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bugaboo

BUGABOO

ENGINEERING CHANGE MANAGEMENT
'VARIABLES, DECISION CRITERIA AND PRIORITIZATION OF ECR'S'

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Preface

To conclude a bachelor study at the University of Twente a research has to be conducted. This is the motive for writing this report. After this bachelor thesis is approved, I conclude my bachelor study of Business Administration.

This bachelor thesis is a result of many months of hard work. I started my internship at Bugaboo from the beginning of September to end December 2011. The internship consisted mainly of the creation of product dashboards for the sustaining products of Bugaboo and of gathering data for this bachelor thesis. After I came back from Xiamen I started with my master Financial Management and with finishing this thesis.

The internship was a great experience for me. Living and working in China is the best way to discover a total different culture compared with the Netherlands. China is a big growing economy which was fascinating to see during my internship at Bugaboo. I am very satisfied with the report and I'm sure that it can help Bugaboo with improving their Engineering Change Process.

To conclude, I wish to thank my supervisors from the University of Twente, Drs. J. Veldman and Drs. ir. P. Terlouw, and my managers from Bugaboo R. Smeding and A. Jansen. The supervisors helped me a lot with the academic background and structure of this thesis and without the practical background from Bugaboo it would be much more difficult to acquire the results I now have. I hope you will read this report in order to obtain useful insights regarding the Engineering Change Process at Bugaboo.

Kind Regards,

Jasper Veurink

Management Summary

This thesis is written for Bugaboo and focuses on the area of Engineering Change Management within companies. The research is executed through an internship at the production facility of Bugaboo in Xiamen (China) and partly at the Head Quarter of Bugaboo in Amsterdam.

Engineering Change Management (ECM) is a general concept within many companies in order to manage and coordinate Engineering Changes (EC) to products, parts or services. The process of ECM has effect on many different levels within a company and is therefore seen as disruptive to the normal routine process. It mainly starts with an Engineering Change Request (ECR) which can have effect on quality, cost price, outlook etc. of a product. These changes are considered as important because the output of these ECR's have direct effect on the products that are responsible for the revenue of a company.

This thesis focuses on the ECR process within Bugaboo regarding the sustaining products. The latter refers to products that are currently sold in the market. The main problems within the ECR process of Bugaboo are threefold. There is insufficient information for assessment on ECR's. The description of ECR's is too short and there are no good or reliable business cases of ECR's. A second problem is that there are no decision criteria within the company to assess these ECR's. It is therefore unknown when ECR's should be accepted or rejected. The third problem is that there are too many accepted ECR's which results in the fact that there is insufficient capacity to work on these ECR's. Prioritization of accepted ECR's is therefore required but a good and fixed methodology to support this process is missing.

In this thesis, the three problems are analyzed through literature research and interviews with different actors of the ECR process. The aim is to design solutions that solve the problems mentioned above. A new business case is designed in order to support assessment of the profitability of ECR's. To judge whether an ECR is profitable or not, the variables 'effort' and 'added value' of ECR's are considered. With this business case, more vital information is available of ECR's. This information supports decision making on ECR's but also the prioritization of ECR's. The second solution is the creation of decision criteria which are based on the product goals of the sustaining products and the profitability of ECR's through the concepts 'Cost of Waiting' (COW) and 'Pay Back Time' (PBT). ECR's should always reflect the product goals of the products, otherwise they will be rejected. Besides that, investments need to profitable within a certain time, otherwise it can be too risky. Therefore, the concepts COW and PBT are introduced on which the ECR's can be assessed as well.

The third designed solution is a methodology to support prioritization of ECR's in order to create transparency about what ECR's have the greatest impact on the company. Bugaboo wants to implement investments which have the greatest positive impact on their products. Assessment of approved ECR's is therefore required in order to recognize the ECR's which are the most profitable. This is the basis for the suggested solution of a prioritization methodology. The last designed solution concerns the ECR process. This process is partly redesigned in order to implement the designed solutions of this thesis.

List of abbreviations

BXM	Bugaboo Xiamen
CT	Core Team
CCB	Change Control Board
DLE	Deputy Lead Engineer
EA	Engineering Asia
ECM	Engineering Change Management
ECN	Engineering Change Note
ECO	Engineering Change Order
ECR	Engineering Change Request
EC	Engineering Change
LE	Lead Engineer
NC	Non Conformance
QE	Quality Engineering
SPM	Sustaining Project Manager

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1. Introduction of Bugaboo and their sustaining products

1.1. Introduction of Bugaboo

Bugaboo is a Dutch company which started its production in 1999 with a totally new stroller concept designed by Max Barenburg who graduated at the University of Eindhoven with this project in 1994. After graduation he tried to sell his concept to several stroller companies but there was not any interest for it so he decided to make the first prototype by himself. Together with investor Eduard Zanen he introduced the stroller in the market. Nowadays, Bugaboo is selling their strollers in Europe, America, Australia and Asia.

Figure 1, Xiamen and the factory of Bugaboo

Bugaboo's Head Quarter is settled in Amsterdam with about 150 employees. Their products are produced in their factory in Xiamen, China (fig.1). About 700 employees are working in Bugaboo Xiamen (BXM). Bugaboo only produces the fabrics of the stroller 'in-house', all the other parts are produced by suppliers in China and also in Taiwan. Bugaboo started their production in Xiamen in 2008. At the beginning the production hall was situated in Taiwan. That's one of the reasons that they still have contracts with suppliers in Taiwan. Besides that, Xiamen is situated right in front of the border of Taiwan so the distance is still relatively short. The different parts (except the fabrics) are brought to Xiamen and assembled in the factory. This means that they have two production lines in China: an assembly line and a stitching line.

1.2. Sustaining Products Bugaboo

Within Bugaboo, two types of products are developed. The New Product Development (NPD) consists of the products which are not yet on the market but are still in development. These products can be in the designing or testing phase but are not sold to the market. The Sustaining Products are the current products which are already on the market and are responsible for the revenues of

Bugaboo. This thesis focuses only on the sustaining products which are outlined below.

Bugaboo produces three different kinds of strollers, shown in the picture below, and accessories for these strollers. The Cameleon is the oldest Bugaboo stroller and is responsible for a major part of the revenue which makes it a very important product for Bugaboo. The Cameleon can be seen as a more general stroller intended for all areas due to the possibility to transfer the stroller into different positions for each area (different areas are for example the beach, city and the mountains).

The Bee is developed as a compact and nimble stroller which is ideal for being mobile in the cities. The last one is the Donkey which is launched in the market last April. The Donkey has the possibility to change from a one seat stroller to a two seat stroller. The accessory product line contains of products which can be used for the Bee, the Donkey or the Cameleon. E.g. parasols, sun caps, seat liners or new fabric sets to give the stroller a totally new outlook.

The sustaining products each have their own core team which is responsible for the management of the products, hence there are four teams in total. The leaders of these core teams are the product managers, together with a lead engineer, the head of compliance and quality, and a sustaining project manager (SPM). To support the core teams, sustaining teams that consist of three or four engineers are composed to support engineering changes to the strollers. The different core teams have their own product goals and plans which are mostly generated on a yearly basis.

Figure 2, Sustaining product, from left to right: Bee+, Cameleon, Donkey

Bugaboo wants to “sustain” their existing products to keep them on a certain level. Sustaining examples are quality, costs and service. During the lifecycle of the products, the products change or have to change due to different reasons. Examples are mold changes, durability, safety issues, compliance issues but also cost savings, improving production efficiency etc. For implementing such a change, the manufacturing of the product has to change. Many companies, and also Bugaboo, have an Engineering Change Management (ECM) process to manage those changes within the whole organization. A process is required because the changes have impact on most departments within the company and are seen as disruptive to the normal routine process.

To initiate a change about a product within the organization of Bugaboo, an Engineering Change Request (ECR) is needed. An ECR relates to an initiation for a change to a product, part or drawings of new product design that were previously released for production. At Bugaboo, the requests are discussed firstly by a Change Control Board (CCB) in Xiamen with members from different

departments. They can accept or reject ECR's only in order to meet cost or manufacturability requirements, like productivity, quality and lead time improvement, without impact on outlook, product performance, safety, reliability or maintainability. ECR's that affect the product itself, for example the outlook, have to be approved by the core teams. The ECR's that can be approved by the CCB are more production oriented but these decisions are still the responsibility of the core teams.

Common questions for companies concerning the ECR process are when to approve or reject an ECR and according to what criteria ECR's will be assessed. Another issue is capacity problems for dealing with those ECR's which forces companies to make choices about which ECR's need to be done first or to be stricter during judgement. Decision making about ECR's and the prioritizing of those ECR's are the key points of this thesis. In the following chapter the problem definition and goals of this research are pointed out.

In this chapter an introduction of Bugaboo and their products was outlined. Furthermore, the different teams were introduced shortly and a brief explanation of Engineering Change Management was given. In the next chapter the research problem, goals and objectives of this thesis will be discussed. Besides that, the research questions and the research structure will be explained.

2. Problem identification, goals, objectives, research questions and structure of the thesis.

2.1. Problem definition & goals

According to van Aken et al. (2007) a problem can be defined as a state of affairs in the real world with which important stakeholders are dissatisfied, while they believe that things can be improved. The problem definition and goals of this thesis are explained and outlined below.

An ECR can be raised by anyone within Bugaboo, in the Netherlands and in Xiamen. The production plant is situated in Xiamen; therefore ECR's initiated in China are more often production oriented. Examples are: improvements to the production process or a decrease of labour or material costs. The employees in the Netherlands focus more on service issues because they receive feedback from customers every day or face compliance issues due to new regulatory.

The ECR's are managed by a Sustaining Project Manager (SPM) in Xiamen who discusses the different requests during a meeting with the Change Control Board (CCB). The initiator of an ECR has to make a form to explain why the Engineering Change is needed. The information received from the initiators (from Xiamen and NL) is currently insufficient to support decision making on ECR's. Examples of this lack of information are: vague business cases, unclear what the specific effects of an ECR are to a product (output of the ECR) and what the workload is to implement the ECR (input of the ECR). The information about the 'input' and 'output' of an ECR is important during decision making. If for example the workload and the investment are considered as 'high' and the output, like quality, is 'low', it would be obvious that the core teams will reject the ECR. During decision making, clear criteria are important to make sure the decisions are in line with the goals or plans of the company. As mentioned before, the core teams want to achieve their product goals. These goals are assumed to be important for the products and for the company as well. They are presented yearly to the management team of Bugaboo who approve the goals of the core teams and will finally assess the teams if they reached their goals at the end of the year. Therefore, the criteria for decision making should reflect these product goals.

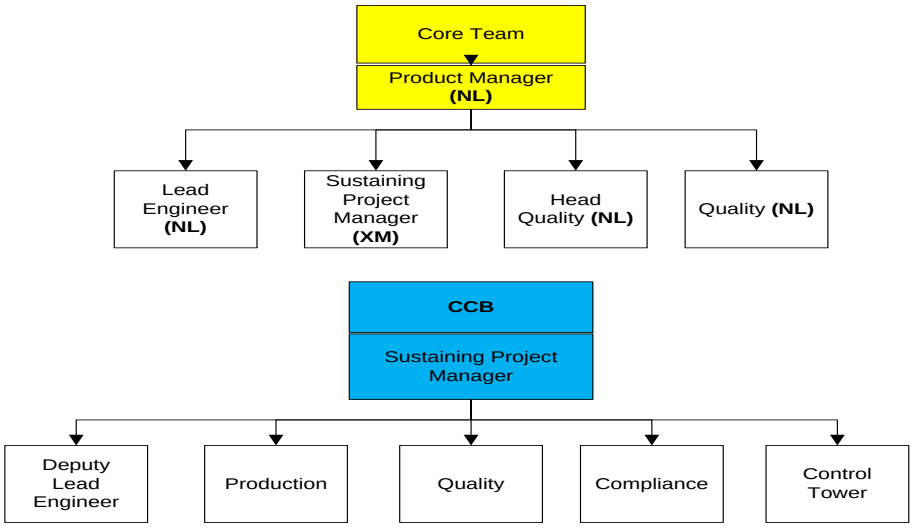

Figure 3, Organic structure of the CCB and the Core Teams

Currently, the criteria to make decisions about ECR's are not clearly defined and unavailable for employees within the company. This results in the fact that low or non-added value ECR's are requested and even accepted.

Figure 3 gives a good understanding of how the CCB and the core teams are organized. The different roles of the members of the teams are outlined further in this thesis. Important to explain at this point is that all the members of the CCB are situated in Xiamen and the members of the core teams are settled in the Netherlands with exception of the SPM. The SPM is member of both the CCB and the core teams and is also leader of the CCB. Furthermore, the sustaining teams who have to support the core teams with changes to the product are situated in Xiamen as well and consist of three engineers.

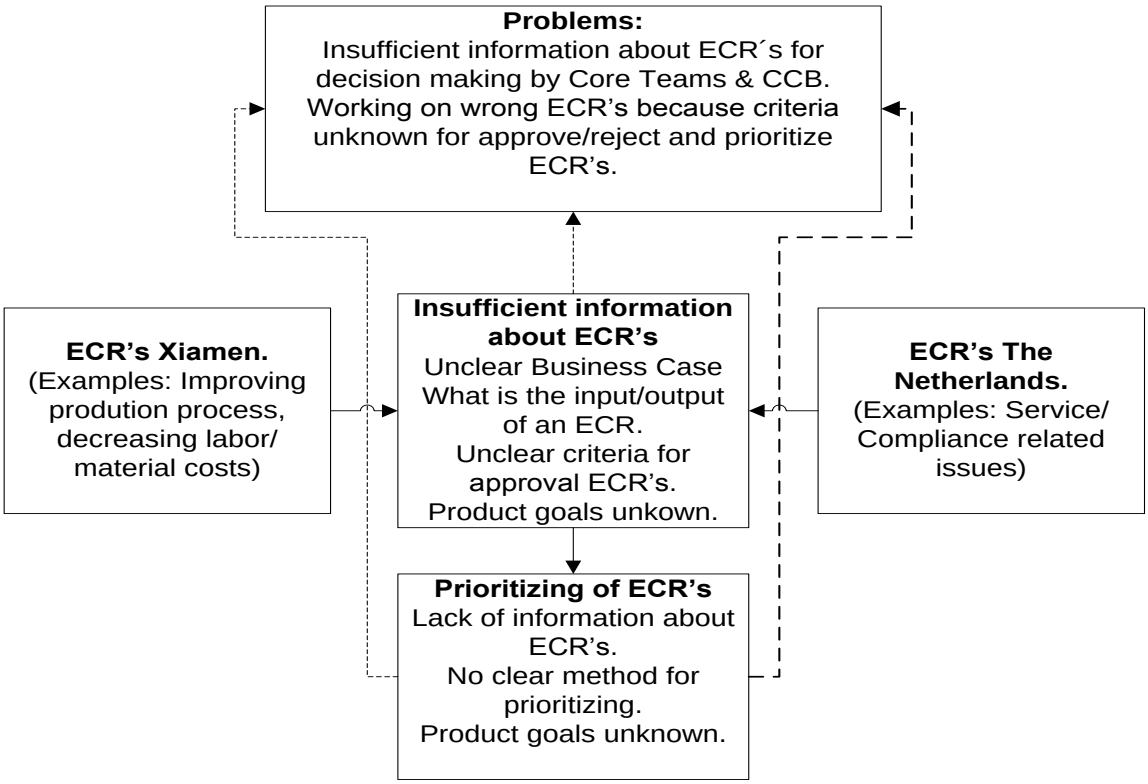

Figure 4, The 'problem mess'

The decisions and assessment on ECR's are executed by both the CCB and the core teams. The CCB is authorized by Bugaboo to be the final decision maker about production oriented ECR's. Still, the core teams are responsible for all decisions on ECR's and therefore also for the decisions of the CCB. Communication and alignment on the assessment of ECR's between the teams is therefore important. According to this, it is essential for the core teams that the CCB acts according to their product goals, to make sure the decisions on ECR's are related to these goals. This is currently not the case because the product plans are unknown for the CCB and they do not work according to the product goals at all.

The different core teams have their own sustaining teams to work on the different ECR's together with other departments like quality and compliance. The sustaining teams are situated in Xiamen.

Not all approved ECR's can be assessed directly which means the core teams have to prioritize which one to do first. Prioritizing is important for the core teams because they want to implement ECR's that have the greatest impact on their product goals. The core teams can, for example, strive for a higher quality of their products and thus, prefer to implement ECR's with a high impact on quality. The important actors to 'steer' the teams and to prioritize according to the product goals are the SPM and the lead engineers. The SPM because she is working together with the teams in Xiamen closely and the lead engineer because he is the functional leader of the DLE.

One of the problems during prioritizing of the accepted ECR's is that it is hard to compare the different ECR's with each other. The 'output' and 'input' of the accepted ECR's are unknown which creates uncertainty on which ECR's the sustaining teams have to work. The teams consist of members who are situated in the NL's and in Xiamen who both have their own view on which ECR has the greatest impact on the product. Because of the lack of information about the ECR's, including on what criteria they are assessed, employees are more driven to implement the ECR's raised by themselves because they experience the problem/cause on which the ECR is raised every day. This makes it hard for the product managers to prioritize the ECR's. They do not have enough information about the ECR's and get input from two different views about which Engineering Changes have the greatest impact on their product. To 'steer' the sustaining teams, prioritization of the accepted ECR's by the product managers is important. A fixed methodology to support the core teams to prioritize is not available within the company. This methodology is needed to create transparency and clarity for employees to understand why and how prioritizing decisions are made.

The key problems of this research are stated in the upper box of figure 4. There is insufficient information about ECR's to support the core teams and the CCB by their decisions and the criteria to assess these ECR's are unclear. This results in the fact that low or non added value ECR's are requested and approved. Besides that, there is no method to prioritize the accepted ECR's. Therefore, within the company, it is unknown which ECR's have the greatest impact on the product goals.

2.2. Objectives of the research

The goal of this research is threefold. The first one is to identify measurable criteria about ECR's to be used for the assessment of ECR's. Measurable variables which can be used during the ECR process to assess the different Engineering Change Requests. The second one is to create clear criteria for approval of ECR's according to the variables of the specific ECR which reflect the product goals of the sustaining products. The last one is to create a prioritizing methodology with which ECR's will be approved and executed based on criteria that reflect the product goals of the sustaining products. The methodology and rules are a guideline for the core teams in order to assess which accepted ECR adds the highest value to their product. In order to be a useful guideline for the core teams, it should give fixed rules to analyse the accepted ECR's and a fixed method on which these ECR's will be prioritized.

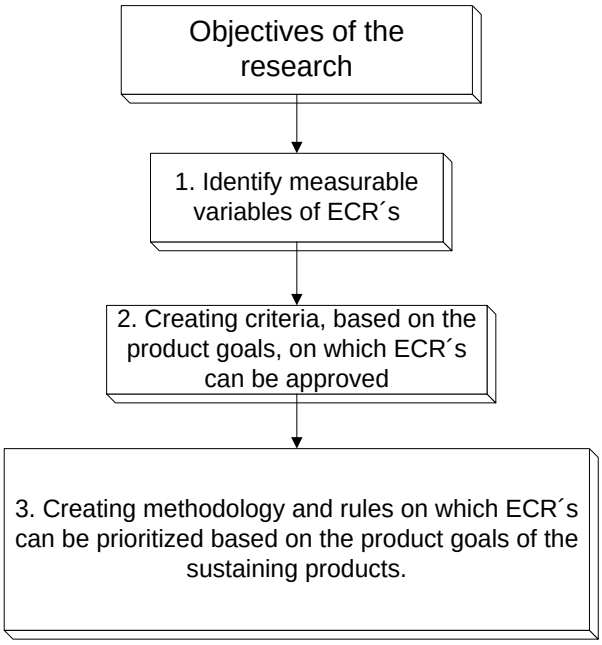

Figure 5, The research objectives

2.3. Research Questions

In this paragraph the research questions are defined to support the different goals mentioned in the previous paragraph.

1. What is the current ECR process? Who is involved in this process and based on which variables and criteria are ECR's approved and assessed? What kinds of problems occur during the current process?
2. Who is prioritizing the ECR's for the sustaining teams and how do they do that? Based on which criteria do they prioritize and what difficulties do they experience?
3. What are the product goals of Bugaboo, how are they defined and communicated within the company?
4. What measurable variables of ECR's must be available to support assessment and decision making on ECR's?
5. What criteria, derived from the product goals, can be used for the assessment and decisions on ECR's?
6. What methodology and rules can be defined to prioritize accepted ECR's according to the product goals?

A short note about the questions is defined below.

1. Based on theories of Engineering Changes the current ECR process will be defined and analysed. The differences between the described processes derived from the literature and the process of Bugaboo are outlined. The method or process how Bugaboo assesses ECR's and the question who is making the decisions within the ECR process is explained. The criteria used to assess ECR's and how these criteria refer to the product goals of the sustaining products is analysed. Further problems or difficulties for the different teams during the ECR process will be described.

2. The ECR's are, as explained before, prioritized by the Core Teams. But is this really the case, or are there other actors in the organization who influence the prioritization of the accepted ECR's? The criteria or methods used to prioritize are described to give an answer on this question.

3. Product goals are created by the product managers. How are the goals defined in the product plans of the sustaining products and are the goals clear for the employees within the organization? Especially the employees who have to deal with the sustaining issues and have to take decisions on ECR's, have to know what the product goals are.

4. The measurable variables and other information which has to be available to support assessment and decisions on ECR's are described. This will be derived from interviews with the employees who execute these assessments and decisions and from the investigated literature. Furthermore it focusses on how Bugaboo can ensure that these variables are available during ECR's as well.

5. Possible criteria derived from the product goals are described which can be used to support decision making. As explained before, these goals are important for the company which is assumed in this thesis as well. Therefore, the created criteria have to reflect these goals.

6. A methodology and fixed rules that can be used to prioritize the accepted ECR's is given and described. Aim is that ECR's which have the greatest impact on the product goals are executed firstly because they are considered as most important for the products.

In the chapter below, the research methodology and data collection methods used for the questions above, are explained.

2.4. Structure of the thesis

In chapter one and the previous paragraphs, an introduction about the company, the problem definition and the research questions and objectives were given. Chapter three will discuss the methodology used for this research. In chapter four the literature found about Engineering Change Management will be outlined. The processes and definitions of Engineering Change Management are discussed in detail in this chapter. Chapter five will focus on the current engineering change process at Bugaboo and the product goals of the sustaining products. Through this analysis, the first three research questions will be answered. The problems stated in the problem definition will be validated according to the data received from interviews and the literature about this subject. In chapter six possible solutions will be designed based on information received from Bugaboo (using interviews) and the literature in order to solve the business problem. The last chapter focuses on the last three research questions.

3. The research design, method and structure of the thesis

3.1. Research design and unit of analysis

Van Aken (2007) mentioned that the literature on methodology distinguishes qualitative from quantitative research methods. Creswell (2008) state that it is also possible to have a mix of quantitative and qualitative research. 'Qualitative research methods are particularly important if one intend to study people, groups, organizations and societies. Some authors define qualitative methods in a more specific manner. For example, it is claimed that a study is qualitative when the research data consist of texts of which the textual nature is retained in analysis.'(Van Aken et al., 2007) Graham Gibbs (2002) defined qualitative research in a number of different ways:

- by analysing experiences of individuals or groups,
- by analysing interactions and communications,
- by analysing documents or similar traces of experiences or interactions.

The nature of this thesis is more qualitative than quantitative. For a good understanding of the business problem, interviews with open questions and observations within the organization of Bugaboo are executed. Qualitative research can provide other views, causes or explanations on the business problem. During this qualitative research, different key actors within the ECR process of Bugaboo are interviewed in order to investigate the possible causes for the problem definition.

After validation of the causes of the problem, possible solutions have to be designed according to the requirements of Bugaboo. Van Aken et al. (2007) defined several specifications for the requirements of a solution design. These requirements consist of functional and user requirements and boundary and design restrictions. These requirements are outlined and captured in a framework at the beginning of chapter six. Later on, these requirements will be used for the evaluation of the designed solutions. The input for these requirements consists of, according to van Aken et al. (2007), three types of input: problem related inputs; model of the current business system; ideas for a possible solution.

The problem related input consists of the validated causes of the problem definition in chapter four and five. Problems which were overseen during the creation of the problem definition but are recognized during the research are also taken into account during the design phase.

'Typically a solution to a business problem is a redesign of an existing system or tool'. (van Aken et al., 2007) It is possible that the solution in this thesis is a redesign of the existing engineering change process of Bugaboo and will be important during the (re)design step in chapter six. The literature can give guidelines to the redesign of Engineering Change Processes. Some authors have studied performance factors of Engineering Change Processes which are useful to consider.

Van Aken et al. (2007) discussed different sources of ideas for possible solutions. Firstly the diagnosis of the causes of the business problem can be used. Secondly is the client organization itself, this will be done through different data collection methods discussed later in this chapter and below in figure 6.

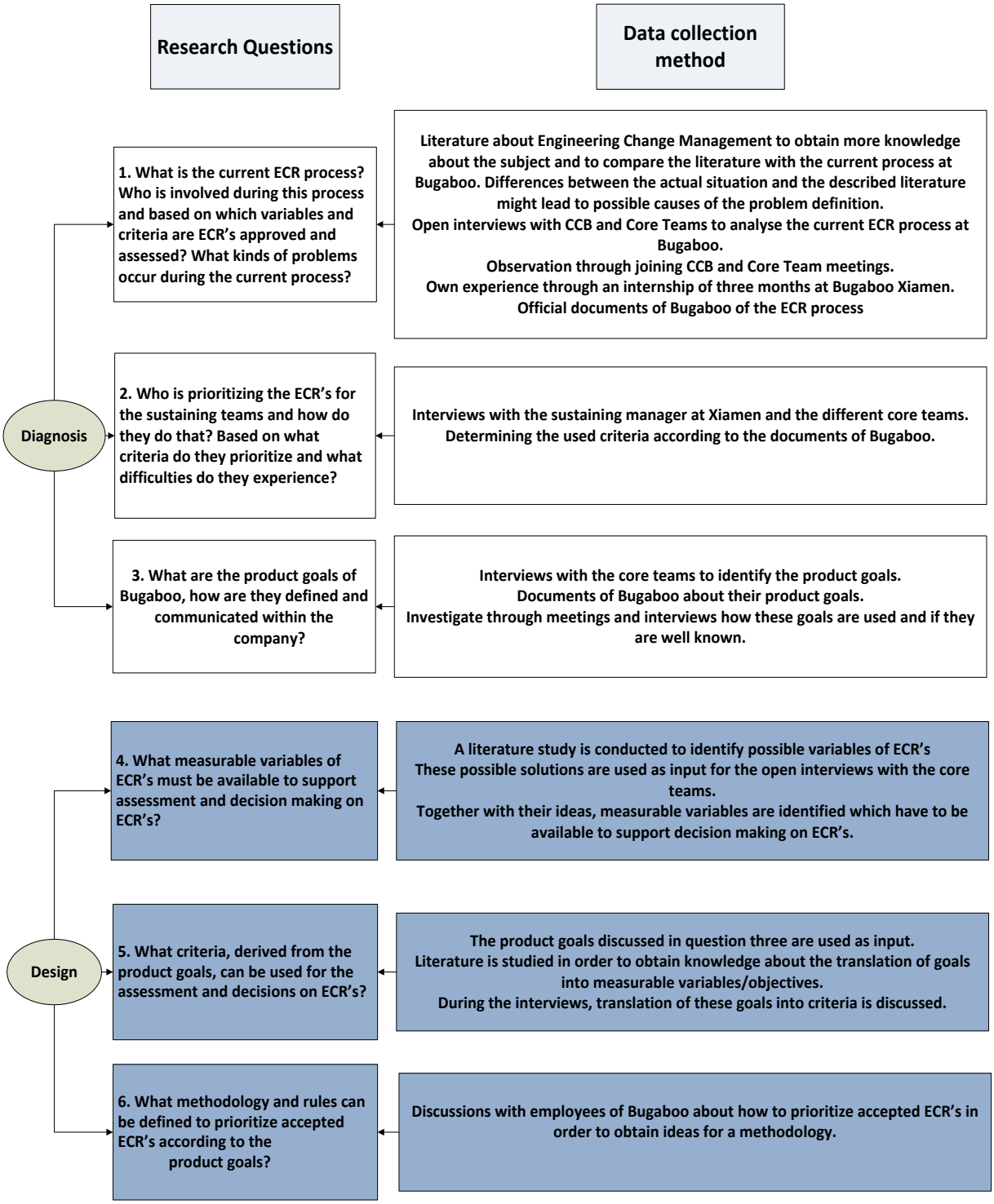

Figure 6, Structure of the thesis

Literature is the last source for ideas for possible solutions. 'In fact both the scholarly and the management literature provide a wealth of solution concepts, and general ideas on how to plan an organize business activities of all kinds'. (van Aken et al., 2007) The different data collection methods used for this research will be discussed in chapter 3.4.2 and in figure 6 is shown which methods are used per research question.

3.2. Unit of analysis

In order to be able to select data and doing the research, the unit of analysis has to be chosen (van Aken et al. 2007). In this thesis, the Engineering Change Management process within the organization of Bugaboo is the unit of analysis. There are several possibilities for gathering data within this process. Examples are the people who are involved and the available documents within the process. The main actors within this process which have to be interviewed are: members of both Core Teams and the Change Control Board. Other employees who can add value to the research will be interviewed as well. Besides that, documentation of the ECR process will be analysed: ECR forms; ECR tracking file; reporting data regarding ECR's; business cases of ECR's; ECR process documentation (e.g. Sop's/flow charts/procedures).

There are several research methods used for this thesis. The different methods will be outlined below.

3.3. Research methods: Literature study and field study

3.3.1. Literature study

Most of the business problems are not new and are already investigated and discussed in the literature. 'Given the long history of management research, it is likely that problems comparable to a specific business problem have been studied already.' (Van Aken et Al., 2007) 'It is inefficient to discover anew through the collection of primary data or original research what has already been done and reported at a level sufficient for management to make a decision.'(Cooper & Schindler, 2006) The literature will not provide all the answers on the questions of the research but it can inform and give possible solutions or causes of the problem definition. To gather the literature for this thesis, articles in scientific journals, conference papers and books will be used.

The data gathered from the literature will be analysed and summarized in chapter four. It provides a better understanding of Engineering Change Management (ECM) within organizations and describes different processes and models to deal with ECM in general. The last is used for comparison with the current process of Bugaboo in order to identify possible causes of the problem definition. Furthermore, the literature can be used as a guide for the design of solutions for the different problems.

3.3.2. Field study through interviews, observations and analyzed documents

The research design, as discussed in paragraph 3.1, is in this thesis more qualitative than quantitative. The gathered data of the field study can provide other views, explanations or probable causes of the problem definition on the final solution or redesign. There are many different types of qualitative data. ´The most common form of qualitative data used in analysis is text: this can either be a transcription from interviews or field notes from ethnographic work or other kinds of documents.'(Gibbs, 2007) The different types of data collection methods used for this thesis are outlined in the paragraphs below.

3.3.2.1. Interview

Interview is, in business problem solving projects, one of the main methods of data gathering (van Aken et al., 2007) and is also used in this thesis. Preparation of the interviews is important. 'First one needs to formulate one or more overall research questions, then draw up a list of possible

informants, both inside and outside the client organization, and define an outline of what one want to know from each informant'(Van Aken et al., 2007) There are various response strategies for the design of the interview itself. In this thesis an 'unstructured response' (Cooper & Schindler, 2006) or 'open-ended response' is chosen. This stimulates that the respondents will give their own explanation on the problem definition.

Firstly, the members of the Change Control Board in Xiamen are interviewed. These interviews will give insight on how decisions are made in the CCB meetings and according to what criteria. The information on the ECR form about an ECR is clarified in order to gain more knowledge on the different variables of ECR's.

Secondly, the core teams in Amsterdam will be interviewed. Main subjects are what criteria are used to assess ECR's, how the core teams prioritize the ECR's and the question if the information of ECR's is appropriate to support decision making. Further, the product goals created by the core teams will be discussed. How are they defined and are they well understood by employees who have to work with it?

3.3.2.2. Participative Observation

An internship of three months was done at the factory of Bugaboo in Xiamen and almost two weeks at the Head Quarter in Amsterdam. During this internship the ECR process of Bugaboo was analysed through joining several meetings of the CCB and the Core Teams. 'Participative observations enable the student to experience organizational processes from within' (van Aken et Al., 2007).

3.3.2.3. Documents

During the internship, many documents were analysed. The ECR process, ECR forms and product plans are some examples and are discussed further in this thesis. Information from these documents is used as data for this thesis but also as an important source for the interviews. During the interviews the different processes and forms were discussed to understand fully how the employees deal with these documents in practice.

3.3.3. Quality Criteria for research

An important aim of this research is the quality of the research itself. 'If a product does not meet its associated quality criteria, it loses much of its value'. (van Aken et al., 2007) Some authors mention that the aim of the research is to yield true conclusions. Van Aken et al (2007) state that it's important to strive for inter-subjective agreement. This refers to consensus between the actors who deal with a research problem. The main factors to reach inter-subjective agreement are controllability, reliability and validity which are outlined in the paragraphs below.

3.3.3.1. Controllability

'As a rule of thumb a study should be described in such a way that somebody else is able to repeat it' (van Aken et al., 2007) In this thesis it is tried to be as transparent as possible. The different research methods used for this thesis were outlined in the chapters above. As mentioned before, the conclusions and findings of the research are important for Bugaboo. Two supervisors from the company itself approved and agreed on the structure of the research. Before they agreed it was clear who the unit of analysis were, which documents were used (like process charts and function

descriptions of employees) and how the data was gathered. Transparency about the used research methods was important for them, otherwise they would not agree on the structure of the thesis.

3.3.3.2. Reliability

The second factor is called reliability. According to van Aken et al. (2007) there are four potential sources of bias recognized in the methodological literature: the researcher, the instrument, the respondents and the situation.

'Research results are (more) reliable when they are independent of the person who has conducted the study'. (van Aken et al., 2007) The interviews are observed during the internship of three months. Because of the small duration and the fact that it is accepted within the company to conduct this thesis, it is easier to keep independent during the research. As mentioned before in the problem definition, there are different views and opinions on the current problems within the ECR process. There are especially differences between employees in the Netherlands and in Xiamen. To stay independent, the internship and interviews were done in Xiamen and at the Head Quarter in Amsterdam as well. As a result, a mix of both views on the problem statement is used to analyze the problem statement and to find solutions. Besides that, the interviews were conducted by a student of the University of Twente who can be seen as unbiased as well. The supervisors from Bugaboo did not had any influence on the final results and on the unit of analysis. They had to approve but did not interrupt or 'steer' the structure of the research.

During this study, several research instruments are used, namely: interview, observation (own experience) and documentation. Van Aken et al. (2007) also state that the reliability will rise when more research instruments are used. In this way, it can be checked if the outcomes of the different data align during the research. During the internship the researcher joined different CCB meetings and Core Team meetings in order to observe how they made their decisions on ECR's. Besides that, all the ECR forms during the internship were available for the researcher as well. The latter was useful because it was possible to observe what information of ECR's was available and on what information ECR's were approved or rejected. The main part of the internship is conducted in Xiamen. The researcher worked in the same office as the NPD project managers and the Sustaining Project Manager. The interaction and observation on a daily basis of the SPM was very important, because she is the leader of the CCB and manages the sustaining teams in Xiamen.

'Different people have different conceptual schemes, different values, different observations and draw different conclusions.'(van Aken et al., 2007) In this research, the most important actors who are involved during the ECR process are interviewed. Examples are the CCB, Core Teams and Leaders of the sustaining teams. In this way the different views and opinions of all the participants are used in this research.

3.3.3.3. Validity

In the handbook of van Aken et al. (2007) they discuss four different types of validity, they are outlined below.

'Construct validity is the extent to which measuring instrument measure what it is intended to measure' (De Groot, 1969). The data collection methods were all focused on the problem definition of this thesis. To do this, the problem definition was explained at the beginning of every interview. As

a result, the interviewee is more likely to give information regarding this problem statement and it is also easier to draw conclusions on the problem statement. Besides that, the researcher checked if the gathered information from observations and documents aligned with the data from the conducted interviews.

'Internal validity concerns conclusions about the relationship between phenomena' (van Aken et al., 2007). As mentioned, the most important actors involved during the ECR process are interviewed. Van Aken et al. (2007) state that studying the problem from multiple perspectives can facilitate the discovery of all causes. Different perspectives were recognized during the interviews because people in Xiamen and Amsterdam were interviewed during this research. The report with the main conclusions for Bugaboo was discussed and finished shortly after the internship. Organizations change very quickly, the conclusions and suggested solutions are therefore more useful and valid for Bugaboo right after the internship. The analyzed problem statement might change in future which also affects the effectiveness of the suggested solutions.

'External validity refers to the generalizability of research results and conclusions to other people, organizations, countries and situations.' (van Aken et al., 2007) The thesis is conducted for Bugaboo only. The external validity is therefore not important in this case.

3.3.3.4. Recognition of results

'Recognisability refers to the degree to which the principal client, the problem owner and other organization members, recognize research results in business problem solving projects'. (van Aken et al., 2007) This is important for this research because the purpose is to change something within the organization in order to solve the problem. To reach this, it is important to involve employees of Bugaboo during the research. In this way you can create awareness for the problem and keep everybody informed about the status of the research. During the interviews in both Xiamen and the Netherlands, the main problems of chapter two were recognized; insufficient information of ECR's, no decision criteria according to the product goals and a need for a fixed method to prioritize ECR's. The alignment of all interviewed employees regarding the problem statement is important. If there is a problem they recognize, they are more willing to support the researcher to find solutions.

A second important factor is that the two supervisors of Bugaboo recognize the results and have enough authority to change procedures and processes within the organization. Rolf Smeding is the Engineering Director of Xiamen and Alfard Jansen is responsible for the engineering process. Hence, they have enough authority to initiate the suggested solutions within the organization. The report focuses only on suggested solutions which will not be implemented by the researcher it self. The willingness of the supervisors to initiate the solutions is therefore important.

But still the main power is, like mentioned before, that the employees in both Xiamen and the Netherlands recognize the core problems of the problem definition. This will increase the chance that the suggested solutions will be implemented successfully.

In the following chapter a literature study is conducted. The study is executed to find theories and models to create better understanding of engineering change management and to find possible causes for the problems stated in figure 5 in chapter two. Section 4.1 discusses concepts according to the Management of Engineering Change (EC). In this chapter the definition of EC is given, how

companies deal with it and what structure they are using within their organization for managing those EC's. The second part focuses on identifiable variables of ECR's and criteria to decide on ECR's.

4. Literature Research - Engineering change management

4.1. The management of Engineering Changes

In this paragraph the management of EC is explained according to the literature. In the literature there are different definitions used for Engineering Change Management and Engineering Changes. The definitions are defined below and the ones used for this research are given.
'An engineering change is a modification of a product's component after the product has entered production' (Tavcar&Duhovnik, 2005). This definition state that an Engineering Change can be requested after a product has entered production. Huang et al. (2003) states that an EC can be done after releasing the drawings or releasing the product design. Released product design is the product documentation which is approved by the company and 'locked' for further work. He defined the following definition after a research done at several production companies in Hong Kong, this definition is used in this research as well.

'Engineering changes (ECs) are the changes and/or modifications in dimensions, fits, forms, functions, materials, etc. of products or constituent components after the product design is released.' (Huang et al., 2003)

Most of the studied literature use a similar definition like Huang. Product design can be released during development of a product or on existing products which are already in production. In this research the focus is on the existing products which are the so called 'sustaining products' at Bugaboo.

4.1.1. Causes of Engineering Change

There are many causes for Engineering Changes described in the literature. The causes are different because it depends on what type of product or company is investigated. Eckert et. Al (2004) defined two reasons for change at a fundamental level: (1) to remove mistakes or make it work properly or (2) improve, enhance or adapt it.

Dale (1982) defined some major reasons for EC's which are summarized below:

- During the launch of a new product design. (examples are changes during development and manufacture to make the product work according to the specifications)
- To take advantage of improvements in manufacturing technology during the product's life cycle.
- The need to improve the life, reliability, maintainability, serviceability, safety, attractiveness, etc. of the product.
- Other optional design changes include those intended to cut production costs, to facilitate changes in supplier, to improve the flexibility of sourcing, to reduce distribution cost, etc.
- An unavoidable cause of design changes is the permanent loss of supply for a component or material. Possible reasons are that the supplier's stops producing or a type or grade of raw material from an overseas source may become unavailable owing to political disruption.

4.1.2. Managing Engineering Changes – Process

Most organizations have a fixed process for managing an EC. This can create some difficulties because it has to be managed through the whole organization. 'An EC usually induces a series of down-stream changes across a company where multi-disciplines work together dealing with these induced changes' (Huang et al., 2003). Dale (1982) mentioned that EC's are disruptive to the normal routine process and to the normal flow of production work.

In this chapter two ECR processes will be discussed. First the definitions used in these processes and in this thesis are defined according to the article of Jarratt et al. (2011). He refers to Monahan (1995) who defined the definitions according to the documents used for supporting EC's. (p. 108)

- *Engineering Change Request form – 'a form available to any employee used to describe a proposed change or problem which may exist in a given product'*
- *Engineering Change Order form – 'a document which describes an approved engineering change to a product and is the authority or directive to implement the change into the product and its documentation'*

Dale (1982) gives an example of an Engineering Change System which is suitable for a multi-product engineering environment having to cope with a fairly high number of design changes. He focuses on the procedure before approval and after approval. The product engineering department has to prepare a 'package' with all the information needed to decide if the EC will be approved or not. One coordinator makes sure this information is gathered from the different departments so the package is complete. 'A committee acts as a 'gate' for accepting, rejection or calling for more information about the change' (Dale, 1982). The article of Dale (1982) is not thorough about what criteria companies use for approving an ECR and what kind of information the 'package' has to contain. Jarratt et al. (2011) describes the ECR process in a six step model shown in figure 7. A short description of the different steps of the model is given in sequence to create a good understanding of the model.

(1) The first step is to raise an ECR. Companies have standard forms for raising an EC. In this stage the originator has to outline the reason for the change, the priority of the change, type of change, which components or systems are likely to be affected, etc. All the EC forms are managed by a 'change-controller' in an engineering database. Huang et al. (2003) also stated that it's common for companies to have one controller for the ECR's: In order to deal with ECs effectively and efficiently, an EC coordinator may be employed to be specifically responsible for coordinating all the EC-related activities.

(2) Potential solutions will be identified, but often only a single is examined due to time pressures, the fact that the solutions is 'obvious' or because engineers stop investigating once one workable solution is found' (Jarratt et al., 2011)

(3) In this step a risk evaluation of each solution must be assessed. Various factors can be considered like impact on design and production schedules for example. This depends on the number of solutions of step two.

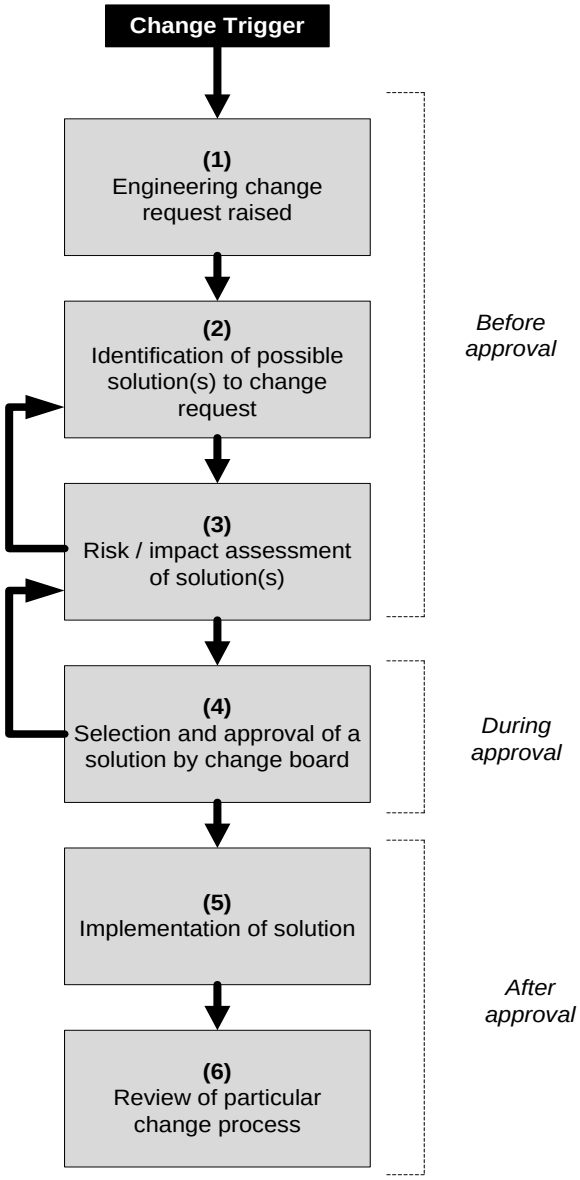

Figure 7, General ECR process (Jarratt et al., 2011)

(4). In this stage the company has to approve or reject the request of an EC according to the data gathered in the previous steps.' Most companies have some form of Engineering Change Board or Committee. The Engineering Change Board must contain a range of middle to senior ranking staff from all the key functions connected to the product.'(Jarratt et al., 2011) They have to evaluate the change, making a cost benefit analysis for the company as a whole and then grants approval for implementation. Huang et al., (2003) states that the major representatives of a board or committee are the shop floor workshop (production), design office and quality department. The literature focuses itself more on who and especially which departments are involved with the decision making and not according to what factors or criteria decisions are made during this stage.

(5) After approval, the implementation of the solution is the next step in the process. Important in this stage is to decide when the implementation has to occur. This can be done directly in high

priority cases or just in steps . An example of high priority decision making is a safety or compliance issue. Sometimes there is a need for change of the product according to new policy of a country; otherwise, the company cannot sell the product anymore.

(6) In this last stage of the process the organization will review the change. Problems which occurred can be analysed to prevent that they will happen again. But according to Jarratt et al. (2011) not all companies carry out such a review process properly.

4.1.3. Decision Criteria in Change Decisions

In the previous paragraphs some ECR processes are described. They mention what the flow is of the process, which departments are involved and who is making the decisions. There is not much literature about what variables/information an ECR has to contain and according to what criteria decisions are made based on these variables. For example a company could say that a business case has to be included and that they require the criteria for instance that the benefit of the ECR has to be 100.000 euro. If that's not the case, the ECR will be rejected.

Steffens et al. (2007) did some research on this subject with the question: *What kind of a change management approach and decision criteria are used and need in complex product development?* He conducted a multiple-case study within one company.

Seven cases were investigated which are product development projects who were already completed or nearly completed in telecommunications network infrastructure development. An important note here is that the product investigated in the cases are different compared with the products in this research. It gives at least some examples towards which decision criteria a company can have to make a change decision. According to the interviews of Steffens et al. (2007) he concluded that the following topics are most explicitly considered by the interview respondents when evaluating and deciding on changes. If those criteria are used for decision making about an ECR it is obvious that that information should be available before a company (or board/EC-coordinator) can judge about an ECR.

Project efficiency

The efficiency of the project, an Engineering Change, is an important criterion. Regarding this topic the respondents mentioned that project scope, project schedule, project budget and product quality are considered when evaluating and deciding on changes in their projects.

Customer impact

In all the cases investigated during this research product functional performance and fulfilment of customer needs are considered during the decision making. The respondents mentioned that customers are a major cause for many ECs and can even be seen as the driver of change. 'Almost all case projects additionally consider the impact to technical product specifications, possibility to solve customer's problems, and customer satisfaction towards the product.' (Steffens et al., 2007)

Project portfolio

Steffens et al. (2007) concluded that impact of the changes on technology platforms and resource dependencies were considered during the decisions on changes. Besides that impact of changes to

the product or technology roadmap, development of other products in the same product line, and on-going development projects in other product lines.

Business success

All the respondent of this research mentioned the time-to-market as an important criterion for decision making. Further factors according to business success were changes on sales volume, business income, and potential growth opportunities. Some projects used a systematic two layer approach according to change management. 'This screening was done by a pre-defined team which, based on its analysis suggested to further evaluate those change requests which had a positive impact on the business success, whereas those which showed a negative impact were not handled any further.' (Steffens et al., 2007)

He discussed the future impact and additional criteria as well but the respondents did not consider them as important indicators during the decision making process.

4.1.4 Documentation during the process

In the previous paragraphs some ECR processes were described and criteria for making decisions about a request are given. Before companies can make decisions they need information about that EC. As stated in the ECR process, most of the time, companies have a fixed document for that, which they call an ECR form. According to Huang et al. (2003) this form is principally concerned with proposing a need for EC at the initial stage of the process. 'Its function is to collect and clarify the information related to the proposed EC, especially what and why the EC has originated' (Huang et al., 2003). He also concluded that the content and the format are different from one company to another. 'It depends highly on what kind of information it is intended to collect and what level of detail of the collected information is expected in the companies' (Huang et al., 2003). This could be one of the reasons that there is not much literature written about what kind of information is needed for making decisions on ECR's because the challenges companies faces can be totally different.

4.2 Conclusion

In this chapter a study about engineering change management was conducted. Two different engineering change processes were described and analysed. Jarratt et al. (2011) defined a six step model which is a common process for many companies to deal with ECs (fig. 7). Dale (1982) gave a model which is focusing on the procedure before and after approval about an EC. Criteria for decisions were created by Steffens et al. (2007). He interviewed several companies about what criteria they use for decisions on ECR's during project management and defined the most important criteria according to the respondents.

The literature study of this chapter is used to obtain more knowledge about Engineering Change Management. This knowledge will be used in the next chapter to compare the differences between the literature and the current process. The differences are mainly highlighted in the sub conclusions of chapter 5. Differences between the literature and the actual situation at Bugaboo might lead to possible causes of the problem definition.

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