaser of Inventi is more familiar with the component market than the product engineers of a market group. Inventi’s purchaser can support an engineer to provide a short list of possibly suitable components or to provide references, which can be contacted by an engineer. However, Retail Support argues the importance of the purchaser’s technical knowledge. The purchaser should understand the language of the engineers and the problem that have to be faced. The market group doubts whether Inventi currently has the necessary capabilities.

According to the market group manager of Energy Systems, Inventi will be more involved in component selection in the future.

In contradiction with Retail Support and the market group manager of Energy Systems, other interviewees do not recognize the added value of Inventi’s involvement in the selection of strategic or bottleneck components (AG1,2, ES4). Agri’s own purchasers are able to support Agri’s developers. The purchasers are closely located to the engineers, which is necessary for quick product development processes. Involvement of Inventi will slow down the NPD process (AG1,2,4). However, Inventi’s preferences regarding component distributors and manufacturers will be taken into account. These preferences will be discussed in chapter 5.

Furthermore, component distributors are often asked to support the market group’s engineers by selecting the right component in the design (RS2,3). This request implies a direct contact between a technical salesman of a specific component distributor and the market group engineer. This technical support can be valuable for an engineer, who will maintain a relationship with that distributor.

In this kind of situations, Inventi will keep its responsibility to procure the components for production. This also includes the choice for a specific component distributor. This choice can be based on price and other purchasing criteria. Inventi’s choice for another component distributor, which cannot provide the necessary support to the market group’s engineer, may disappoint the first component distributor. Probably the distributor will not be inclined to support the market group the next time. Communication between the market group’s engineers and Inventi’s purchasers is needed to ensure both, good support for the market group’s engineer and good supplying performance for a reasonable price.

Comparison

Differences can be identified between Inventi and the market groups with regard to Inventi's tasks in the selection of strategic and bottleneck components in the basic design step.

- ≠ Both, market groups and Inventi want to be in charge of procurement of samples of components.
- ≠ Retail Support will appreciate Inventi's support in selecting strategic or bottleneck items. Energy Systems is also intended to involve Inventi for this task in the future.

4.2.2 Design for manufacturability related tasks in basic design

DFM analyses need to be initiated during the basic design step. The first task is the selection of production technologies, which will be presented in this paragraph. The second task, DFM analyses in the detailed engineering step, including prototyping, will be discussed in paragraph 4.3.1. DFM tasks, which are related to the production process design step, will be presented in paragraph, 4.4.

Inventi

The production technologies are mainly determined by the choice for a certain product technology. For instance, the choice to use paint to make a PCB water resistance implies the use of the paint robot. Therefore the manufacturability has to be taken into account during the basic design step.

Inventi argues to get involved in the selection of the production technologies (IN1). This is especially important for production technologies which are new to the market group or Inventi. The determination of production technologies has to be considered as a common task. The task consists in the first place of the choice for a production technology. In the second place, the choice to outsource the production step or to perform the production step in-house has to be made. If Inventi decides to integrate the new technology, the type and brand of the production equipment will have to be determined.

Moreover, process engineers of Inventi can screen the basic design on the expected manufacturing problems. Based on this screening they can urge on specific aspects. The market group's engineers can take these aspects into account during the detailed engineering step. Inventi's process engineers have to stay involved during the remaining development steps.

Market groups

Agri, Retail Support and Energy Systems are intended to involve Inventi in the selection of production technologies. This involvement will be restricted to new technologies (AG1,2,3,4, ES1, RS1).

Moreover, the market groups are not intended to involve Inventi in this stage to perform DFM analyses.

Comparison

- ≠ The market groups will only allow involvement with regard to selection of unfamiliar production technologies. Currently, Inventi is not always involved in the selection of new production technologies. Both Inventi and the market groups are aware of the importance to involve Inventi. In future projects, this task will have to be performed jointly.
- ≠ A gap can be identified with regard to Inventi's wished DFM analyses. Market groups do not want to involve Inventi to perform this task.

4.3 Detailed engineering

The expectations about Inventi's tasks in the detailed engineering step will be presented in this section. In the first place, the results from both perspectives will be provided with regard to design for manufacturing tasks. In the second place, the results will be mentioned regarding Inventi's test development tasks.

4.3.1 Design for manufacturability related tasks in detailed engineering

Normally, the production of Inventi contains a few sequence steps. First, small components are automatically attached on a printed circuit board. After that, other components like connectors are attached manually. Finally, the printed circuit board with all the attached components will be assembled in a casing.

To ensure the manufacturability of all these production stages, Inventi can perform DFM analyses during the detailed engineering step. The DFM aspects of the three production stages will be discussed separately. Some DFM tasks are currently applied, other DFM tasks are related to the wished situation.

Manufacturability aspects in automatic attachment production step

Inventi

A service provided by Inventi is making prototypes. *Protec*, a special group of skilled production employees who are also in charge of the very small production series, will produce the prototypes for the market groups.

Protec wants to perform DFM analyses of the automatic attachment production step. Protec has the competence to make a layout for the PCB. On demand of the market group, they can perform the layout task. When the market group decides to make the layout by itself, Protec will control the manufacturability of that layout during the prototyping. Protec is involved with the automatic attachment of both low and high volume production orders. This implies that Protec is experienced and can perform these DFM analyses. After making a prototype, Protec will always write a report with all the feedback.

Market groups

For the attachment of small components on a printed circuit board, market groups depend on Inventi. Inventi is the only party of Nedap that possesses the needed production facilities. All researched market groups expect from Inventi to carry out this step.

The market groups expect feedback from Inventi on their designs, depending on the degree of Inventi's involvement in the prototypes. A document with feedback, which is directly sent with the prototype, will be useful (AG1,2,3,4, RS2,3, ES3,4). One interviewee (ES3) mentioned it as 'simply a part of making a prototype'.

Although feedback about manufacturability will be valuable, it might not always be useful information for the market group. This is also mentioned by the engineers of Retail Support (RS1,2). They are in favour of changes. The components as well as their position could be modified. However, this is not always possible because of the sensitiveness of the products. These restrictions result sometimes in difficulties related to producing the products.

Manufacturability aspects in manual attachment production step

Inventi

Inventi/Protec wants to perform DFM analyses of the manual attachment production step as well. Many specific DFM aspects related to the manual attachment are known within Protec. Protec has less experience in realizing high production with low skilled production workers. This lack of experience is caused by using the small production series and the well skilled production workers. Employees of Inventi, who are in charge of the high production volumes, can help to assist with the DFM analyses.

Market groups

Components that are not suitable for automatic placement have to be attached manually. In production these components will be soldered automatically, but in order to make some prototypes this is also possible by hand. This possibility prevents the market groups from depending on Inventi. Engineers of Retail Support want to keep the manual attachment in the market group. They only want Inventi to perform the automatic placement of components. Agri and Energy Systems want Inventi to deliver a complete PCB with both manual and automatic attached components. They argue that manual soldering of components for prototyping is against industrial guidelines (AG1, ES1).

Manufacturability aspects in final assembly production step

Inventi

Employees of Inventi, who are related to the final assembly, want to analyze the manufacturability of the final assembly of a new product. This is not possible during the prototyping of Protec. Inventi's engineers wish to be involved by the market group in order to ensure the DFM aspects.

Market groups

Assembling the prototypes is an activity, which can be performed by both the market groups as well as Inventi. Employees of Agri argue for the importance of assembly and testing of the prototypes in the market groups. It is a way to maintain specific knowledge in the market group. Retail Support also wants to execute the assembling of prototypes. Energy Systems considers leaving this to Inventi as a serious option. The PCB's of Energy Systems often only need to be assembled in a casing, which is a relative easy and small task.

Moreover, market groups do not want to involve Inventi's engineers in their project teams to ensure the manufacturability of the final assembly (RS1,2, AG1,3,4, ES4).

Comparison

Differences can be identified between Inventi and the market groups with regard to Inventi's tasks in DFM tasks in the detailed engineering step:

- ≠ Inventi wants to integrate the final assembly prototyping tasks, which will not be allowed by all market groups. The prototyping task is very useful to give DFM feedback to the product designers. However, due to the absence of end-assembling the prototypes, not all DFM aspects can be analysed during the prototyping.
- ≠ The market groups are not intended to involve Inventi early in the detailed engineering or in the basic design step to perform DFM analyses. Inventi wishes to perform this task during the prototyping task.
- ≠ The market groups want to perform the DMF analysis of the final assembly without involving Inventi engineers. Inventi wishes to be involved in the project team.

4.3.2 Test development tasks in detailed engineering

For the presentation of the results with regard to the test development tasks, a distinction is made between test strategy development, test plan development and test equipment development (see Figure 13). Test strategy development and test plan development are related to the detailed engineering step. Test equipment development is related to the production process design step.

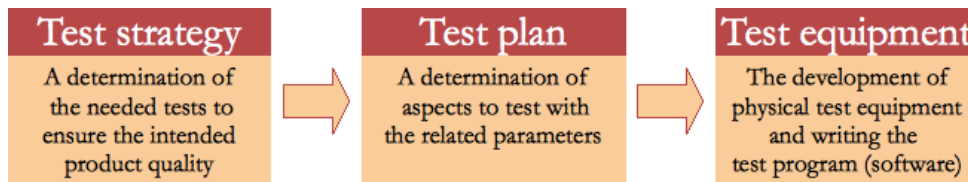


Figure 13: Three levels of test development

Inventi

Inventi wishes to be highly involved in test development, to ensure a proper functioning of the test equipment in the production stage. First, the determination of the test strategy has to be performed jointly. This determination should be based on a rational analysis of the product design and its application.

Secondly, the market group's engineers have to develop the test plan. The needed test plan depends on the selected tests in the test strategy. A high level of product knowhow is crucial for this task. The high level of technological knowhow of the product is only available in the market groups, which implies the allocation of this step to the market group's engineers. In the third place, test equipment has to be developed. Inventi's intended test equipment development tasks will be presented in paragraph 4.4 Production process design.

Market groups

The market groups are not intended to involve Inventi regarding the determination of the test strategy. However, Inventi can allocate its testing knowledge by providing this knowledge explicitly. The market groups have to write the test plans, because specific product knowledge is needed.

Comparison

Differences about the test strategy determination can be noticed.

- ≠ Inventi expects to have the capability to contribute to the determination of the test strategy. However, the market groups do not consider the test strategy development as a task, which could be shared with Inventi. Within the market groups the necessary knowledge and experience to perform this tasks are available.

4.4 Production process design

In this section, the results with regard to the production process design step will be presented. Inventi's as well as the market groups' expectations will be discussed in the following paragraphs.

4.4.1 Tasks related to production process development

In order to make the prototypes of a product, Inventi has determined a production process for the PCB. However, depending on the prototyping task of Inventi, other production processes (the final assembly) are not developed at that stage.

Inventi

Inventi is responsible for the production process and wishes also to perform the related development task (IN1). This task consists of the determination and development of all production process steps. The production process steps are related to the attachment of components as well as the final assembly.

Process development tasks like ‘setting up the supply chain’ and ‘designing versatile fixtures’ need to be carried out by Inventi. However, for these tasks and also for the selection of the needed production techniques, involvement of the market groups is required. Inventi will ask the market groups to take part of the decision making process. The suggestions of the market groups will be considered seriously, but Inventi will be responsible for the final choice of the production techniques (IN1).

The cooperation will ensure the manufacturability of the products, without concessions related to the function of the product. Inventi is definitively not intended to accept a production process developed by a market group, without being involved.

Inventi will also take care of the documentation with regard to the production. The documentation will consist of a process flow, drawings and a process FMEA.

Market groups

Retail Support and Energy Systems want to allocate this NPD task to Inventi. They focus on R&D and marketing and leave the production to Inventi. Inventi is, as manufacturer, the capable company for performing the production process development task. According to an employee of Energy Systems (ES4): *“it doesn’t care how Inventi produces it, they have to produce it properly.”* This expression stresses Inventi’s responsibility and tasks with regard to production process development.

Agri has another approach to process development. It wants to be in charge of the principles of the production process design. Agri provided three reasons (AG1):

- Production process development in the market group must preserve Agri’s manufacturing knowledge.
- Production process development within the market group is easier, because of the presence of all the product engineers. Problems can directly be solved in an informal setting and adjustments to the product or process design can be easily executed.
- An in house developed production process Agri provides the possibility to easily change from supplier if it is needed. By developing a supplier independent production process, Agri prevents itself from being locked to a supplier. If Inventi delivers a bad performance, Agri wants to have the opportunity to change quickly to another supplier. As ‘owner’ of the production process design and the specific production equipment, Agri can pick-up the production equipment and transfer it to another supplier.

As mentioned in 4.2.2, Agri acknowledges the importance to involve Inventi in the selection of new production technologies. This results in a situation where Agri will determine the production process design. However, it will involve Inventi when new production processes technologies are needed. Inventi will elaborate the production process design in more detail, like writing work instructions and machinery settings.

Comparison

Both Inventi and the market groups are intended to allocate the production process development tasks of the PCB to Inventi. This process is to a great extent developed in order to produce the prototype of the product. A different approach is found with regard to the production process design task of the final assembly.

- ≠ Inventi wants to perform the production process design task of the final assembly jointly with the market groups’ engineers. Retail Support and Energy Systems want to

allocate this task completely to Inventi. Agri wants to perform the task within the market group and Inventi will be involved in its elaboration.

4.4.2 Test development tasks in production process design

As presented before, the test development could be subdivided into three levels, which are: test strategy, test plan and test equipment development. Inventi's tasks with regard to the first two levels are presented in paragraph 4.3.2. Inventi's tasks, which are related to the test equipment development, will be presented below.

Inventi

The test plan results in development of the test equipment. Inventi has the capability to perform this task. Inventi's test engineers can develop the hardware part as well as the related software. Depending on the demand of the market group, Inventi or the market group will develop the tests. However, Inventi wants to be always involved in the test equipment development. The related tests are needed in the production process of Inventi. Inventi's test engineers need to get involved to ensure the testability and the related quality standard of the products.

Market groups

Retail Support and Agri will perform the development of the test equipment. However, they want the test engineers of Inventi to be involved. These test engineers can ensure the efficiency and effectiveness of the test equipment during production. Energy Systems will allocate the test equipment development task to Inventi. Based on the test plan of Energy System, the test engineers of Inventi have to develop the tests.

Comparison

Inventi's and the market groups' expectations about test equipment development are comparable. Inventi wants to perform the related tasks. Inventi is also willing to allow the market groups to be in charge of the test equipment development task. However, Inventi absolutely wishes to be involved. The market groups want to involve Inventi in these tasks or will allocate the tasks to Inventi completely.

4.5 Start of production and ramp-up

Inventi

Before Inventi will accept a product, it wants to perform a final control. All production steps, the procurement of components as well as the order quantities will be reviewed. After this final check and the first production order, all agreements will be signed. At this stage, Inventi can guarantee the agreed performance level and cost price.

Inventi argues for a formalized agreement between Inventi and the market groups. The document has to consist of delivery agreements and other aspects like product quality and product liability. Recently, Inventi started with the development of 'service level agreements' for existing products.

Market groups

Inventi has to execute a final control of all documents and designs (RS1, ES4). For the last time the manufacturability of the product and procurement of components will have to be checked. The market groups stress the importance of this step. The acceptance will ensure the market groups an accurate delivery in accordance with the agreed quantities, delivery time and quality level. Some interviewees argue to formalize this kind of agreements in a document like a 'service

level agreement'. However, according to Agri, the standard purchasing and sales conditions are sufficient to satisfy the need of both companies (AG1,2,3). Inventi has to perform like an independent supplier. Agri will neither sign extensive agreements with other suppliers.

Comparison

Although it is clear that production related aspects have to be communicated before the definitive start of production, differences are found in the expected formalization level.

- ≠ Agri and Inventi are arguing about the desired level of formalization. According to Agri, the standard purchasing and sales conditions are sufficient to satisfy the needs of both companies (AG1,2,3). However, Inventi wishes to establish these conditions in a separated 'service level agreement' (IN1,4).

4.6 Overview; differences in intended task distribution per development step

An overview of intended tasks allocated to Inventi, from both perspectives will be provided in Table 6. The top part of the table presents Inventi's wished situation. The lower part provides the market groups wished situation. The indicated gaps will be summarized in Table 7. Possible solutions to bridge these gaps will be discussed in chapter 7.

Table 6: Overview of wished tasks for Inventi per development step

	ESI dimension TASKS				
	Functional specifications	Basic design	Detailed engineering	Process design	Production ramp-up
Inventi's NPD tasks from Inventi's point of view	-	Procurement of samples ¹	Prototyping (incl. final assembly)	Development of PCB production process	Documentation (instructions, pFMEA)
		Support in selection of strategic components ²	DFM analysis of PCB in project team ³	Development of final assembly production process ⁶	Agreements formalized in a Service level agreement ⁷
		Selection of new production technologies	DFM analysis of final assembly in project team ⁴	(Involvement in) test equipment development	Start of production
			Determination of test strategy ⁵		
Inventi's NPD tasks from the market groups' point of view	-	- ¹	Prototyping PCB	Development of PCB production process	Documentation (instructions)
		Selection of strategic components (Only RS) ²	DFM analysis of PCB during prototyping ³	Final assembly production process design allocated to Inventi (RS,ES) ⁶	Non-formalized agreements (AG) ⁷
		Selection of new production technologies	- ⁴	(Involvement in (AG,RS)) test equipment development	Start of production
			- ⁵		

Table 7: Indicated gaps with regard to task allocated to Inventi

	Subject	Inventi	Market group
TASKS	1	Procurement of samples	Procurement of samples of components by Inventi
	2	Strategic and bottleneck components	Procurement of samples of components by market group
	3	DFM of PCB	Support in selection of strategic components
	4	DFM of final assembly	DFM analysis of PCB in project team
	5	Test strategy	DFM analysis of final assembly in project team
	6	Final assembly production process	Involvement in determination of test strategy
	7	Service level agreement	Inventi determines final assembly production process
		Formalized agreements in SLA	Support will not be allowed (ES,AG)
			DFM analysis of PCB during prototyping
			No DFM analysis of final assembly by Inventi
			No involvement in determination of test strategy
			Agri determines final assembly production process
			No formalization of agreements

The numbers in the first column of Table 7 refer to the numbers in superscript in related cells of Table 6.

5 Research results of resource allocation

The results with regard to the early supplier involvement dimension ‘resources’ will be presented in this chapter. In the previous chapter, the NPD tasks have been discussed. However, to perform NPD tasks, resources are needed as well. Inventi can allocate resources to NPD tasks, which will be executed by the market groups or Inventi. Moreover, providing resources can be useful to realize the desirable influence.

Inventi is intended to allocate several resources to the development projects of its customers. These are knowledge/information, capital or human related. The allocation of Inventi’s resources aims at:

- Selecting preferred components in product designs
- Enabling the manufacturability of the products
- Ensuring the availability of necessary production facilities for NPD projects

The researched market groups also argue for the allocation of several resources of Inventi. Most of the desired resources are knowledge related, but also some human and capital resources are needed.

The expectations of both, the market groups and Inventi will be mentioned with regard to the allocation of Inventi’s resources. The expectations will be presented per NPD step. Furthermore, an overview will be provided in Figure 15a and Figure 15b.

5.1 Functional specifications

In this paragraph, the needed resources in the functional specifications step will be presented. In the first place, Inventi’s intended allocation of resources will be provided. In the second place, the resources, which are mentioned by the market groups, will be presented. The resources do not necessarily need to be provided during this step, but they ultimately influence it.

Inventi

Inventi is highly experienced in the manufacturability of product designs. It intends to use this knowledge for new product designs. The goal is to share this knowledge in order to realize a higher level of manufacturability awareness among the market groups’ engineers (IN1).

Inventi considers this knowledge transfer as PR-activities by emphasizing its technological possibilities. This promotion is needed to inspire the market groups’ engineers to use all facilities most effectively.

This method of communication focuses on commercial effect as well as a product design effect. Inventi wants to distinguish itself from competitors by underlining the technological possibilities (IN1,2).

Market groups

According to the market groups, Inventi needs to provide information about the technological possibilities of Inventi (RS1,2,3, ES1,4, AG1,4). This information about competences should include:

- Providing information by showing production processes to other market groups. This could result in practical and useful ideas for new products.
- Providing the specifications of Inventi’s machinery.
- Exploring the market for new production technologies.

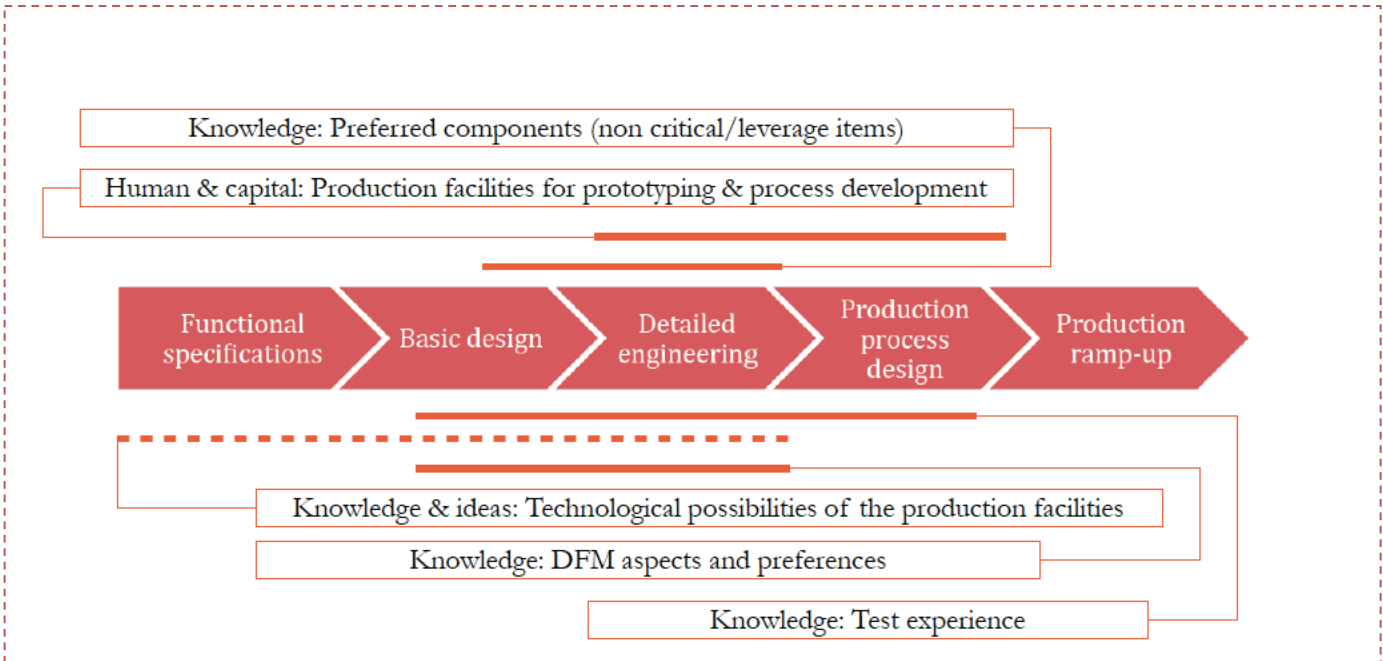
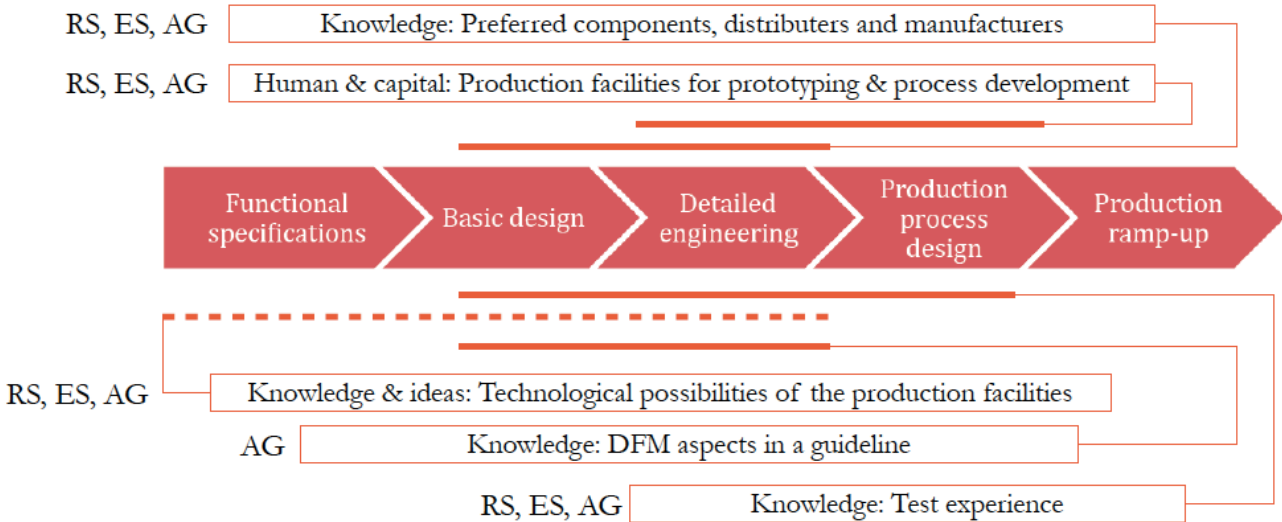


Figure 15a: Inventi's intended resource allocation

The resources, which Inventi wishes to allocate, are mentioned in the textboxes. The lines parallel with the NPD steps, indicates which resources are related to specific NPD step. Some resources are available during specific NPD steps (the straight lines in the figure). These resources are related to the information for selecting preferred components and availability of production facilities. Other resources like the technological possibilities of Inventi can also be allocated in between NPD projects (the dotted line in the figure). All lines indicate which NPD step will be influenced by allocating the resource.



RS = Retail Support, ES = Energy Systems and AG = Agri

Figure 15b: Market groups' demand for resources of Inventi

Inventi's resources, which are indicated by the market groups, are mentioned in the textboxes of Figure 15b. Abbreviations are used to refer to specific market groups.

The market groups emphasize the necessity for Inventi to keep its knowledge up-to-date with regard to new production technologies. Inventi does not have to focus on intensive exploration of the component market (RS2,3, AG2). According to the market groups, Inventi does not benefit of this kind of research, because it is only involved in production tasks. The market groups are responsible for exploring the market.

Comparison

The market groups and Inventi agree about the resources needed in the functional specifications step. It is necessary to allocate Inventi's production knowledge to the market groups. This process of knowledge allocation has to be related to current production processes. Providing this knowledge will influence the successive NPD steps.

5.2 Basic design

The needed resources in the basic design step will be provided in this section. The resources are related to component selection and design for manufacturing. For both aspects, Inventi's expectations as well as the market groups' expectations will be presented. In the first place, Inventi's intended allocation of its resources will be provided. In the second place, the mentioned resources by the market groups will be presented. Test equipment related resources, which are also related to the basic design step, will be discussed in paragraph 5.3.

5.2.1 Component selection related resources in basic design

Inventi

In the basic design step, strategic and bottleneck components have to be selected. As mentioned in the previous chapter, Inventi wishes to get involved in this selection task. Performing this task automatically implies allocation of specific knowledge. Therefore, Inventi does not need to provide a list of preferred distributors and manufacturers for strategic and bottleneck components.

Market groups

At this moment, Agri and Energy Systems are not intended to involve Inventi in the selection of strategic and bottleneck components. They stress the importance of the availability of a preferred distributor and manufacturer list. For specific groups of components Inventi can provide a list of its preferred distributors and manufacturers. According to the market groups, they can use this list to ensure the procurement of the components. More involvement of Inventi in the selection of components will not contribute to the market groups' NPD success.

Comparison

- ≠ The market groups Agri and Energy Systems specifically demand for a preferred distributor and manufacturer list, because they do not want to involve Inventi in the selection task. Inventi wishes to execute the component selection task together with the market groups.

5.2.2 Design for manufacturing related resources in basic design

Inventi

Within Inventi's approach to transfer DFM knowledge, two key aspects could be mentioned. In the first place, Inventi wants to teach the engineers general DFM aspects and specific preferences related to product designs. For example, a specific preference is the use of click-connections instead of screw-connections.

In the second place, it focuses on designing products according to the current production standards. Inventi's facilities are modern and competitive. However, not all engineers are familiar with the specifications. Subsequently, the machinery is not used to the edge. Information about DFM preferences is needed to suit Inventi's production facilities more adequately.

Inventi is intended to transfer this knowledge by organizing seminars. These seminars can be supported by some documents. For example guidelines could be established in order to develop a product with a design for manufacturability approach.

Market groups

An important aspect of a product is the manufacturability. Reduction of the production facilities in the market groups also implies a reduction of specific knowledge about production processes and techniques. The three market groups want contributions of Inventi about used production techniques in order to guarantee the manufacturability of the product. Informal transfer of these aspects will be expected (ES2, RS2,3). Furthermore, a tool is mentioned to ensure the knowledge sharing about the manufacturability of products. Employees of Agri suggested to establish a guideline which can support the engineers with regard to the manufacturability of a product. This guideline can contain information about minimum distance between components, preferred sizes, testing aspects etc. (AG1,2,3). The guideline has to aim at providing low-price manufacturing knowledge.

Moreover, Agri (AG1) focuses on the need for contact information. Therefore, a list of the responsible employees for the different business aspects is needed. The employees of Energy Systems (ES2) and Retail Support (RS1,2) mentioned the informal relationship with Inventi employees. They know the contact persons for specific issues and for them a contact person list is not necessary.

Comparison

According to both Inventi and the market groups, Inventi has to allocate its preferences and knowledge with regard to the manufacturability of the products. This allocation will support the market groups' engineers to design products. These products are inexpensive to produce and meet the quality standard. Guidelines as well as personal communication are considered as useful ways to communicate Inventi's DFM knowledge and preferences. Inventi has to consider providing detailed contact information.

5.3 Detailed engineering

Based on the basic design, the product will be developed in detail. Important resources in the detailed engineering step are related to component selection, DFM and testability. The resources will be presented in the following three sections.

5.3.1 Component selection related resources in detailed engineering

Inventi

The components selected in the product designs are very important for Inventi, because Inventi has to procure them. Inventi categorizes components by using Kraljic's (1983) classification. Different purchasing strategies are applied for all groups of purchase items. Inventi's policy aims at reducing the strategic and bottleneck items. For non critical and leverage items Inventi wants to encourage the use of familiar components. This will reduce the purchasing cost as well as the logistic cost like warehousing.

With regard to non critical and leverage components, Inventi wants to allocate information about preferred components. Inventi is intended to provide lists of preferred components, distributors and manufacturers/brands. These lists should be digitally available to the market groups' hardware engineers, who choose the components in the product designs. Currently some kind of preferred distributor list is available on the intranet of Nedap and Inventi. However, an accurate and complete list of preferred components is not available for the hardware engineers.

Market groups

All researched market groups stressed the importance of a list with familiar components of Inventi. The benefits (price reduction, handling cost reduction) of using familiar components by bundling purchase orders are acknowledged. The availability of components is also guaranteed by using the preferred components. Engineers can use the list of components to control the familiarity of Inventi with a selected component. If a component is not available on the list an engineer can select another component of a preferred brand/supplier. According to the market groups, Inventi has to contribute to the development process by providing this list. The allocation of this knowledge resource is applicable for non critical and leverage items (Kraljic, 1983). Important aspects of a component list are:

- Component price (RS, ES, AG). In the early stages of the development process the market groups want to be able to estimate the cost price of the product. A valid estimation of the cost price can be realized through indication of the actual component price.
- All relevant specifications of the component (RS, ES, AG).
- Drawing (RS2,3). A drawing of the component can be used as a quick check to an engineer to control if the right type of component has been selected. This could be used, for instance, to check directly if a connector has a clip on top.

The Nedap market groups do not know which exact components are used in the products of other market groups. A preferred component list allows a better insight in the used components throughout the Nedap N.V. company. All market groups expect to benefit from this knowledge.

Comparison

The selection of non-critical and leverage components is a task of the market groups' engineers. In order to benefit from Inventi's purchasing conditions, components lists are needed. Inventi has to consider integrating drawings for specific users.

5.3.2 Design for manufacturing related resources in detailed engineering

Inventi

An important task of Inventi is prototyping. In order to perform this task, Inventi wants to allocate its production facilities. The facilities will be used for prototyping and process development. Employees who are in charge of the prototyping activities will be available as well. However, market groups have to pay the costs for producing the prototypes (IN2).

Market groups

The allocation of production facilities and production workers in order to ensure prototyping and process development is needed (RS, ES, AG). The market groups do not have the facilities to produce the prototypes.

Comparison

Both companies emphasize the availability of Inventi's production facilities. The market groups depend on Inventi's production facilities in order to produce prototypes. The allocation of these facilities is directly related to Inventi's prototyping task, which is discussed in chapter 4.

5.3.3 Testing related resources

Inventi

Inventi has a long history with PCB (printed circuit board) production, which resulted in a high level of knowledge and experience in testing PCBs. Inventi wants to allocate this knowledge in order to develop an appropriate test strategy, test plan and test equipment (see Figure 13, p36). Currently, Inventi experiences a lack of good test strategy development within the market groups (IN1). Several tools are available to support the developers in the selection of tests. The tests should be selected and developed in order to meet the expected non-defect rates in production. For most of the current products of the market groups the tests are selected based on usages of the engineers. Inventi wants to allocate its test knowledge and introduce tools for proper selection of tests.

Market groups

The market groups argue the importance of a good testing strategy. In their opinion, the market groups have the capability to select the right tests. The integration of Inventi's testing experiences is very important for the test equipment development (RS, ES, AG). However, if Inventi provides its strategy development knowledge and tools, the market group will consider to use these tools (AG1,2,3, ES1).

Comparison

- ≠ The need to integrate Inventi's test strategy development knowledge is not supported by the market groups. However, providing specific tools can support market groups in test strategy determination.

5.4 Production process design

In the production process design step, the production process will be developed in detail. According to both, the market groups and Inventi, the detailed development of the production process will be a task of Inventi (see paragraph 4.4). Inventi can use its own resources like the

production facilities. However, to prepare the production process, Inventi needs specific product information from the market groups.

Inventi

Inventi wants to allocate its knowledge and preferences with regard to the quality assurance aspects of products. Universal documentation and proper FMEA analyses are primordial for low-price manufacturing (IN1). Communication about documentation ensures a smooth transfer from detailed engineering to production process design.

Market groups

For Inventi and the market groups it is more efficient to adjust documentation to both organizations. According to the market groups, Inventi does not need to transform a market group's documents into its own document (AG1,2 ES3). However, Inventi has to establish written documentation when it needs more detailed or other documentation.

Comparison

Both companies stress the importance of a good documentation transfer from the market group to Inventi. The market groups need information about Inventi's required information. Inventi has to provide this information.

5.5 Start of production and ramp-up

The production ramp-up tasks will be a task of Inventi. Therefore, Inventi does not have to allocate specific resources to the market groups.

5.6 Overview; differences in intended resource allocation per development step

An overview of the intended allocation of Inventi's resources from both perspectives will be provided in Table 8. The top part of the table presents Inventi's wished situation. The lower part provides the market groups wished situation. The indicated gaps will be summarized in Table 9. Possible solutions to bridge these gaps will be discussed in chapter 7.

Table 8: Overview of wished resources of Inventi per development step

	ESI Dimension RESOURCES				
	Functional specifications	Basic design	Detailed engineering	Process design	Production ramp-up
Needed resources from Inventi's point of view	Information about Inventi's production facilities	- ^A	Preferred distributor and manufacturer list for non-critical and leverage items	Preferences with regard to document transfer and QA aspects	-
		General ^B and Inventi's specific DFM related knowledge	Availability of production facilities		
			Test strategy ^C and equipment development knowledge		
Needed resources from market groups' point of view	Information about Inventi's production facilities	Preferred distributor and manufacturer list for strategic and bottleneck items ^A	Preferred distributor and manufacturer list for non-critical and leverage items	Preferences with regard to document transfer	-
		Inventi's DFM related preferences	Availability of production facilities		
		List of contact persons (Only AG)	Test equipment development knowledge		

Table 9: Indicated gaps with regard to resource allocation

	Subject	Inventi	Market group
RESOURCES	A Strategic and bottleneck components	No need for allocating specific list	Preferred distributors and manufacturers list for strategic and bottleneck components
	B DFM knowledge	General DFM knowledge	No need for general DFM knowledge
	C Testing knowledge	Test strategy development knowledge	No need for test strategy development knowledge

The characters in the first column of Table 9 refer to the characters in superscript in related cells of Table 8.

6 Research results of responsibility distribution

In this chapter the results of the research with regard to the last ESI dimension will be provided. The last ESI dimension is ‘responsibilities’. The responsibilities will be discussed per NPD step. In the previous chapters, the NPD tasks and resources have been discussed in detail. If a specific NPD task is allocated to Inventi or the market group, it will be responsible for the execution of the task. Furthermore, the owner of specific resources will be responsible for providing this resource. However, the responsibility of the execution of a whole NPD step has not been discussed. A NPD step consists of several specific tasks and related resources. Both Inventi and the market groups will be included in this chapter. The intended situation will be related to the NPD steps.

Inventi will not be responsible for the product design. This has been pointed out in chapter 4 and 5. Although Inventi is not responsible for the product designs, it wants to be responsible for some NPD steps, which will be presented in this chapter. Inventi’s wished responsibility distribution is visualized in Figure 16.

Within a step Inventi may perform the tasks it is responsible for. This will not imply responsibility of the whole NPD step. For example, Inventi’s prototyping tasks do not entail any responsibility of the detailed engineering step.

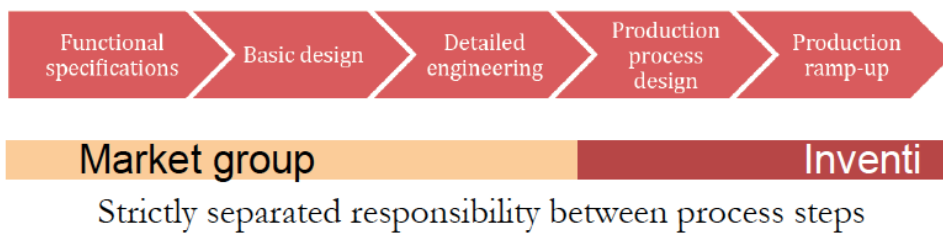


Figure 16: Inventi's intended distribution of responsibilities

All of the market groups do not expect Inventi to develop a part of a product. Inventi will not be responsible for the product design. It is only charged with the production process. However, differences are found between market groups with regard to the exact moment of responsibility transfer. The differences will be presented in this chapter and are visualized in Figure 17. The diagonal lines represent a gradual transition of responsibilities between the market groups and Inventi.

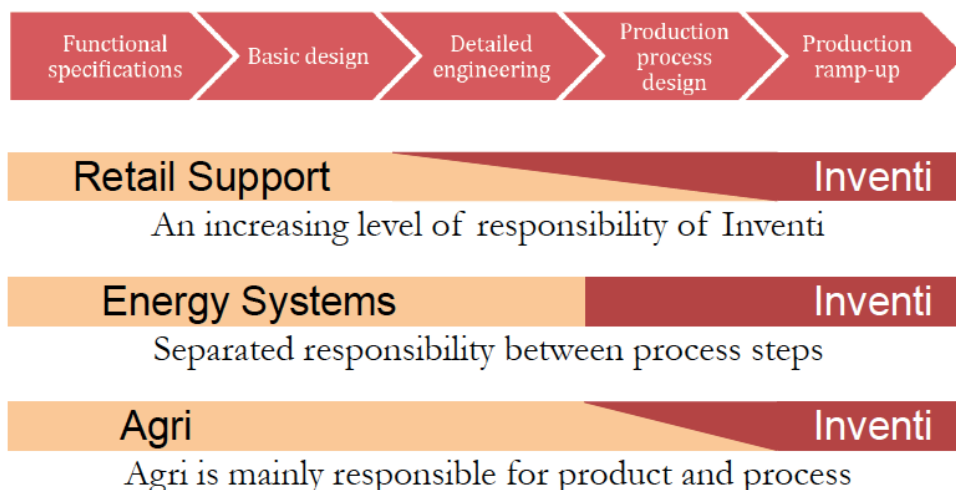


Figure 17: The market groups' intended distribution of responsibilities

6.1 Functional specifications and basic design

Inventi

Inventi does not want to be responsible for product designs of the market groups. The core business of Inventi is to deliver production- and man-hours. It is a capacity supplier. That is why Inventi does not want to be responsible for the development of (a part of) a product. However, Inventi's management emphasizes that it intends to be a technical partner for the market groups (IN1). The technical partnership should be related to production processes. Inventi will not have an R&D department to develop products.

Market groups

The market groups will transform the market's demand into products. The market groups focus on Inventi's production services (AG1,4 RS1, ES2,3). Inventi has been founded in order to realize low cost production. Product development is not Inventi's core business. Therefore, Inventi cannot be accountable for the product design. The market groups will maintain their responsibility.

Comparison

All interviewees decline Inventi's responsibility in the functional specification and basic design steps.

6.2 Detailed engineering

Inventi

Inventi does not want to be responsible for the product design, because product design is not Inventi's core business and it is definitely not its final responsibility. At the end, the market groups are responsible for the designs of the products, which they will sell (IN1).

Market groups

All three market groups argue that the market groups will keep the responsibility of the detailed engineering step as well. Inventi is not responsible of the product design. However, it can contribute to this NPD step and can perform some development tasks. For instance, Inventi can perform the prototyping task (see chapter 4 and 5).

Retail Support has a slightly other approach to Inventi's responsibility of the detailed engineering step. Retail Support is used to work with an own well-qualified production department. These qualified production employees were able to translate a product design into a production process. Because of the transfer of production activities to Inventi, Inventi will be forced to practice self-support (RS2,3). For example, Inventi can decide to adjust an antenna for a specific situation. Inventi makes these adjustments in the detailed design, in order to allow series production. Therefore, Inventi's responsibility starts in the detailed engineering step in Figure 17.

Comparison

In general, Inventi is not responsible for the product designs. Only Retail Support, which demands for low-volume production orders, expects Inventi to take its responsibility with regard to product adjustments. Other market groups will not allow Inventi to make adjustments to the product design in specific settings.

6.3 Production process design and production ramp-up

Inventi

Inventi wants to be responsible for the last two development steps. Moreover, Inventi is responsible for a reliable production process. Inventi has to meet the intended production standards with regard to volumes and quality. The market groups will use these performance indicators to measure Inventi's performance as supplier. In order to ensure a satisfactory output, Inventi's management emphasizes that it has to be responsible for the production process design (IN1).

Although Inventi want to be responsible for the last two development steps (see Figure 16) it expects the market groups to contribute to the process design.

Inventi is responsible for its own performance. The independent status of Inventi is guaranteed by focusing strictly on the separated responsibilities of the process steps (IN1). This aimed separation enables a separate evaluation for each company. The separation makes it possible to evaluate both companies for its own speciality. The market groups will be accountable for the product design and Inventi will be accountable for production performance. Furthermore, the separation allows certification of Inventi as an individual company. An example of a certification is an ISO TS certification. The certifying organization and other possible auditors can audit Inventi without involving Inventi's customers.

Market groups

Ultimately, Inventi will be responsible for the production process design. However, some differences are found between the market groups' approaches. Each market group will be presented separately.

The development of a good and reliable production process is a responsibility of Inventi. To ensure the quality of this process some tests are needed. Market groups' engineers make decisions about the parameters to be tested and the deviation. This is a part of the detailed engineering step and a responsibility of the market group. Differences are found with regard to the physical test equipment development and the transformation from parameters towards tests. If a market group develops test equipment without involving Inventi, Inventi cannot be completely responsible for the production process development step.

Retail Support

According to Retail Support, Inventi has to be responsible for the design of the production process. However, the development of functional/end tests is a responsibility of the market group. Inventi will be responsible for other tests, like an ICT test⁵. Inventi has to ensure a production line with high quality level, which will result in high quality performance. In order to ensure a reliable production process, an additional ICT test may be needed. Inventi can decide if this is the right tool to ensure the product quality (RS2,3).

Retail Support's test development prevents Inventi from getting the complete responsibility (see Figure 17) of the production process design step. However, involvement of Inventi's test engineers will be considered.

⁵ An In-circuit test (ICT) uses electrical probe's to test a printed circuit board. It checks for shorts, opens, resistance, capacitance and other basic quantities, which will show whether the assembly was correctly fabricated.

Agri

Agri wishes to maintain responsibility of the production process design (AG1,2,4). In order to maintain its freedom, Agri does not want to lose control. If quality requirements are not met by a certain manufacturer (e.g. Inventi), the market group wants to be able to change manufacturers. By keeping the process responsibility in house, Agri can easily change to another manufacturer with its own, not supplier dependent, production process.

With regard to test development, Agri wishes to be responsible for the development of the functional/end tests. It wants also to be responsible for the ICT tests. However, it acknowledges the importance of Inventi's commitment and involvement, which are needed for the testability of the products.

Moreover, Agri wishes to keep a part of the process development in the market group without involvement of Inventi. Therefore, the responsibility of the production process design step has to be shared (see Figure 17).

Energy Systems

The production process is the responsibility of Inventi. Inventi has to develop a production process, which suits the product, the order quantity and the needed quality standard.

The development of tests is integrated in the NPD process of the market group. However, the test equipment development will be provided as a (paid) service by Inventi (ES2). The engineers of the market group are responsible for the determination of the parameters, which have to be measured. The parameter determination results in a 'test plan'. Inventi is responsible for the translation of the test plan into a testing device.

This distribution of tasks results in a strictly separation of NPD responsibilities between the detailed engineering and the production process design step.

Comparison

Inventi and the market groups do not agree about Inventi's assumed responsibility of the production process design step. Inventi wishes to be the responsible company of this NPD process step. However, Agri and Retail Support wish to maintain some responsibility of this step. Especially Agri wishes not to allocate the production process design step completely to a supplier. Without the responsibility of this step, Agri loses the possibility to transfer its production orders easily to another supplier.

The market groups and Inventi allocate the production ramp-up responsibility to Inventi.

6.4 Overview; differences in intended responsibility distribution

An overview of the intended responsibility distribution from both perspectives will be provided in Table 10. The top part of the table presents Inventi’s wished situation. The lower part provides the market groups wished situation, separately. The critical gap will be mentioned in Table 11.

Table 10: Overview of intended responsibility distribution per development step

	ESI Dimension RESPONSIBILITIES				
	Functional specifications	Basic design	Detailed engineering	Process design	Production ramp-up
Inventi’s intended responsibility distribution	Market group	Market group	Market group	Inventi	Inventi
Market groups’ intended responsibility distribution	Energy Systems	Energy Systems	Energy Systems	Inventi	Inventi
	Retail Support	Retail Support	Retail Support	Retail Support / Inventi ¹	Inventi
	Agri	Agri	Agri	Agri	Inventi

Table 11: Indicated gap with regard to responsibility distribution

RESPONSIBILITIES	Subject	Inventi	Market group
	I	Production process design	Inventi wants to be responsible for the production process design step

7 Bridging the gaps and selecting the appropriate coordination approach

This chapter will answer the fifth research question: *How can the gaps between Inventi's and the customers' expectations be bridged in order to provide a satisfactory solution?* An overview of indicated similarities and gaps between the expectations of the market groups and Inventi will be provided in appendix IV. All three ESI dimensions are integrated in this overview.

Approaches and instruments to bridge the indicated gaps will be provided in paragraph 7.1. In paragraph 7.2, the coordination approach for the cooperation, which suits Inventi's situation, will be presented.

7.1 Approaches to bridge the gaps

Inventi aims at *ensuring that customers will outsource their production to Inventi* (Inventi, 2007). Inventi considers the market groups as its customers. All allocated tasks and resources of Inventi in the NPD processes have to fulfil demands of the market groups. Anticipating on the customers' demands will increase the willingness to outsource to Inventi. Therefore, Inventi has to focus on the market groups' preferences. To a great extent, Inventi depends on the willingness of market groups. Inventi has to aim at making its services as attractive as possible for the market groups.

The gaps will be discussed per topic of cooperation, like DFM or component selection. These discussions will mention tasks, resources and NPD steps. After the discussion, instruments will be provided to bridge the gaps. For practical implementation of the instruments, four main projects will be provided as well. With these main projects Inventi will be able to get its intended early involvement.

7.1.1 Design for manufacturability

In this paragraph all DMF related gaps will be discussed. A distinction is made between DFM aspects before prototyping, DFM aspects of prototyping and DFM aspects of final assembly. The paragraph will conclude with the presentation of the first project: "Continuing and extending prototyping and print layout services."

Design for manufacturability aspects before prototyping

DFM aspects have to be taken into account during the early stages of product development. Moreover, production related personnel are best qualified to analyze the manufacturability of a product. Within Nedap N.V., only Inventi facilitates production. Therefore, involvement of Inventi in the early stages of an NPD project is a logical step. However, market groups do not want to involve Inventi in these early stages. They are not convinced of Inventi's product knowledge to contribute to the NPD processes. Inventi has to focus on production processes instead of NPD processes. According to the market groups, involvement in all NPD projects will negatively influence Inventi's focus on low-cost producing.

To bridge this gap, Inventi can use two instruments. On the one hand establishing a guideline with specific DFM related preferences. On the other hand, Inventi can aim at taking over the print layout development tasks. Both instruments will be discussed below.

A guideline will support engineers in choices about for instance distances between components or screw types. It will be difficult to develop a guideline, which is both, easy to use for the

engineers, and comprehensive to cover all DFM related aspects. In order to ensure a proper use of the guidelines and comprehension of Inventi's preferences, Inventi has to present its preferences as well. The DFM related presentations are part of the 'NPD project independent knowledge transfer' and will be described in paragraph 7.1.4. After the presentation, the market groups' engineers can use the guideline as reference. Inventi can be contacted in case of any questions. The contact information of all disciplines has to be included in the guideline.

As mentioned in chapter 4, Inventi (Protec) has the competence to develop print layouts. The print layout is only one aspect of the product design, but determines the manufacturability of the PCB to a great extent. Performing the print layout development task will result in control of the manufacturability of the PCB. In this case, Inventi will not need the market group to perform DFM analyses.

The allocation of this task to Inventi will not only be valuable for Inventi. Market groups will benefit from higher manufacturability, which results in a lower cost price and less product flaws. Inventi has to emphasize on these benefits to acquire more print layout orders of the market groups.

Involvement in print layout development will indirectly allow Inventi to get involved in other aspects of the detailed engineering step. To develop print layouts, Inventi has to communicate with the market group. Subsequently, Inventi gets insights in other development parts, like the product's casing. Inventi can comment on these aspects as well.

Besides the print layout service, Inventi can also provide specific templates for print layout programs. Market groups, which decide to perform the print layout task internally, can use these templates. The templates include the mandatory elements of print designs like space for barcode labels and edges.

Design for manufacturability aspects in prototyping

Both the market groups and Inventi acknowledge the importance of performing DFM analyses during the prototyping task. Three aspects are important:

- Evaluation of component positioning.
- Practical method of attachment.
- Other PCM assembly related tasks.

If Inventi performs final assembly prototyping tasks it has to analyze these aspects as well.

The market groups expect Inventi to provide feedback on their product designs. Oral and written communication is possible. The market groups indicate the feedback forms, which Inventi has introduced recently, as valuable feedback. On demand of the market group, Inventi can explain the feedback in a face-to-face setting.

Design for manufacturability aspects of final assembly

There is a gap identified between Inventi's and the market groups' intended situation with regard to the DFM analyses of the final assembly. Inventi wishes to be involved in the project team to ensure the manufacturability. The market groups want to ensure the manufacturability on its own. Especially the final assembly task will be problematic, because Inventi will not always be in charge of the prototyping. However, some possibilities to get influence on the design of this part are available. The possibilities are:

- Integration of final assembly aspects in the DFM guideline.
- Integration of these aspects in the DFM promotion activities. These activities will be discussed in 7.1.4.
- Small DFM related adjustments. These can be made at the production stage. The adjustments allow Inventi to be self-supportive at the moment of production. In cooperation with the market group, these adjustments can be made. The adjustments may absolutely not influence the function or the exterior design of the product.

- Involvement of Inventi in selection of technologies. Market groups will involve Inventi when new production technologies are needed for the final assembly. With the selection of new production technologies and equipment for a product, Inventi has to take the manufacturability of the new product into account.

To get the wished influence on the manufacturability of the products, Inventi needs to implement the above provided instruments. Therefore, the first project is formulized, which will be presented below. Moreover, the fourth project is also related to DFM. This will be provided in paragraph 7.1.4 (p61).

Getting involved in the NPD processes of market groups will be a dynamic process. There is no need for Inventi to implement all projects at the same moment. The main projects that will be presented in this chapter are:

1. Continuing and extending prototyping and print layout services.
2. Providing component selection related resources and services.
3. Realizing added value of involvement in test strategy and test equipment development.
4. Forming a core-team for DFM and technology knowledge transfer.

Each project can be managed and evaluated separately. Therefore, the projects do not have to be executed at the same time. Performing the projects sequentially or at the same time mainly depends on the availability of the related employees. Moreover, the results of the project will have consequences for the market groups. Market groups will need some time to adjust its processes and to get used to the new services of Inventi. In order to ensure a good introduction, it will be necessary to introduce the new services sequentially.

Within each project, sub-projects can be formed. For example, the realization of the needed IT infrastructure can be a sub-project. The project leader will be accountable for the organization of these sub-projects.

The first project will be presented below:

Project I: Continuing and extending prototyping and print layout services

The project to start with, is related to the existing prototyping and print layout services. It will be an obvious choice to start with this project, because Inventi is currently providing these services. To get more influence on the product designs and to control the manufacturability, Inventi can evaluate the current prototyping activities. Subsequently, it can adjust the process to the market groups' needs. Furthermore, it can promote its print layout services. Aspects, which the project team has to consider, are:

- Evaluation of the current feedback forms after prototyping. Generally, the feedback is appreciated. However, which aspects are important and what can be improved?
- Realization of communication about product designs after prototyping.
- Evaluation of current response speed on prototype orders. What can be improved; delivery time proto, delivery time proposal or procurement of samples?
- Encouragement of procurement of samples by Inventi.
- Encouragement of allocation of final assembly prototyping to Inventi.
- Promotion of Inventi's print layout development service. Examples are emphasizing on the benefits, like layout adjustments to machinery or providing discount for prototypes.
- Improvement of print layout service.
 - Development of templates.
 - Integration of testability check.
 - Integration of manufacturability check of final assembly.

Inventi's department Protec is in charge of the prototyping and print layout services. Employees of Protec can execute this project.

7.1.2 Component selection

In this section, a distinction is made between strategic and bottleneck components and non-critical and leverage components. Both groups of components will be discussed. At the end of this paragraph, the second project “providing component selection related resources and services” will be presented.

Strategic and bottleneck components

Inventi wishes to get involved in the selection of strategic and bottleneck items in order to ensure the procurement. Important aspects of the procurement are price agreements, delivery terms and the possibility of second sourcing. Two approaches to realize the intended influence of Inventi are mentioned in the result chapters. In the first place, some market groups argued for establishing a list of preferred manufacturers and distributors. In the second place, Inventi argued for involving a technical purchaser of Inventi and to perform the procurement of sample components. Both options will be discussed.

Establishing a list of preferred manufacturers and distributors

Providing a list of preferred manufacturers and distributors will have some advantages and disadvantages for the cooperating companies. Two important advantages can be indicated. The first advantage is primarily related to the market groups, the second is related to Inventi.

In the first place, a digital list will be directly available for market groups’ engineers. The market group’s engineer will be independent of Inventi to select a component. Based on the list, the engineer can contact a distributor for more information, technical support or procurement of sample components. This freedom for the engineer to contact distributors and order samples, will speed up the NPD process. Furthermore, the engineers can use the specific knowledge of manufacturers and distributors directly in the product designs.

In the second place, a high level of efforts is not required from Inventi. Inventi’s purchasers have to develop one list, regardless of the number of components, which has to be selected. All market groups’ engineers and purchasers can use the list on every moment. However, Inventi has to keep the lists up to date.

Disadvantages can be noticed as well. In the first place, strategic and bottleneck components are very specific and unique components. A preferred component and distributor list cannot cover all specific components, which market groups will look for. To be innovative, market groups will always look for a broader range of components. It is impossible for Inventi to provide a list of preferred manufacturers and distributors, which covers the worldwide part market.

In the second place, Inventi cannot guarantee the procurement of the selected component completely. Especially, if the engineer will not involve Inventi to order the samples, Inventi cannot control the procurement of the specific component in early stages of the NPD process.

Involvement of Inventi’s purchaser in component selection tasks

The involvement of a purchaser of Inventi includes two aspects. Inventi’s purchaser can assist market groups’ engineers in the selection of strategic and bottleneck components. When a market group is interested in a component, Inventi will order a sample of the component. Two advantages for Inventi can be distinguished.

In the first place, Inventi’s purchaser can directly check all purchasing related aspects of the component. Selection of components, which will be difficult to procure, will be avoided in the early stages of the NPD process.

In the second place, involvement of Inventi’s purchaser will keep Inventi informed of future projects and market trends.

Disadvantages of involving Inventi's purchasers can be noticed for Inventi. In the first place, Inventi has to invest in technical knowledge about components. The technical purchaser of Inventi has to speak 'the language of the engineers'. To deliver this service, Inventi has to attract a well skilled technical purchaser.

In the second place, involvement in the selection and purchasing of strategic components will entail for a high level of efforts of Inventi's purchasers. Several market groups with multiple NPD projects might request for Inventi's involvement at the same time. This high level of requests undermines the execution of primary purchasing tasks. Moreover, Inventi has to respond quickly and guarantee a high service. A low performance level, due to high demands of the market groups, may not influence Inventi's relationship with the market groups negatively.

In the last place, not all market groups are willing to involve Inventi in the selection tasks of strategic and bottleneck components. In this research only Retail Support mentioned it as a relevant service. This does not imply Inventi's involvement in the selection of all strategic and bottleneck components. Furthermore, procurement of all samples by Inventi might result in unnecessary delays of the NPD project.

The best option to ensure the procurement of strategic and bottleneck components

Both mentioned options do not suit the situation optimally. Inventi has to combine both approaches to ensure the procurement of strategic and bottleneck items in. Inventi depends on the willingness of the market groups to accept its involvement in component selection.

The researched market groups will use a list of preferred manufacturers and distributors. Inventi has to develop the list to meet the demand of the market groups. The list will motivate engineers to select components of preferred brands. This will prevent Inventi from getting an exponential grow of component suppliers. Nevertheless, the list has to be easy to use for the market groups' engineers. If they cannot find the needed information easily, the list will probably not be used. It will be needed to involve representatives of the market groups to establish the structure and format of the list.

An important aspect of the list is the integration of vendor ratings. Inventi has insights in the distributor's daily business performance. In contradiction, the market groups' engineers only experience the distributor's performance with regard to NPD support. The list can be useful to communicate the delivery performance to the NPD project members.

Despite the usefulness of the list, it will not provide the preferred manufacturers or distributors for all the needed strategic or bottleneck items. Therefore, Inventi's purchasers can support the market groups on demand.

Inventi has to create a high degree of accessibility for the market groups. Inventi has to inform the market groups' engineers and purchasers of the specific contact information of its purchasers. Furthermore, Inventi can emphasize on its relations with all kind of components suppliers for the different market groups. Inventi can be the connecting factor to transfer component knowledge between the independently operating market groups.

To provide this support, Inventi has to attract a high-qualified technical purchaser. In addition to the job requirement for a strategic purchaser, an extensive knowledge base of electronics is needed.

The last aspect, which is related to the selection of strategic and bottleneck items, is the procurement of component samples. To persuade the market groups to procure samples by Inventi, Inventi has to deliver extra value for market groups. For example, Inventi can stress its good relationships with the component suppliers, which ensure fast deliveries. Furthermore, Inventi can emphasize on the reduction of administrative tasks for the market groups. It also has to stress the fact that often the samples have to be attached on a PCB by Inventi.

Non-critical and leverage components

Both, the market groups and Inventi are arguing for a preferred component list for non-critical and leverage components. The following aspects have to be taken into account:

- The actual cost price. This price will have to be integrated in the list and will be used in the first cost price calculations. The selection process of specific components will be influenced by price.
- The expected level of demand for components. This is a dynamic process. A classification of the expected procurement conditions in the future is needed. For instance, some high volume products might be in the decline stage of the product life cycle. Subsequently, the demand for related specific components will decrease. As a result, the cost price of the components may increase. Therefore, the attractiveness of these components to select in new (low volume) products will change. A low price will not be guaranteed for the future.
- A universal and detailed way of component descriptions. This is primordial for engineers to find the needed components in the list.
- Digital availability of the list. The list has to be digitally available and up-to-date.
- Practical use. The list has to be easy in use. It has to be compatible with the market groups' software.

The purpose of the component list is to select the preferred/familiar components in product designs. The use of familiar components will result in a decrease of unique components. Subsequently, this will entail lower material handling costs. The market groups have to use the list. If an appropriate component cannot be found in the list, the engineer has to look in the preferred manufacturer/brand list to know which brands are preferred for that kind of components. This can be integrated in the list of strategic and bottleneck components. Inventi has to involve market groups to develop the lists in order to fulfil the market groups demand.

Project II: Providing component selection related resources and services

The second project is related to component selection in product designs. Both the market groups and Inventi expect to benefit from using Inventi's preferred components. Informing the market groups about Inventi's preferences is a task of Inventi's purchasers. This project has to aim at getting market groups informed of these preferences. Furthermore, the market groups have to be encouraged to select Inventi's preferred components. Two important aspects have been distinguished. In the first place, lists of Inventi's preferences have to be developed. The lists will consist of preferred components (including non-critical and leverage components), preferred manufacturers and the related distributors (including strategic, bottleneck, non-critical and leverage components). In the second place, the market groups can involve Inventi's purchasers for component selection related questions.

The project team has to consider the following aspects:

- A proper categorizing of components, which is logical for all users of the list.
- Classification of component groups for the different lists.
- The way of providing (the information technology solution) and maintaining the list.
- The way of encouraging market groups' engineers to select preferred components.
- The appointment of a technical purchaser.
- The way of realizing contact between the technical purchaser and the market groups.

Inventi's purchasers can be in charge of this project. Market groups have to be involved in the categorizing of components and the integration in the software systems. If Inventi decides to attract a technical purchaser, the new purchaser can be the project leader. The project can be used to introduce the technical purchaser to the market groups.

7.1.3 Test strategy, plan and equipment

The market groups and Inventi agree to allocate the test plan⁶ development to the market groups. After the development of a test plan, the test equipment has to be developed. The market group will involve Inventi in the test equipment development or Inventi's test engineers will be in charge of the development of the test equipment.

Inventi and the market groups do not agree on the allocation of the test strategy development task. Not all the market groups allocate the test strategy development task to Inventi. In contradiction, Inventi believes it can contribute in the test strategy development.

Good test development will influence the quality standard of Inventi's end products. To ensure a proper test strategy development by the market groups, Inventi has to allocate its test strategy knowledge. In between projects, Inventi has to present the possibilities in test strategy development. For example, Inventi has to mention the indicators of products, which determine the need for a specific test. Moreover, Inventi has to allocate 'tools', which can be used to estimate the need for specific tests. If market groups will use these resources, they can contact Inventi for additional support.

Project III: Realization of added value of involvement in test strategy and test equipment development

Test development is the topic of the third project. Inventi has a special 'test and measurement' department. This department has to be in charge of the third project. Inventi needs to focus on two aspects of test development: the test strategy and the test equipment development.

First of all, Inventi has to determine how it can contribute to test strategy development. Some relevant questions for the project team are:

- What are the important aspects of test strategy development?
- What knowledge does Inventi need?
- How can Inventi acquire the lacking knowledge?
- Which tools can Inventi and the market groups use in test strategy development?
- How can Inventi allocate its relevant knowledge and tools to the market groups?

In the second place, Inventi is involved in test equipment development. The test and measurement department is not developing the test equipment only for the manufacturer Inventi. Its test equipment development is also a service for the market groups. Therefore, the test and measurement department has to be customer focused. The service has to fit the expectations of the market groups. Furthermore, the test employees have to determine how their services have to be organized and how the cooperation with the market groups has to be managed.

7.1.4 Project independent knowledge transfer

Inventi has to communicate its technology, test and DFM knowledge independently of specific NPD projects. The market groups have to provide Inventi with the necessary knowledge. However, they are not willing to involve Inventi the project teams. For instance, the market groups are not intended to involve Inventi for test strategy development or in DFM analyses in the basic design stage. In order to provide the relevant knowledge, Inventi can keep the market groups informed in between projects by organizing meetings. The market groups will appreciate this kind of information and will be more inclined to provide the needed information. This knowledge transfer will not be related to a specific NPD project, but can be used in several projects.

⁶ See for an explanation of the terms test strategy, test plan and test equipment Figure 13: Three levels of test development (p 36).

Some points about this knowledge transfer have been mentioned in the previous paragraphs. This transfer consists of design for manufacturing, test development and production technology knowledge. After the discussion of these topics, the fourth project will be provided: “Forming a core-team for design for manufacturability and technology knowledge transfer.”

Production technology knowledge

The first topic of NPD project independent knowledge transfer is production technology. The market groups and Inventi agree about the importance to inform market groups about Inventi’s production technologies. The information will consist of three points.

In the first place, Inventi has to inform market groups about the possibilities of its current production facilities. The basics of the production technologies as well as the specifications of Inventi’s facilities have to be communicated.

In the second place, Inventi needs to inform itself about new production technologies. Inventi has to inform market groups about these new production possibilities.

In the third place, Inventi can present its production abilities by informing market groups about its production portfolio for other market groups. Market groups are interested in the way other market groups solve specific product or production related problems.

These aspects of technological knowledge transfer aim at realizing product designs, which fit the current technological possibilities of Inventi’s production facilities. Moreover, Inventi will be able to adjust its technology roadmap to the market groups’ product roadmaps.

To ensure relevant topics and content of technological knowledge exchange, Inventi can introduce technology-experts-teams. The technology-experts-teams (TET), which are described by Schumacher, Schiele, Contzen, & Zachau (2008), aim at bringing the engineering and purchasing functions together.

Members are experts, which have extensive knowledge of the current state and future trends in products, production technologies or purchasing. The members can speak freely about technological possibilities for the future. These technological possibilities can be related to component innovations, production technologies as well as general technological trends.

Market group employees can be involved to contribute to topics of their expertise. The indicated trends of the TET can be compared with the technological ‘road maps’ of the market groups. Suppliers of production facilities or components could be invited to benefit from their detailed understanding of new technologies.

Design for manufacturability knowledge

The second topic, which Inventi has to present, is its DFM preferences.

Market groups are not intended to involve Inventi in all the DFM analyses. A DFM guideline can be provided to transfer Inventi’s specific manufacturing preferences. However, providing a guideline will not be sufficient to convince market groups’ engineers of the necessity of DFM. The guideline has to be embedded in a total DFM program. Besides the guideline, DFM presentations can be organized by Inventi for the market groups.

Inventi has to present its DFM preferences, which are related to the PCB and the final assembly. Furthermore, Inventi has to present the benefits of DFM in general and the benefits of using the guideline. Practical examples will be useful to indicate the cost of non-optimized product designs and the potential of using DFM.

The goal of providing DFM knowledge is realizing products designs, which fit Inventi’s production processes. Furthermore, it can convince market groups to involve Inventi earlier in the NPD process to execute DFM analyses.

Test development knowledge

The third topic of NPD project independent knowledge transfer is test development. Inventi wishes to be involved in the development of the test strategy for a new product. The market groups are not intended to involve Inventi in this task. Inventi will be allowed to present its knowledge and specific tools in between projects. In this way, Inventi will be able to convince market groups to use a more comprehensive test strategy determination.

Market groups can use tools, which are provided by Inventi, to determine the test strategy. On demand, Inventi's test engineers can support the market group in using these tools. Furthermore, examples can help convincing market groups to use the tools. Moreover, Inventi has to stress the need for a proper test strategy development. A better test strategy can prevent high cost of product failures. It can also reduce the test equipment development costs.

Test engineers of Inventi can provide the tools and have to initiate this knowledge transfer.

Project IV: Forming a core-team for design for manufacturability and technology knowledge transfer

The last main project will ensure transfer of DFM and technology knowledge between market groups and Inventi.

Above, the concept of technology experts teams (TET) has been introduced. This concept can be elaborated by forming a core-team, which will be in charge of all DFM and technology related knowledge aspects. This team can initiate all kind of programs related to knowledge transfer. Important tasks are:

- Exploring new production techniques, which are available on the market.
- Following trends in the electronic component market.
- Organizing discussions with market groups about the future technologies.

Representatives of several departments of Inventi have to be integrated in the team. These are process engineers of automatic and manual attachment of components, engineers of the final assembly and purchasers. However, not all members have to be involved in all programs. Furthermore, other disciplines can be involved on demand, like market group's specialists. Moreover, this team has to be involved in the selection of new production technologies.

The team with its related programs will result in a solid knowledge base within Inventi. This central knowledge base can be used to provide answers for all kind of DFM or production technology related questions. The market groups or Inventi can ask these questions.

In order to get the intended early involvement, the team has to start with the following topics:

- Compilation of the current knowledge related to DFM and production technologies.
- Complementation of missing knowledge.
- Determination of design criteria, which has to be taken into account by market groups' engineers.
- Determination of relevant topics for seminars.
- Determination of aspects, which can be integrated in a DFM guideline.
- Realization of seminars and guideline.

7.1.5 Production process development

In this research the market groups have clearly indicated the involvement they expect from Inventi. This involvement is more extensive than the current process of taking over production tasks. In this paragraph a distinction will be made between the development of the PCB production process and the development of the final assembly process.

Production process of the printed circuit boards

Inventi wishes to be in charge of the development task with regard to the PCB production process. The market groups are also willing to allocate this to Inventi.

In the first place, Protec (Inventi) has to develop the production processes of the automatic attachment part. It is the only department within Nedap or Inventi that has the needed specific knowledge and facilities. Moreover, Protec has to perform the automatic attachment in production stage of the product as well. Therefore, Protec is capable of performing this task. It has the needed production technology knowledge and high volume production experiences. Both are needed to develop a high-quality and efficient production process.

In the second place, Protec will develop the production process of the manual attachment as well. However, Protec has to cooperate with Inventi's other production sites in this task.

Production process of the final-assembly

Inventi's influence on the development of the final assembly production process is also relevant. The market groups will acknowledge the importance of involving Inventi regarding the selection of new production technologies.

Many final assembly tasks consist of the placement in a casing. According to Agri and Energy Systems, this task is relatively simple and involvement of Inventi is not needed. Furthermore, during the start-up of the final-assembly production, Inventi can still make some adjustments in the process.

Inventi has some negative experiences with taking over production processes of market groups. Therefore it insists of being in charge the production process development of the final assembly. Not all of the market groups are intended to allocate this task completely to Inventi. Nevertheless, Inventi will have more influence in future NPD projects. This influence will be ensured by being involved in technology selection. Therefore, Inventi will be able to get its wished influence to a great extent.

There is no need for Inventi to initiate a project with regard to the production process design topic. The intended situation is currently applied or will be applied from now on. In the first place, a task, which is currently allocated to Inventi, is the PCB production process development. This task will not result in earlier involvement of Inventi in the NPD processes. Moreover, it will not change the cooperation with the market groups.

In the second place, the market groups will involve Inventi, with regard to the final assembly, in the selection of new production technologies.

7.1.6 Start of production and documentation

With regard to the start of production and its related documentation, the market groups and Inventi agree on many aspects. A good exchange of documentation has to be ensured. However, the need for a 'service level agreement' is not commonly shared.

Exchange of documentation

Inventi will be in charge of the start of production step. When needed, Inventi and the market groups have to establish written documentation in the production process development step. Examples of this documentation are drawings and process instructions. To ensure a proper transfer of documentation between the market groups and Inventi, two aspects are essential.

In the first place, the market groups and Inventi have to adjust the formats of documents to both companies. These formats can be related to, test equipment, process flows or FMEAs.

In the second place, relevant documents have to be available to both companies. Exchange of the latest versions of documents has to be ensured. Documents like drawings and bill of materials, can be exchanged by connecting the information systems. Inventi has to provide an infrastructure, which is compatible with the software of the different market groups. If Inventi

decides to implement a Manufacturing Execution System (MES⁷), the information flow with market groups has to be taken into account.

Service level agreements

At the end of the NPD process, the market groups and Inventi have to agree about production volumes, prices and delivery times. Inventi wishes to formalize these agreements in a ‘service level agreement’ (SLA).

Agri argues for using the normal sales and purchase terms. A high degree of formalization can result in a negative influence on Inventi’s flexibility. For example, the ability to order extra products has to depend on Inventi’s current operational possibilities. It should not depend on a term in a SLA.

SLAs are needed for agreements related to logistics, liabilities, finance, production planning and purchasing. They are established at the end of the NPD process. A advise of the whole concept of SLA cannot be provided in this research, because a SLA is not only related to NPD. However, recommendations with regard to the NPD aspects will be made.

Agreements with regard to task and responsibility distribution in NPD projects have to be formalized. These agreements can be integrated in Inventi’s sales terms or in a general part of a SLA. Inventi has to aim at providing one document, which includes its NPD tasks and responsibilities for all market groups. Tasks and responsibilities descriptions that can be mentioned in the document are:

- Providing a list of preferred components, distributors and manufacturers.
- Informing market groups about its technological possibilities.
- Informing market groups about its DFM related preferences.
- Producing PCB prototypes (delivery times, etc.).
- Being involved in test development.
- Being in charge of the production process development.
- Performing a product acceptance check (including the check of tests, procurement, documentation).

Developing the acceptance check and connecting document management systems

The last project is developing the acceptance check, which will be used before taking a product into production. Inventi has to perform these checks. Furthermore, a connection between the document management systems of both companies is needed to accomplish this final check. Inventi has to develop a plan for this connection as well. The execution of this project is a relatively short process compared to the four main projects. Moreover, it will not result in earlier involvement of Inventi in the NPD processes of the market groups. Therefore, this project is not one of the four main projects.

An extensive project team is not needed. One employee, for example the quality manager of Inventi, can be responsible for the elaboration of this project.

7.2 Selection of coordination approach for the intended cooperation

As mentioned in the previous chapters, both Inventi and the market groups prefer some kind of coordination. In this paragraph, the selection of a coordination approach will be discussed. In the first place, the preferred coordination approach of both companies will be presented. In the second place, a coordination approach will be selected, which suits the situation.

⁷ MES manages and monitors the production processes. A product can be managed during its whole life cycle. It starts with the first prototypes and ends in the decline stage of the product.

7.2.1 Inventi's and market groups' preferred coordination approach

Inventi and the market groups have preferences with regard to the coordination approach (see for more information about coordination approaches of supplier involvement paragraph 3.6.). Some differences could be established, which will be provided in the following sections.

Inventi's preferred coordination approach

Inventi aspires a membership of the project teams of the market groups. Depending on the stage of the product development, different disciplines of Inventi has to be involved. Inventi wishes to involve to following four areas:

- Purchasing
- Testing and measuring equipment
- Automatic and manual attachment of components (Protec)
- Final assembly

In Inventi's opinion, an integrated coordination approach (see paragraph 3.6, p 20) is the best way to realize the intended involvement. Membership of the NPD project team of a market group results in an automatic involvement of the necessary areas of Inventi (purchasing, production and testing). These areas need to be involved in all the meetings and decisions, which are related to its area. According to Inventi, the disconnected sub project coordination approach will not result in the necessary involvement in all development steps. Moreover, Inventi cannot develop a part, which can be disconnected from the new product. Inventi wants to be involved in the development steps, which implies the impossibility to disconnect the development team.

According to Inventi, a direct ad hoc contact approach is also not ideal to realize the intended involvement. The use of a direct ad hoc contact approach entails Inventi's dependency on the willingness of market groups' employees to involve Inventi's counterparts. Inventi cannot ensure its influence on the product designs by using this approach.

Market groups

The three market groups have different opinions about Inventi's position in the project team, which will be presented below.

Energy Systems' preferred coordination approach

At this moment, a permanent membership of Inventi in a project team is not necessary. It is suggested to add an employee of Inventi in the mailing list of the project team (ES3). The employee automatically gets all information. An Inventi engineer is allowed to join a meeting, if relevant aspects will be discussed. This approach reflects the direct ad hoc contact approach. However, Energy Systems argues for a high-level of cooperation and an active role of Inventi in future projects. Energy Systems will consider allocating the purchasing related tasks in NPD to Inventi (ES1). Therefore, a purchaser of Inventi will have to be integrated in the project team. This will result in an integrated coordination approach for the purchasing function. Other functions will be contacted on an ad hoc basis.

Agri's preferred coordination approach

Agri declines the formation of an integrated project team. Within a project, one employee of Agri is the contact person for Inventi. This contact person can introduce all Inventi's suggestions during project meetings. Inventi's involvement will only be allowed by means of feedback documents, guidelines and a preferred component list (AG1,3,4).

Agri prefers a form of cooperation which is quite similar to the disconnected sub project coordination approach. Agri wishes to develop the product and the basics of the production process. In Agri's point of view, Inventi has to implement the production process and to develop the supporting tools and processes. Involvement with regard to DFM and component selection has to be formalized. Inventi may provide preferred component lists and DFM guidelines.

However, a direct ad hoc contact approach can also be recognized. Agri argues the importance of the involvement of Inventi's test engineers. Agri's test engineers have to contact Inventi's test engineers during the test development tasks. Moreover, Agri wishes to involve Inventi in the selection of new production technologies.

Retail Support's preferred coordination approach

Formal project teams do not exist at Retail Support. An engineer manages the project and when needed other disciplines will be involved. Membership in a project team is therefore not possible for Inventi. However, the engineer can involve Inventi if necessary. For instance an Inventi purchaser can be asked to contribute in the selection of a supplier for strategic components.

The intended coordination approach of Retail Support is a good reflection of the direct ad hoc contact approach. The developers of Retail Support will contact their counterparts when needed. Retail Support also allows Inventi to contact Retail Support employees on its demand.

7.2.2 Ideal type coordination approach

In the determination of a coordination approach, Inventi primarily depends on the market groups' willingness to involve Inventi in their NPD projects. Inventi wishes to be a member of an integrated project team. However, this membership is not main focus. Inventi aims at realizing better component selection, better product designs and better production process designs. The necessary instruments to achieve these goals have been described in paragraph 7.1.

Drivers for a more integrated coordination approach are:

- Diverting expectations of the cooperating companies
- Long-term collaboration objectives
- Necessity for intensive contact

These drivers will be discussed in this paragraph.

Both companies stress the importance of focussing on the manufacturability. Therefore, the expectations of the cooperation do not considerably differ.

The collaboration will aim at maintaining long-term relationships. However, it will consist of several independent relatively short NPD projects. Inventi's engineers will not be structurally involved in NPD projects of all market groups.

The necessity for intensive contact consists of three aspects. In the first place, the technological complexity is an important factor. Inventi facilitates relatively complex production machinery. The products of the market groups are often complex due to, for example, high frequency or high electric current technologies. Nevertheless, the goal of the intended cooperation is not exchanging extended knowledge of high frequency or high current technologies. It will neither involve explanation of the detailed principles of machinery. This cooperation will focus on the implications of machinery on product designs and the implications of certain technologies on the manufacturability of the products. Therefore, the technological complexity is not a necessity for intensive contact.

In the second place, a high level of task dependency increases the need for intensive contact. Most of the allocated tasks to Inventi can be performed at Inventi's production sites. These tasks can be performed independently of the market groups. The market groups can perform

their tasks, like determination of the functional specifications, independently of Inventi. Therefore, the task dependency is not a necessary for constant intensive contact.

In the third place, the resources to share can require personal contact. Several resources of Inventi are needed for the intended cooperation. Resources like component lists have to be allocated in an explicit form. The allocation of Inventi's implicit DFM knowledge in early stages of the detailed engineering step and the basic design step requires more intensive contact. However, market groups are not intended to involve Inventi's engineers in these early stages.

The direct ad hoc contact approach fits the intended distribution of tasks and responsibilities. It also fits the intended allocation of resources. However, Inventi wished to be a member of the market group's project team. Nevertheless, Inventi will acquire its intended involvement by using the mentioned instruments (see paragraph 7.1) in combination with the direct ad hoc contact approach. In order to achieve the influence, Inventi has to provide component lists, guidelines and proper feedback. It also has to organize supporting seminars. Otherwise, market groups' engineers will not be inclined to use the resources or to get in touch with its counterparts at Inventi.

Finally a form of sub-project integration will be realized if a market group gets in touch with Inventi employees. For instance, the involvement of Inventi's test engineers will result in a sub-project team, which is in charge of the test development. This sub-project team consists of test development specialists of Inventi and the market group.

7.2.3 Implications of selected coordination approach on preconditions

An extensive investigation of the preconditions of successful supplier involvement has not been part of this research. However, some notes can be made with regard to these preconditions. The intended cooperation and coordination approach have implication on the preconditions. These will be mentioned in this paragraph.

The market groups are not intended to integrate Inventi in projects. This will partly impede an ongoing active role of Inventi. Inventi depends on market groups to get involved in the project. However, the choice for the ad hoc contact coordination approach will not necessarily result in a lack of information flow. The allocation of several tasks, the connection between information systems and the personal relationships will ensure an ongoing information flow. Moreover, the personal relationships will provide a good atmosphere for information sharing.

The current personal relationships between Inventi's and market groups' employees are essential for applying a direct ad hoc contact approach. Employees who maintain personal relationships with employees of the cooperation company will be earlier inclined to contact them. Inventi has to maintain these relationships.

Permission of the management is necessary for market groups' engineers to contact Inventi. This support is primordial in a successful direct ad hoc contact approach. As stated above, top management commitment related problems are not expected.

All interviewees of the market groups are familiar with Nedap's policy to transfer most of the PCB production to Inventi. This implies that the market groups' employees feel support to cooperate with Inventi. None of the interviewees mentioned a management barrier to involve Inventi. However, Agri's management argues for a limited involvement to eliminate the chance of being locked into Inventi's technologies.

8 Conclusion and recommendations

The last chapter of this report will provide the conclusion, recommendations and limitations of the research.

8.1 Conclusion

This research is conducted to answer the central question. The central question is: *“What should Inventi do to be involved in early product development phases of its customers?”* To answer this question, a better understanding has been provided of both, the possible involvement in the early product development phases and the market groups’ demand for Inventi’s involvement. Moreover, solutions to get more influence in the NPD process have been provided in chapter 7. Furthermore, an approach to coordinate the cooperation has been determined.

Inventi’s integration in the market groups’ NPD project teams, which will be formed in the early stages of product development, will not be realized. Market groups will not allow Inventi to take part in the project team. Moreover, not all the market groups make use of project teams.

To get involved, individual employees of Inventi have to be contacted by employees of the market groups. This approach corresponds with the direct ad hoc contact coordination approach. Inventi depends on the willingness of market groups to get involved. Therefore, Inventi has to ensure that market groups’ engineers can easily get in contact with Inventi’s employees.

Furthermore, Inventi has to use the mentioned possibilities to influence the NPD projects. The application or allocation of the following aspects will ensure Inventi’s involvement in its customers’ product development processes:

- Providing lists with DFM and component preferences.
- Providing feedback on prototypes and print layouts.
- Being involved in test development tasks.
- Providing relevant production technology and DFM knowledge.

From this moment, these instruments can be introduced.

Instead of a direct ad hoc coordination approach, Inventi wished a more integrated cooperation. This is especially relevant for performing DFM analyses. DFM aspects have to be taken into account in the early stages of the NPD process by a multidiscipline team. The manufacturer needs to be integrated in this team. To increase the manufacturability of the products in the future even more, Inventi has to focus on becoming more involved in these teams. However, it has to establish more confidence of market groups to get involved. Good performance of Inventi during NPD projects will increase the confidence of the market groups in Inventi’s NPD capabilities. More confidence in Inventi’s NPD capabilities can convince market groups to involve Inventi in other NPD aspects like DFM analyses in the early stages of product development.

This research provided the necessary aspects to get more influence on product design. The involvement will result in an increase of the product manufacturability, improvement of the production’s quality performance and advantages of using preferred components. However, integration in NPD project teams is not possible at this moment.

8.2 Recommendations

In this paragraph, the recommendations will be provided. In the first place, cooperation between Inventi's production sites will be discussed. In the second place, the concept of trust building will be mentioned.

Cooperation within Inventi regarding production process development

Inventi will allocate the production process development of the manual attachment of components and the final assembly to Protec. However, Protec will not produce the products in the production stage. The production process has to be optimized for the definitive production site. Due to the differences between Inventi's production sites and Protec, it will be difficult for Protec to adjust the process to the different setting. Important differences are the kind of workforce and specific production facilities. Moreover, Protec is less experienced with large production series. Protec can underestimate the consequences in large production series.

In order to cope with this problem, Protec has to cooperate with Inventi's other production sites. The involvement of employees of Inventi's other production sites has to ensure the efficiency of the production process in high volume production.

Inventi should determine how the different departments within Inventi could cooperate in production process development.

Trust and confident building

Inventi seems to experience a high level of affective based trust (based on personal relationships between individuals). This type of trust is fragile. In the future, this type of trust needs to be transformed to cognitive based trust (based on past experiences). Successful involvement in several NPD projects will result in a higher level of this type of trust. Cognitive based trust is less fragile because it is not built on the relationship between specific individuals. Cognitive based trust will hardly be damaged when individuals leave a market group or Inventi.

Many interviewees mentioned some problems with internal suppliers in history. Some quality and delivery problems occurred. The market groups missed a customer-focused approach of internal suppliers. Currently, Inventi is a separated company of Nedap and the market groups acknowledge some improvements. Although the earlier problems are not NPD process related, Inventi should convince the market groups of its capability to support the NPD processes. This confidence building should occur during future NPD projects.

Involvement of Inventi in NPD projects is new for both companies and will extend the current cooperation. Confidence of the market groups in Inventi's capabilities to perform NPD tasks has to grow. Confidence building is a dynamic process and will need time to establish.

Inventi should invest in confident building to realize more integration in NPD projects in the future. Trust and confident building are special disciplines. These aspects have not been integrated in this research. More research is needed to develop a comprehensive approach for realizing more confidence in Inventi's capabilities.

8.3 Limitations of conducted research

The limitations of this research will be discussed below.

In the first place, the found literature on this topic has mainly been conducted from a buyer's perspective. Therefore, the theory had to be adjusted. In the future more research has to be conducted from the suppliers perspective in these kind of collaboration. A new research topic could be: "successful strategies for a supplier to get involved in its customers' NPD processes."

The second limitation is related to the time-set of the research. The current year has been a turbulent year for Nedap and many of its market groups. The market groups were forced to reorganize their businesses and to eliminate their production activities to a great extent. Often, the interviewees were not sure about the future organization of the company. Market groups' employees and managers were not always able to formulate their intended cooperation with Inventi. Not all of the needed independent factors for the future cooperation were clear at the moment of the interviews. Therefore, it is possible that some of the market groups' visions on the cooperation will change in the future. Subsequently, the extent of Inventi's involvement might change as well.

In the third place, the results of interviews are not always objective. The answers can be influenced by the current relationships between employees or recent experiences in cooperation. The reorganization can also have an impact on the interviewees. Allocation of tasks to Inventi might reduce the necessity of the interviewee's own job. As a result, the interviewees could be less inclined to involve Inventi.

In the fourth place, the research results are only applicable to the relationship between Nedap market groups and Inventi. The three researched market groups represent to a great extent all the Nedap market groups. Therefore, the results can be generalized to all Inventi's relationships with Nedap market groups. The results cannot be generalized to other settings, like other branches or companies.

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Lists

List of Abbreviations

DFM	Design For Manufacturability
ESI	Early Supplier Involvement
ICT (test)	In-circuit test
NEDAP	Nederlandse Apparaten Fabriek
NPD	New Product Development
PCB	Printed Circuit Board
R&D	Research and Development

List of Definitions

Capacity supplier	A supplier which delivers production capacity. The supplier produces on demand of its customers. The supplier does not develop products on its own and does not have its own brand of products.
Market groups	Market groups are departments of Nedap N.V. Each department operates in its own markets. Each market group is responsible for its own product development, marketing, organization and operations.
Modular design	Modular design is an approach that subdivides a system into smaller parts (modules) that can be independently developed.
Nedap	Nedap consists of the bundling of all market groups. The company focuses on developing and supplying innovative and sustainable solutions in the fields of security and electronic control units as well as automation, management and information systems for organizations (Nedap N.V., 2009).
Supplier involvement	Supplier involvement refers to the resources (capabilities, investments, information, knowledge, ideas) that suppliers provide, the tasks they carry out and the responsibilities they assume regarding the development of a part, process or service for the benefit of a buyer's current and/or future product development projects (Echtelt, Wynstra, van Weele, & Duysters, 2006).
Familiar components	Familiar components are components that are already used at the production site of Inventi. If a developer selects a familiar component, this component will be used in at least two products (one existing product and the new product)
Protec	A department of Inventi, which is located in Groenlo and Neede. It consists of a special group of skilled production employees who are in charge of the small production series, prototyping and the automatic attachment of small components.

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Appendices

Appendix I Nedap N.V. and the founding of Inventi

Nedap and the founding of Inventi

This appendix contains a brief description of (1) Nedap and its activities, (2) the history and the role of production processes within Nedap and (3) the origin of Inventi. It gives a summary of organization development through time and it indicates which change drivers were mentioned by Nedap/Inventi employees. The purpose of this document is twofold. As first, this document provides the interested reader more background information, which makes it easier to place and understand the thesis in a broader, corporate perspective. Secondly, it points out the relevance of the research to Nedap N.V. and Inventi employees. This document makes clear why the research is primordial for Nedap N.V. as a corporation.

Nedap

NV Nederlandsche Apparatenfabriek 'Nedap' is an internationally operating company with more than 600 employees. It has its headquarters in Groenlo, the Netherlands. Nedap focuses on developing and supplying innovative and sustainable solutions in the fields of security and electronic control units as well as automation, management and information for organizations. Nedap focuses on different markets as shown in figure I. In order to prevent distances between Nedap employees and customers, Nedap has an exceptionally flat organization structure. Excluding its subsidiaries, the organization in Groenlo does not have any official divisions or departments. All employees formally work directly for Nedap N.V. Employees have a very high degree of freedom and are encouraged to work in a creative and open way with both colleagues and customers.

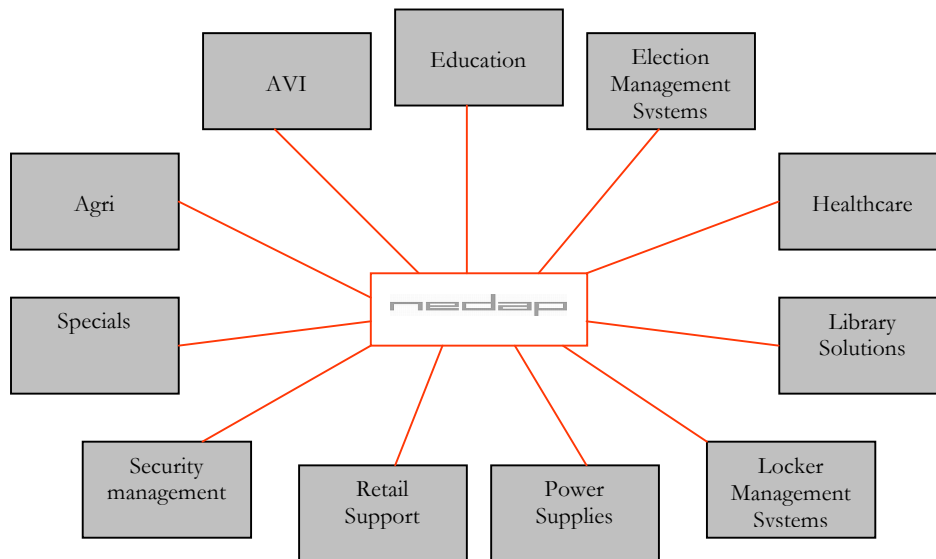


Figure I different market groups Nedap N.V.

All market groups are responsible for their own product development, marketing & sales, purchasing, assembly and shipment. These market groups were created to improve the quality and the speed of the innovation process. This transformation was enabled by clustering all the activities within a market group. Product development, sales and production can cooperate naturally to adjust the product portfolio to the market's needs.

Due to price pressure and increase of scale Nedap has been forced to outsource parts of the production. Besides a production site, Nedap N.V. has subsidiaries, which are in charge of sales activities within the Netherlands and abroad. This enables Nedap to emphasize on innovation in

the Groenlo headquarters. Depending on type of product and sales quantity the production has been outsourced all over the world. After persistent problems with suppliers concerning the assembly of printed circuit boards for the market groups Specials and Power Supplies, Nedap started to look for a producer who can meet the expectations of Nedap regarding flexibility, quality and price. The company was not able to find any appropriate candidate at this particular stage which urged Nedap to start its own production company (Inventi) in the region, which should be able to meet the expectations.

Inventi

The production site Inventi absolutely needs to guarantee competitive prices, good quality and a high level of flexibility, which is primordial for competing with the cheapest producers in Europe. The company should be able to offer their products for the same prices as the cheapest producers. Inventi choose an innovative approach to achieve this position. On the one hand they choose to work with minimum wage earners. These are young people who had all kind of problems in education and other areas. Nevertheless, this is a high potential group of employees. The organization also employs ‘Hamelanders’. This term refers to people, working for the sheltered work organisation Hameland, with intellectual or psychological limitations who need additional care in their work situation. On the other hand, Inventi encourages its employees to initiate bright and stimulating ideas to improve the product quality and the production process. This requires close contact with the Nedap market groups and loyal and dedicated employees. Finally this will result in a flexible production site which produces quality products for reasonable prices.

The following figures visualize the evolution of the market group idea from the original idea towards the current situation. The yellow boxes within the blue boxes refer to activities and tasks.

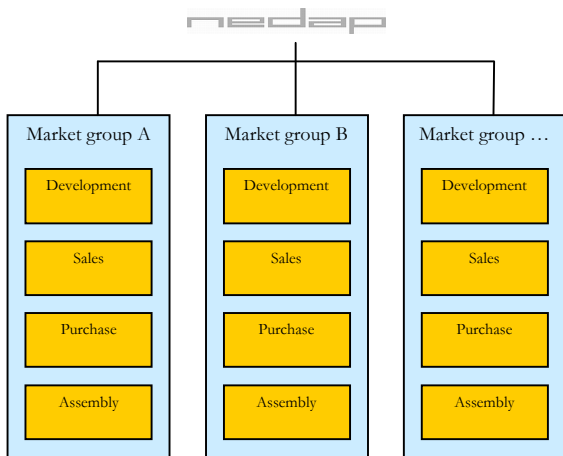


Figure II: Initial structure market groups

The activities of the market groups were clustered to achieve the intended natural collaboration. Each market group executes its own development, sales, purchase, assembly and supporting activities (see Figure II).

Figure III displays the outsourcing phase. Because of the reasons mentioned before, some market groups outsourced several purchase and production activities, which resulted in a gap between the market group and its production. The arising gap conflicts the original market group idea.

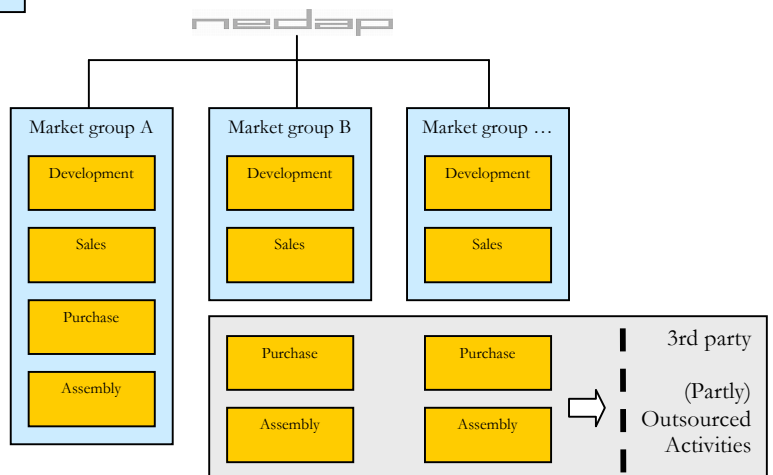
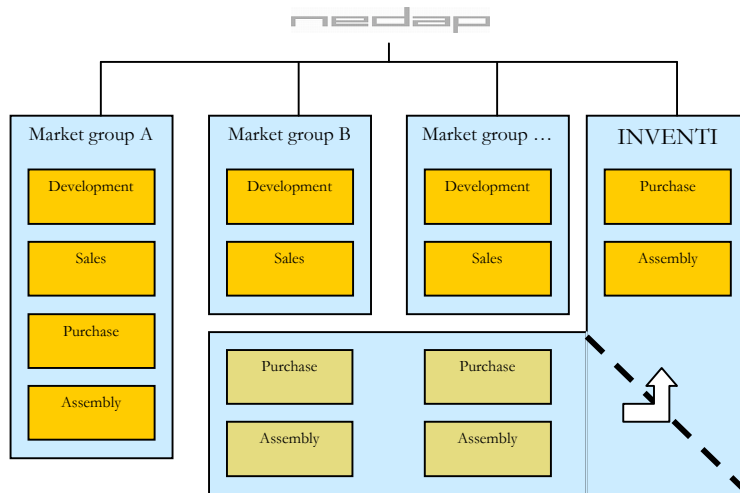


Figure III: Structure activities market groups before Inventi

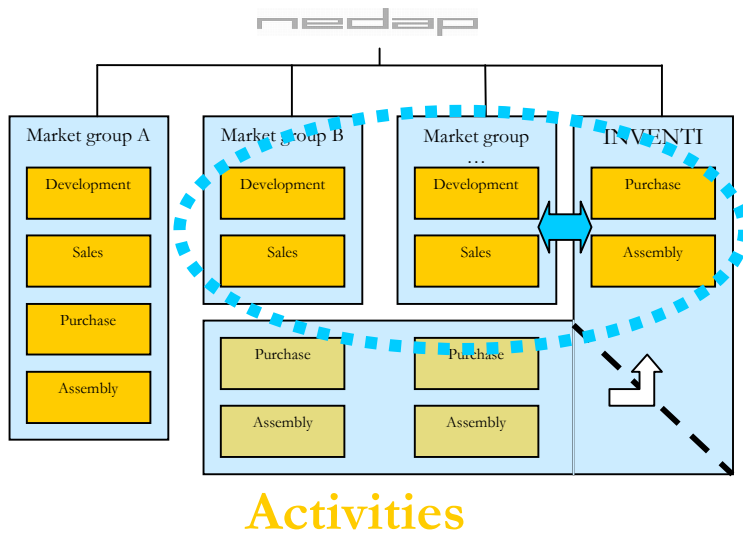


Through the foundation of Inventi, Nedap N.V. reintegrated the production activities in the company. These activities are not physically located in the market groups, but in the subsidiary Inventi (see figure IV). The shift is shown by the bent arrow.

Figure IV: Structure activities market groups with Inventi

The reintegration of the production in the company should lead to further improvement. Nedap has to benefit from this organizational change by considering Inventi as a reliable, flexible and inexpensive supplier. Moreover, it needs to look upon Inventi as a partner in product and process development. Therefore, the communicational and organizational structures between both organizations have to be optimized. Improvement of these structures can ensure new opportunities such as innovation and growth in the near future. Nedap intends to transfer production capacity from Groenlo and other production sites to Inventi (Doubling the capacity of Inventi in the next year).

The intended connection is visualized in figure V:



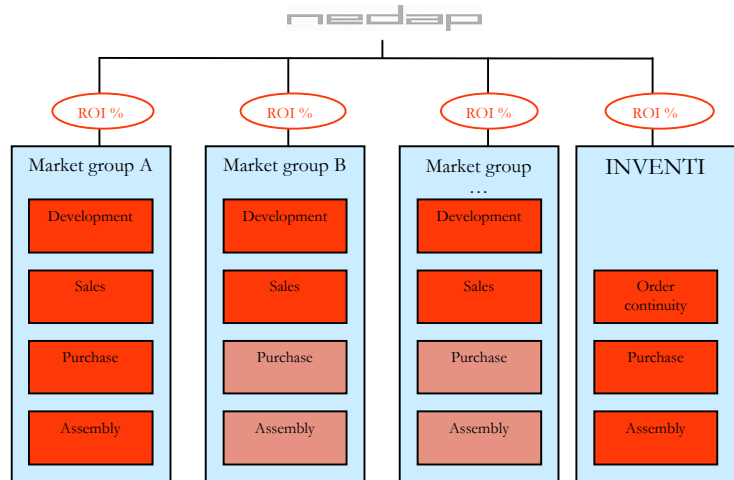
The activities, which require cooperation, are encircled by the dotted line. The horizontal arrow symbolizes the interaction between production/purchase and development/sales.

Figure V: Connection Inventi & Nedap market groups regarding to the activities

One of the principles of Nedap is to give the working staff high responsibilities. The general thought is *empowering people gives them the opportunity to initiate ideas and will enable them to deliver a higher performance*. Furthermore it is more likely to innovate radically if employees enjoy freedom. With these principles in mind, it is not likely that Nedap is inclined to force market groups to cooperate with Inventi. Market groups are free to choose products, costumers and suppliers that they want. Consequently, if a market group experiences that other suppliers are performing better, it will outsource its production activities elsewhere. Furthermore, Inventi is responsible

for its own profitability. Nedap cannot guarantee a constantly filled order map. As market groups are empowered to select a suitable supplier, Inventi is responsible for its own attractiveness to the market groups.

Summarised; in the interest of Nedap N.V., Inventi and the market groups should cooperate to achieve excellent performing market groups with high returns and great product innovations, besides an inexpensive manufacturer. Based on the vision of Nedap N.V., this can only be realized by categorize both, Inventi and market groups, as investment centers. Inventi uses 'full-cost transfer prices' for its products. All investment centers are responsible for their own return on investment (ROI) and are empowered to realize the intended returns (huge investments should be made in consensus with the corporate management). For a brief overview of the responsibilities distribution see figure VI.



Responsibilities

Figure VI: Responsibilities market groups and Inventi regarding

ROI and are empowered to realize the intended returns (huge investments should be made in consensus with the corporate management). For a brief overview of the responsibilities distribution see figure VI.

Appendix II Overview of interviews and introduction to market groups

INVENTI (IN)

Function	Date	Code
General Manager	July 23, 2009 (e.g.)	IN1
Manager Protec	July 14, 2009	IN2
Manager Inventi I	June 12, 2009	IN3
Purchaser Inventi	July 7, 2009	IN4

MARKET GROUPS

Retail Support (RS)

Function	Date	Code
Production Responsible	5 June 2009	RS1
Electronic Engineer	14 July 2009	RS2
Coordinator R&D and designer	14 July 2009	RS3

Energy Systems (ES)

Function	Date	Code
Market Group Manager	November 11, 2009	ES1
Business Controller	July 2, 2009	ES2
Hardware Engineer	June 6, 2009	ES3
Salesman	July 9, 2009	ES4

Agri (AG)

Function	Date	Code
Market Group Manager	July 7, 2009	AG1
Production Responsible	July 1, 2009	AG2
Production Contact Person	July 20, 2009	AG3
Coordinator R&D	October 1, 2009	AG4

Introduction of researched market groups

In this paragraph introductions of the researched market groups will be provided in order to have a better understanding of them. The market and products of the market groups, the market group's organization and the relationship with Inventi will be summarized.

The majority of market groups are changing their internal organization towards a different policy. This results in organizations, which are more focused on marketing and product development. The market groups are eliminating most of their production activities. Inventi will perform eliminated production activities.

Production was very important in the history of Nedap. The name Nedap is an abbreviation of NEDerlandse APparaten fabriek (Dutch Devices factory). The production facilities were situated at the same location as the employees who are in charge of sales or product

development activities. Communication lines between product development and production were usually very short.

Retail Support

Recently, Inventi started to produce for Retail Support. Retail Support focuses on retail shops. Retail Support is one of the largest market groups of Nedap and provides solutions for control loss prevention, like RFID label identification. Retail Support aims at improving the profits of its retail customers by considering loss prevention as an integrated part of their business process. Nedap was the first company that offered an internet connected Electronic Article Surveillance system (EASi Net). The uniqueness of this system was the possibility to provide retail management with useful information and control.

Retail Support does not have a formalized NPD process. However, this might change in the near future. The relationship with Retail Support is relatively new. Currently, Inventi assembles antennas for entrances, exits and checkouts.

Energy Systems

Inventi is currently producing for the Nedap market group Energy Systems. Since the foundation of Inventi, Energy Systems has been a customer of Inventi. Furthermore several employees of Inventi were working at Power Supplies. Energy Systems is a part of Power Supplies, which implies that several employees are personally involved with Energy Systems. This resulted in a strong relationship between Inventi and Energy Systems.

Energy Systems focuses on a new product concept, called the PowerRouter. Energy Systems presents it as follows: “The PowerRouter combines energy from various renewable sources, routing energy bi-directional when and where it is needed, i.e. to battery storage, grid, generator or consuming devices. Route power for industrial or residential supply with ease” (Nedap Energy Systems, 2009).

Energy Systems uses a formalized process of product development. Inventi will start the production of the PowerRouter at the end of this year. Energy System is a relevant and interesting market group for this research because of the market, the organization, the long-term relation as well as the intended ramp-up for production.

Agri

Nedap Agri develops, produces and markets automation for the animal husbandry worldwide. Nedap Agri enables meat- and milk producers to use their resources in an effective way by automating vital processes like feeding, milking and oestrus detection. By allowing individual animal management on large-scale farms, higher production results per animal are achieved.

Currently Inventi produces one product for Agri, the Lactivator, which enables oestrus detection. The product is produced in high production quantity. In the near future Inventi might produce more products for Agri.

Agri has more experience with outsourcing production activities. It has a strategy to restrict the in-house activities to the vital production chores. In the future Agri might consider to outsource its production to Inventi.

Appendix III Interview protocol

Interview protocol leveranciers betrokkenheid

Marktgroepen

Als leverancier van diverse marktgroepen van Nedap heeft Inventi de wens kenbaar gemaakt om eerder betrokken te worden bij de ontwikkeling van te produceren producten van de marktgroepen. Deze betrokkenheid kan leiden tot een betere dienstverlening door Inventi en uiteindelijk resulteren in een lagere kostprijs. Inventi verwacht vooral winst te behalen bij het selecteren van componenten in de ontwerpfase en het laten aansluiten van de ontwerpen aan de productie faciliteiten van Inventi. De verwachte resultaten zijn voor zowel de marktgroepen als Inventi interessant.

Dit interview vindt plaats om meer inzicht te krijgen in de wensen van de marktgroepen, de mogelijkheden voor samenwerking en de huidige manier van product ontwikkeling van de marktgroepen. Met productontwikkeling wordt specifiek de ontwikkeling van het fysieke product bedoeld en minder de ontwikkeling van een dienst of software.

Algemeen

- a. Kunt u kort omschrijven wat uw functie is en welke taken daar primair bij horen?
- b. Wat u de typerende punten noemen waarin uw marktgroep onderscheidt van andere marktgroepen?
- c. Kunt u aangeven wat uw rol is binnen product ontwikkeling van uw marktgroep?
- d. Hoe staat u tegenover het betrekken van Inventi in de ontwikkelingsprocessen van de marktgroep?
- e. In hoeverre wordt een samenwerking tussen Inventi en de marktgroep gesteund of aangemoedigd door de leiding?

Productontwikkelingsproces en Inventi's betrokkenheid

1. Wordt het ontwikkelingsproces begeleid door formele documenten of procedures? (mochten er document beschikbaar zijn, dan zou ik indien mogelijk graag een kopie willen ontvangen.)
2. Kunt u in enkele zinnen omschrijven wat uw verwachtingen zijn van het betrekken van Inventi tijdens productontwikkeling?

Gedurende het volgende gedeelte zal een veralgemeniseerde product ontwikkelingsprocedure als richtlijn dienen. Deze is te vinden achteraan deze vragenlijst. We zullen toetsen of de gehanteerde procedure van de marktgroep te vertalen is naar deze procedure en de verschillen bespreken.

Vervolgens zal per stap een drietal dimensies besproken worden:

1. Inventi's bijdrage
2. Inventi's taken
3. Inventi's verantwoordelijkheden

Overige vragen

De meeste aandacht gaat uit naar de feitelijke productontwikkeling, maar ook lange termijn verwachtingen kunnen worden besproken met de leverancier. Hierin kan besproken worden wat voor soort producten worden verwacht in de toekomst en welke technologieën of productiemiddelen daarvoor nodig zijn. Hierdoor kan de leverancier beter inspelen op de behoefte van haar klanten in de toekomst, door bijvoorbeeld kennis van bepaalde productie technieken in huis te halen. De leverancier kan ook de klant informeren over trends in de markt wat betreft productie technieken. De klant kan deze kennis gebruiken in toekomstige producten.

3. Ziet u het nut van het regelmatig bespreken van lange termijn verwachtingen en de ontwikkelingen in de markt? Zou u of uw collega's medewerking willen verlenen voor dergelijke besprekingen?
4. Heeft de cultuur binnen Nedap en de specifieke relatie met Inventi invloed op de samenwerking? Zo ja, waar uit zich dat in?
5. Waar liggen de mogelijke knelpunten met betrekking tot het betrekken van Inventi in het ontwikkelingsproces?
6. Heeft u nog iets toe te voegen of is een aspect onderbelicht gebleven in de voorgaande vragenlijst?

Bedankt voor uw medewerking!

Veralgemeiseerd NPD proces Nedap



	Stap 1	Stap 2	Stap 3	Stap 4	Stap 5
Titel	Functionele specificatie	Concept ontwerp	Detail ontwerp	Productie ontwerp	Vrijgave/SOP
Activiteiten	De functionele eisen van het product worden bepaald of zijn bepaald door de opdrachtgever.	Technologische keuzes worden gemaakt: (bij Nedap elektrische oplossing) Onderverdeling hardwarematig (elektrisch/mechanisch, en software matig. Kostprijs wordt ingeschat.	Concretiseren van concept. Detail uitwerking van hardware, software en mechaniek. Vaak wordt een projectteam samengesteld.	Productie ontwerp wordt bepaald. De benodigheden en inrichting voor fabricage worden bepaald. Programma's worden geschreven. Nul series worden gedraaid.	Het beheer van de configuratie wordt vastgesteld. 'Start of production' punt. De productie is volledig overgedragen aan producent.
Uitkomsten	Documentatie	Vooraf documentatie	Prototype	Productie plan met daarin instructies, programma's en keuringen.	Beheersplan/ €

(Deze stap kan meerdere repeterende slagen bevatten om uiteindelijk aan de functionele eisen te voldoen. Hierin kunnen ook voorlopige modellen of "spinnenkoppen" voorkomen.)

(Deze stap kan meerdere repeterende slagen bevatten om uiteindelijk het product goed en betrouwbaar te reproduceren.)

NB1: Deze procesbeschrijving heeft als doel om per stap de gewenste bijdrage, taken en verantwoordelijkheden van Inventi te inventariseren bij de verschillende marktgroepen alsmede bij Inventi zelf.

NB2: De stappen zijn sequentieel aangegeven, maar kunnen in praktijk ook gedeeltelijk parallel of overlopend uitgevoerd worden.

Appendix IV Indicated similarities and gaps

Both, Inventi and the market groups agree to allocate the following NPD dimensions related aspects to Inventi:

Similarities between Inventi's preferences and market groups' preferences

Similarities between Inventi's preferences and market groups' preferences			
	Subject	Similarity Inventi and market group	
TASKS	1	Strategic and bottleneck components	Support in selection of strategic components (only Retail Support)
	2	New production technologies	Joint selection of new production technologies and equipment
	3	Prototypes PCB	Inventi has to produce the PCB prototypes
	4	PCB production process	Inventi has to develop the PCB production process
	5	Final assembly production process	Inventi has to develop the final assembly production process (only Retail Support and Energy Systems)
	6	Test equipment development	Inventi has to be involved in test-equipment development or will perform this development task
	7	Documentation	Inventi has to be in charge of instruction and other production specific documentation
	8	Agreements	Retail Support and Energy Systems accept Inventi's service level agreements
	9	Start of production	Inventi will be in charge of the start of production
RESOURCES	Subject	Similarity Inventi and market group	
	A	Non-critical and leverage components	Inventi has to provide a preferred component, distributor and manufacturer list for non-critical and leverage items
	B	Production technologies	Inventi has to inform market groups about the possibilities of its production facilities
	C	DFM knowledge	Inventi has to providing its specific DFM preferences
	D	Production facilities	Inventi has to allocate production facilities and time for prototyping and process development tasks
	E	Testing knowledge	Inventi has to allocate its experiences with test equipment development
RESPONSIBILITIES	Subject	Similarity Inventi and market group	
	I	Functional specifications and basic design	Both, Inventi and the market groups wish to split up the responsibilities in NPD projects. The market groups will be in charge of the first NPD steps. Inventi will be in charge of the last NPD step(s). The market groups have to be in charge of the functional specifications and basic design steps
	II	Production ramp-up	Inventi has to be in charge of the production ramp-up NPD step

Besides the similarities, gaps between Inventi’s and the market groups’ preferences are noticed. The differences have been presented in the results chapters (4-5). These gaps will be summarised in the table below.

Gaps between Inventi's and the market groups' preferences

Gaps between Inventi's and the market groups' preferences				
	Subject	Inventi	Market group	
TASKS	1	Procurement of samples	Procurement of samples of components by Inventi	Procurement of samples of components by market group
	2	Strategic and bottleneck components	Support in selection of strategic components	Support will not be allowed (ES,AG)
	3	DFM of PCB	DFM analysis of PCB in project team	DFM analysis of PCB during prototyping
	4	DFM of final assembly	DFM analysis of final assembly in project team	No DFM analysis of final assembly by Inventi
	5	Test strategy	Involvement in determination of test strategy	No involvement in determination of test strategy
	6	Final assembly production process	Inventi determines final assembly production process	Agri determines final assembly production process
	7	Service level agreement	Formalized agreements in SLA	No formalization of agreements
	Subject	Inventi	Market group	
RESOURCES	A	Strategic and bottleneck components	No need for allocating specific list	Preferred distributors and manufacturers list for strategic and bottleneck components
	B	DFM knowledge	General DFM knowledge	No need for general DFM knowledge
	C	Testing knowledge	Test strategy development knowledge	No need for test strategy development knowledge
	Subject	Inventi	Market group	
RESPONSIBILITIES	I	Production process design	Inventi wants to be responsible for the production process design step	Agri will not allow Inventi to be completely in charge of the production process design step. Retail Support will keep the test equipment development in-house and will keep the related process responsibility