Management Control, Innovation and Strategic Objectives

Interactions and Convergence in Product Development Networks

Berhausen, Nico Peter

COPENHAGEN BUSINESS SCHOOL
HANDELSHØJSKOLEN
SOLBJERG PLADS 3
DK-2000 FREDERIKSBERG
DANMARK

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Nico Peter Berhausen

Supervisor:
Sof Thrane, Associate Professor
Department of Operations Management
Copenhagen Business School

Doctoral School of Language, Law, Information, Operations Management and Accounting and Culture
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Resume

Management Control, Innovation and Strategic Objectives – Interactions and Convergence in Product Development Networks

> *Discussing my future with my boss, he asked me: "What would you like to do in the future, which kind of job would you like to do?" I thought about my job for a second, about the countless business cases I had calculated thus far, the endless list of component recommendations and product alternatives I had presented to management. Then I said: "I would like to be a decision maker; I would like to be the one who decides and not the one who recommends." To which he replied: "Well, I don't think you will ever decide more than you have in the last four years of your job."*

Many studies have focused on the topic of product innovation. As a key element of how industrial organisations work, of how competition is shaped and how economic growth is realised, innovation provides an interesting research field, which will never be fully explored. Industrial organisations explore these grounds through strategic processes in which objectives should guide product development processes. Ideas, alternatives or decisions form these processes in which heterogeneous actors need to be aligned and coordinated towards the final product innovation. Heterogeneity is a key aspect here; different, new technologies, conflicting objectives, different opinions and different management practices for example, are part of this process. Although these elements have been studied extensively in extant research, I identify several gaps in the existing literature, which I in turn strive to fill with this thesis. First, a perspective of the interactions in innovation processes is needed with a focus on control mechanisms and the mobilisation of strategic objectives. Secondly, focusing on control, the way

calculative boundaries are created and explored and how these may be overcome needs more development and empirical insights. Thirdly, the interaction of control mechanisms and the coordination of product development networks through these interactions lack empirical insights and build an interesting research ground. I do not provide a holistic framework or a contingent perspective of how organisations should manage innovation. Rather I discuss the many ways in which product development networks become convergent through the interaction of control mechanisms, which may act as a vehicle or translator of strategic objectives. The research question to be investigated in this thesis is:

> *How do management accounting and control mechanisms interact with strategic objectives and heterogeneous innovation networks within product development?*

I investigate this question by discussing two strategic issues in product development, namely product greening and aesthetical design. Both are important issues in product development processes and for industrial organisations for gaining competitive advantage and generating customer value. In a series of four research papers I analyse a mid-sized European car manufacturer and provide cases in which these issues have led to conflicts and controversies on the one hand, and to the generation of new product alternatives on the other. With an empirical basis of 71 interviews and numerous internal documents, notes, participant observations and a questionnaire, I display insights into the dynamics of control mechanisms and the mobilisation of strategic objectives in heterogeneous innovation networks. I follow an actor-network perspective (ANT), which is applied to get an in-depth perspective in the study of the phenomena of innovation. ANT explains here how things are formed, are held together or fall apart. The previously discussed elements, such as technologies, objectives or management practices are defined as actors, which are not only intermediaries in the product development process. Through this perspective the papers develop insights into the dynamics of product development, specifically into the mobilisation of strategic objectives and into the interaction of control mechanisms. The four papers build the core of this thesis, which is framed by a cape that discusses the overall research question and generalises the findings and the contributions of the four papers. The overall conclusions of this PhD thesis are the following:

- Calculative and non-calculative spaces are existent in product development networks.
- Strategic objectives are mobilised through the creation and exploration of calculative spaces.
- Within these calculative spaces, collectives are formed and heterogeneity among strategic objectives, calculations, performance measurements and organisational functions are aligned.
- Calculations provide a common language. Although calculations do not represent everything they may align and coordinate heterogeneous actors.
- Some objectives are incommensurable and mobilised by different means than calculations (such as prototypes) in non-calculative spaces.
- Through competition, alternatives are created which form strategic objectives individually and influence the decision process. Objectives are pursued and emerge in this process.
- Calculative and non-calculative control mechanisms interact in product development and both are aligned and coordinated in the process of product development.

- Balancing and compromising are mechanisms that form one collective, which is translated into the final product. Whether a calculative or a non-calculative device is able to concentrate the largest number of actors and is able to translate the product development network towards an innovation is, rather than being predictable, dependent on the actors on the stage.
- Strategic objectives are neither static nor stable, and control mechanisms are active in the making of strategy. Strategising is not a process made only by social actors but by actors such as visualisations and calculations.

Furthermore, this thesis contributes specifically to the literature on product greening and aesthetical design. The papers analysed several cases which point to the following findings:

- Product greening may be subject to calculations through the creation and exploration of calculative spaces.
- Product greening may enter calculative processes as a strategic issue and may become an 'ordinary thing' rather than being a 'charitable and altruistic demand'.
- It thus becomes an integrated part of product development.
- The developments of forms and of functions are important processes in product development; however, their integration seems to be a difficult one.
- In aesthetical design, different control mechanisms such as competition and visualisation of physical material are in place.
- The integration of the generation of forms into the generation of functions is pursued through balancing and compromising between the languages of physical visualisations and calculations, and is enabled through boundary objects.

These contributions and findings are abstracted from the papers and reflect a meta-contribution, which is of a rather broader nature and reflects general answers to the overall research question. By providing these findings through deep insights into product development processes, this thesis contributes to the further exploration of the research grounds presented in the research field of product innovation and the complex processes of product development with its unlimited possibilities of aligning heterogeneous actors and with its endless ways of producing innovations.

Resumé

Management Control, Innovation and Strategic Objectives – Interactions and Convergence in Product Development Networks

Mange undersøgelser har fokuseret på emnet produktinnovation. Innovation er et centralt element i, hvordan industrielle organisationer arbejder, hvordan konkurrencen formes, og hvordan den økonomiske vækst realiseres, hvorfor innovation et interessant forskningsfelt. Industrielle organisationer bedriver innovation gennem strategiske processer, hvor mål skulle styre produktudviklingen, og Idéer, alternativer eller beslutninger former processerne, hvorigennem heterogene aktører skal afstemmes og koordineres mod det endelige produkt. Heterogenitet er et centralt aspekt her, anderledes, nye teknologier, modstridende målsætninger, forskellige perspektiver og forskellige ledelsespraksisser for eksempel, er en del af denne proces. Selv om disse elementer er blevet grundigt undersøgt i forskningen, har jeg identificeret flere huller i den eksisterende litteratur, som jeg tilstræber at fylde med denne afhandling. Forskningsspørgsmålet er: Hvordan interagerer økonomistyring og kontrolmekanismer med strategiske mål og heterogene innovationsnetværk indenfor produktudvikling?

Jeg undersøger dette spørgsmål ved at diskutere og analysere strategiske problemstillinger i produktudvikling. I fire forskningsartikler analyserer jeg en mellemstor europæisk bilproducent, med et fokus på de tilfælde, hvor disse spørgsmål har ført til konflikter og kontroverser på den ene side og på den anden side til generation af nye produktalternativer. Jeg benytter et aktør-netværk perspektiv (ANT), til at få en dybdegående forståelse af innovationsprocesser. Gennem dette perspektiv udvikler papirerne indsigt i dynamikker i produktudvikling, og specifikt omkring mobiliseringen af strategiske mål og

samspillet med kontrolmekanismer. De fire papirer er kernen i afhandlingen, som er indrammet af en kappe, der diskuterer den overordnede problemstilling og generaliserer resultaterne og bidragene fra de fire papirer. De overordnede konklusioner af afhandlingen, er følgende:

- Kalkulative og ikke-kalkulative rum eksisterer i produktudviklingsprocesser.
- Strategiske mål mobiliseres gennem skabelse og udforskning af kalkulative rum. Inden for disse kalkulative rum, dannes kollektiver som tilpasser og koordinerer heterogenitet blandt strategiske mål, kalkulationer, resultatmålinger og organisatoriske funktioner. Kalkulationer giver et fælles sprog. Selv om kalkulationerne ikke repræsenterer alt, kan de tilpasse og koordinere heterogene aktører.
- Nogle mål er inkommensurable og mobiliseres på andre måder end via kalkulationer (såsom prototyper) i ikke-kalkulative rum. Gennem konkurrence, dannes alternativer som påvirker strategiske målsætninger og som påvirker beslutningsprocessen. Målsætninger styrer og emergerer i denne proces.
- Kalkulative og ikke-kalkulative kontrolmekanismer interagerer i produktudvikling og begge afstemmes og koordineres i produktudviklingsprocessen. Afbalancering og kompromisser, er mekanismer, der danner et kollektiv, som oversættes til det endelige produkt. Om en Kalkulative og ikke-kalkulative proces er i stand til at koncentrere det største antal aktører og er i stand til at oversætte produktudviklingsnetværket mod en innovation er ikke forudsigelig, men afhængig af aktørerne på scenen.

- Strategiske mål er hverken statiske eller stabile, og kontrolmekanismerne er aktive i skabelsen af strategien. Strategising er ikke en proces, der kun foretages af de sociale aktører, men også af aktører så som visualiseringer og kalkulationer.

Disse bidrag og resultater er generaliseret fra papirerne og afspejler et meta-bidrag, som er af en noget bredere karakter og afspejler det generelle svar på den overordnede problemstilling. Ved at udvikle disse resultater gennem dybdegående case arbejde, bidrager denne afhandling til den videre udforskning af forskningslitteraturen inden for produktinnovation samt af komplekse processer i produktudviklingen med disse processers ubegrænsede muligheder for at tilpasse heterogene aktører og med deres uendelige måder at skabe innovation.

Contents

List of tables

List of figures

1 Introduction

“Where can we start a study of science and technology?” (Latour, 1987 p. 2) Beginning by posing this question may be one way of introducing a thesis about control and innovation. What I am studying in my PhD are the ways in which a product is made durable through the means of control. But how should this be approached and moreover, how should this be studied, through what perspective, in what theoretical context and with which empirical data? Research is always subject to restrictions, to limitations, to personal taste (e.g. Fontana and Frey, 1998) to time (e.g. curriculum of a PhD) and to space (e.g. empirical domain ‘at hand’). But do we already know the limitations to our studies when we begin a study of science and technology? Do we set clear boundaries with respect to time and space when we begin and is our starting point the one that sets the limitations? Yes and no. We have to start somewhere that’s for sure, as for having to end somewhere, that is less certain, but this thesis, at least the manuscript with its pages, has become real and is the end of a journey of studying science and technology. What happened between then and now is described in the following seven chapters and in the four papers respectively.

1.1 The problem of control in relation to strategy and innovation

The process of innovation is mainly occupied with the realisation of ideas and inventions of new goods, new production or service methods, or markets (Schumpeter, 1942). In this process heterogeneous actors get in new, unexpected connections and controversies and uncertainties are settled. There are controversies and uncertainties about future markets, future customers, future technologies, and future inventions. What is so interesting in industrial organisations, are the mechanisms through which innovation is generated and controlled. Especially in industrial companies controversies and uncertainties are present due to their mature and competitive markets, technological volatility, high production volume and high investments. To study the process from invention to innovation, the settlement of controversies and uncertainties that increase a projects' realisation are thus of interest.

Product development processes that steer the process from invention to innovation are strategic processes in which strategic objectives need to be mobilised and given directions (e.g. Brown and Eisenhardt, 1995; Davila, 2005), and in which heterogeneous views and interests need to be aligned (e.g. Davila, Foster and Oyon, 2009). Much literature focuses on the problem of control and innovation, which is still a problem that is not only interesting for practitioners and theorists alike, but where unexplored research ground still has to be discovered (e.g. Davila, Foster and Oyon, 2009; Davila, Foster and Li, 2009; Chapman, 2005). Controlling strategy (Chapman, 2005) and control in product development (e.g. Davila's works[1]; Bisbe and Otley, 2004; Bisbe and Malagueno, 2009; Cooper and Kleinschmidt, 1996; Jørgensen and Messner, 2010) are two primary issues of this research.

[1] Davila, 2000, 2003, 2005; Davila and Wouters, 2004

The mobilisation of strategic objectives provides a challenging setting for research in the field of management accounting and control. This however, is especially valid when new strategic objectives come into play. Here, whether management mechanisms (e.g. stage-gate processes, target costing, development teams and critical success factors, e.g. Davila and Wouters, 2004) may provide guidance and steer organisational processes in uncertain environments or whether they may be damaging flexibility is discussed in several studies (e.g. Ahrens and Chapman, 2002, 2004; Brownell, 1987; Chapman, 2005; Otley, 1999; Simons, 1995). However, to mobilise strategic objectives in product development processes, they have to influence decisions and generate alternatives. Literature discusses this issue from different perspectives.

For example, calculations may coordinate decisions and activities to achieve a balanced set of strategic priorities (Lynch and Cross, 1992; Nanni et al., 1990) and thus support organisations to implement and describe strategic objectives and to guide decisions through influencing behaviour, and through providing a basis for rewards or punishments. Literature on the choice of calculative processes (e.g. Chenhall and Langfield-Smith, 1998; Malina and Selto, 2004; Tuomela, 2005; Stringer, 2007) shares the view that organisations actively design control systems and performance measurements to link their strategic objectives and the means by which the objectives should be realised. Especially in product development environments, the role of calculations builds an interesting research area due to the complex and conflicting nature of product development. Management control over product development is struggling with focusing on conflicting strategic objectives, such as cost and value, at the same time. Specific strategic objectives such as profitability and efficiency may play an important role in industrial organisations. This means that systems such as activity based costing (ABC) or target costing play central roles in product development environments. Here, literature on product development focuses on the conflicts of innovation and control as one particular issue (e.g. Davila, 2003; Davila and Wouters, 2004; Jørgensen and Messner, 2009; 2010; Mouritsen, 2009).

Focusing on control, the mobilisation of strategic objectives and the process of innovation are two issues that are particularly interesting in product development networks. The study of the dynamics of control mechanisms (e.g. calculations) that mobilise strategic objectives and that coordinate and align product development networks is thus the focus of this thesis.

Focusing less on calculations a strategy-as-practice perspective argues that individuals construct routines and practices, and that strategy is a process that is pursued by being driven through decision practices. (e.g. Jarzabkowski et al., 2007; Whittington, 2003, 2006). This perspective sheds more light on the dynamics of control and strategy than, for example, contingency approaches (e.g. Jørgensen and Messner, 2010). In this process, existing links and networks need to be considered, because they may have significant impact on these processes.

This thesis mainly explores two strategic issues in product development to discuss these problems. The first one is product greening, which is becoming more and more important in industrial environments, and the other is aesthetical product design, which is becoming more and more the focus in creating customer value and a means to generate price premiums. The investigation of both objectives should contribute first, to the discussed body of literature of management accounting, control and innovation, secondly to the literature of aesthetical design and product greening, and thirdly to specific and related issues in product development processes.

I discuss the differing perspectives in this field of research, which reveals an interesting and still rather unexplored research ground (Chapman, 2005) in Chapter 2. The main gaps I discuss in the literature review are first, the lack of a more detailed perspective in order to understand the relationships within innovation processes focusing on control and the mobilisation of strategic objectives. Secondly, the creation and exploration of calculative boundaries in the product development process needs further insights and analyses; it is also important to analyse how these boundaries are overcome. Thirdly, strategic objectives, calculations and control mechanisms may cause conflicts; heterogeneity in product development networks must be aligned towards one final product. Fourthly, the discussed research context needs further research in relation to the two specific issues of product greening and aesthetical design. Both are relevant and rather unexplored fields. I approach these points by applying an actor-network perspective which I will introduce in the next chapter. This perspective helps to explain how things are made, how they are held together or how they fall apart. Strategic objectives or control mechanisms, for example, are not intermediaries but are actors; how controversies are settled between them, how they become translated, and how innovation is formed is thus to be studied by following these actors and by tracing their interactions. Rather than striving for a holistic framework of how to manage new strategic objectives (such as product greening or aesthetical design), I try to display the many ways in which control mechanisms may act as a vehicle or translator of strategic objectives in product development and innovation.

The research question to be followed is thus:

> *How do management accounting and control mechanisms interact with strategic objectives and heterogeneous innovation networks within product development?*

1.2 Short discussion of the theoretical perspective

Originally trained as an engineer, I was focusing on scientific methods and rationalities. I was calculating costs of components and trying to rationally give recommendations to managers and engineers as to what to invest their money in. I saw how new technologies were developed and applied in cars and how machine-like the product development apparatus worked. I had to take a step back and view the making of science and technology from the outside in. I wanted to open the black box "so that outsiders may have a glimpse at it." (Latour, 1987, p. 15). A black box means that something must have been or may become durable; that there is something like a product. If so, then strategic objectives must somehow be inscribed into it, they must become part of it through development processes – and this is exactly the process I want to study. *How do management accounting and control mechanisms interact with strategic objectives and heterogeneous innovation networks within product development?* I will follow the approach of actor-network theory (ANT) to study how things are "in the making" (Latour, 1987, p. 4).

ANT is a relativistic sociology. Epistemology, ontology and reference frames, such as psychology or politics are mixed and not treated independently (Latour, 1999). The reality of these terms is not a fact or a given, but needs to result from transformations. The *real world* is thus the consequence, the output of science, rather than its cause (Latour, 1987). This may be categorised as a constructivist perspective, but here the world is not constructed by human minds but by science – reality still exists, but through the construction of science. The many underlying suppositions of ANT are discussed in Chapter 3. The study of technology doesn't begin with facts, but with fact making and we need to trace the actors' ways of doing that. There is no asymmetry between humans and non-humans, but asymmetry is to be defined in the *making* process and whether actors are intermediaries or mediators depends on this process. The way in which black boxes are created is a translation (Callon, 1986) and needs to be followed and analysed to open up the black box of product development and to trace processes in the *making* through actors and define asymmetries and mediators. It is following the actors, their heterogeneity and their contradictions and tracing how efforts are mediated that enrols humans and non-humans and analysing how controversies are settled (Latour, 1987, p. 144).

ANT is the perspective of how this thesis contributes to science. It should help penetrate "from the outside the inner workings of science and technology" and then "to explain to the outsider how it all works." (Latour, 1987, p. 15). In this thesis I studied the inner workings of a car manufacturer that is described in the next section.

The above approach is applied in this thesis to gain a more detailed understanding to study the phenomena of strategic control and innovation. Current studies don't provide detailed perspectives of the contexts that are created and developed through control mechanisms in product development. Contingency theory, for example, focuses on the fit between given circumstances in technology and environment and organisational action (and thus control) and argues that it is an effect to external factors. Furthermore, studies applying a sense-making perspective argue that individuals, such as managers, make sense and interpret information such as accounting information and strategic objectives and decide for themselves how to act on information (Weick, 1995). In structuration theory, social systems are underlying structural rules and social action is performed within the pre-given context that social structure provides. Structures and rules are, on the other hand, modified or maintained by social action (Giddens, 1984).

Discordantly, in practice theory, the practice of humans is the focus. Social practices are defined through social actions within space (the systems) and across time (routinised behaviour) (Schatzki, Knorr Cetina and von Savigny, 2001). The social perspective suggests that actors within an organisation construct the routines and intended practices and that any action is a proficiency that can be executed on the individual level, the organisational level or both (Denis, Langley, and Rouleau, 2007). Here structures or practices are concepts that are not part of actions and thus do not exist as objects. In ANT this makes them irrelevant for studying networks.

Here ANT explains how things are formed, how they are held together or how they fall apart. Control actions, calculations, and the forming of strategic objectives are not only intermediaries in relation to the environment. They become actors and it becomes “possible to understand how the environment and the accounting inscriptions are constituted simultaneously” (Justesen and Mouritsen, 2011, p. 180). ANT suggests instead social action symmetry between humans and non-humans and that action would not be considered as purely “social”. Study objects in these terms may therefore be items like calculations, strategic objectives, or innovations.

Calculations and other control mechanisms may play a more active role than studied by, for example, contingency, practice, or sense-making theorists. As will be discussed in chapter 3,to get a more detailed perspective and focus on a more active role of control mechanisms one has to follow the actors, their heterogeneity and their contradictions and should trace how efforts are mediated that enrol humans and non-humans and how controversies are settled (Latour, 1987, p. 144).

1.3 Empirical field, outline and findings of papers and thesis

1.3.1 Empirical field

As empirical basis for this thesis, I conducted a longitudinal study of a car manufacturer (Automotive Company). The company is a mid-sized, European company that produces and delivers cars in the premium sector. I have studied the company for a period of three years during which time I, together with a co-author, conducted 71 interviews (Appendix 1) and questionnaires, gathered empirical material, and observed participants in relevant meetings. I studied the product development network in the course of the car development process and focused on calculations and their impact on product decisions. I focused therefore first of all on the mechanisms and processes within the product development networks and on actors that were relevant in this process. Furthermore, I followed episodes, in which new strategic objectives were mediated and decided upon in the product development network. These episodes are discussed in the Papers. In Paper 1 I focus on the issue of the generation of product complexity in product development. In Paper 2, I (together with a co-author) focus on the issue of weight reduction, the introduction of a new headlight technology as an innovation and on the issue of aerodynamics and the connected reduction of CO_2. In Paper 3, I am focusing on certain car projects and the way in which aesthetical product design is conducted. In Paper 4, (together with a co-author) I focus on different mechanisms in technological innovation and aesthetical design discussing cases in which both mechanisms interact and converge towards a final state of innovation. The specific content of the papers and where they are located are discussed in the following paragraphs.

1.3.2 Positioning and relation of papers

All four papers are positioned in the early concept development stage of product development. This has several reasons. First, most of the strategic decisions on the development project are taken at that stage, secondly and consequently, these decisions make up 70-80% of the life cycle cost and this is when the environmental impact is determined (e.g. Leech & Turner, 1985; Ehrlenspiel et al., 2007, p. 11). Thirdly, most controversies are discussed and weighed up against each other when these decisions are made. I will briefly position the papers and their theoretical research question (see Table 1) and relate them to each other.
Paper 1 analyses how a specific strategic objective (*reduction of product complexity*) is mobilised and how the configuration of control and performance measurements influence mobilisation. Focusing on the choice of performance measurements and calculations, it investigates how strategic objectives may be mobilised through performance measurements and calculations, and which barriers and controversies may occur in this process and how they may be overcome.

In Paper 2, different modes of calculation are defined through which certain objectives (e.g. product greening) are mobilised in product development. Certain strategic objectives may lead to conflicts and controversies in product development decisions. The paper argues for the alignment of these controversies through calculations. It discusses six modes of calculations that may create alignment when conflicts occur and thereby addresses the issue of project coordination and alignment of product development networks.

Paper 3 focuses on the processes of aesthetical concept design. It discusses how strategic objectives emerge in the process of aesthetical design and how these objectives interact with forms and visualisations. Aesthetical concept design may have its own *mere mental*[2] interpretation of strategic objectives.

Paper 4 discusses the need for a separation of technological innovation and aesthetical design and the need for the integration of both. Investigating control mechanisms at Automotive Company defines the control mechanisms and the processes and mechanisms through which both create convergence and align the product development network.

[2] see Mouritsen et al. (2009)

Paper 1	*Mobilisation of strategic objectives – The role of performance measurements in their design and choice process*	*How are new strategic objectives (such as reducing product complexity) translated into the new product development process and which role do existing performance measurements play in relation to the choice of performance measurements?*	ocus: Mobilisation of strategic objectives Implementation of performance measurements Barriers and conflicts in the process of mobilisation of strategic objectives
Paper 2	*Calculating green innovation: Creating and exploring calculative spaces for innovation and the environment in the automotive industry.*	*How is greening calculated in heterogeneous product development networks?*	Focus: Conflicts and controversies between strategic objectives and calculations Means and modes of mobilisation Means and modes of creating alignment of heterogeneous views
Paper 3	*The mobilisation of strategic objectives in the process of aesthetical design.*	*How are strategic objectives translated in the process of aesthetical design?*	Focus: Generation of aesthetical concept design Mobilisation of strategic objectives Role of calculations within this process
Paper 4	*Controlling, separating and converging design and product development*	*How is design and technological innovation controlled, when both separation and integration of design and product development is demanded?*	Focus: Generation of aesthetical design and technological innovation Mechanisms of control in both events Convergence of technological innovation and aesthetical design

Table 1 – Overview of Papers in this thesis

All four papers thus address the research question whilst focusing on their own particular issues. Together, all the papers contribute to the issue of product development in relation to management control and the mobilisation of strategic objectives.

1.3.3 Structure of this thesis

This thesis is structured as follows. Chapter 2 discusses the relevant literature to which it contributes, focusing on the strategic nature of MCS, on the role of management control in product development and in stage-gate processes, and discusses the literature on aesthetical design and product greening. The chapter develops both the relevant gaps in the literature and the research question. These are then addressed in the papers and are further developed in Chapter 3. Chapter 3 discusses the perspective and methodology of the thesis. First, the actor-network perspective is discussed; secondly, the ANT approach of following the particular research question of this thesis is discussed and elaborated. In Chapter 4, the research methods that are applied in this thesis are presented, discussing the selection of cases and papers and data collection methods. In Chapter 5, the papers are presented. Chapter 6 discusses and concludes the papers and ties their arguments together. Chapter 7 finalises the thesis with a discussion of limitations and the implications for future research.

Thorough literature reviews are presented within the papers relating to the specific issues of each paper. Furthermore, discussions and conclusions are specifically developed within the papers. The chapters of this thesis reflect a cape, a meta-contribution and a discussion of the single papers. Due to the paper-based thesis, the topic and the contribution of this thesis is of a rather broad nature. The combining of specific issues (discussed in the papers) into a thesis gives the advantage of providing a general view of the topic of control and innovation. The discussion of certain (and several) cases and episodes is inherent to the perspective of actor-network theory and provides the literature with clear and structured insights into the problems of the interaction of control mechanisms with strategic objectives and heterogeneous innovation networks.

2 Theoretical discussion of relevant literature

Schumpeter (1942) emphasised that innovation is paramount for economic growth[3]. An innovation consists of the invention of, e.g. new goods, methods, or markets and its successive implementation.[4] Schumpeter stressed the role of large industrial companies that have the resources for the successful implementation and commercialisation of inventions. Besides investment capital, buying power and distribution channels, research and development functions and task division in large industrial organisations are responsible for advancing technology and science and are a key part of gaining a competitive advantage (Hauschildt, 1993). Product development becomes more and more important to mature and global industries. The successive implementation of an invention through product development is an ambiguous task for industrial organisations. Industrial organisations with high production volumes and mature and competitive markets (such as the automotive industry) in particular are considerably driven by critical success factors such as economic targets, time-to-market or quality. Globalisation leads to more competition, which places industries under time and cost pressure to compete on time and margin requirements. Furthermore, customers place high demands on quality, individualistic products and on the social and environmental performance of both production processes and the product. These exogenous factors make product development an ambiguous and complex task for industrial organisations (e.g. Shepherd and Ahmed, 2000; Tushman and O'Reilly, 1997; Wheelwright and Clark, 1992).

[3] „The fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumers' goods, the new methods of production or transportation, the new markets, the new forms of industrial organisation that capitalist enterprise creates." (Schumpeter, 1942, p.83)

[4] Amabile et al. (1996, p. 1155) define innovation "as the successful implementation of creative ideas within an organization. In this view, creativity by individuals and teams is a starting point for innovation; the first is a necessary but not sufficient condition for the second. Successful innovation depends on other factors as well, and it can stem not only from creative ideas that originate within an organization but also from ideas that originate elsewhere (as in technology transfer)."

From the perspective of strategy and control, control mechanisms mobilise and shape strategic objectives through exogenous and endogenous assessment, which should steer organisational action (e.g. Chapman, 2005). Product development becomes a strategic process in which strategic objectives are mobilised to define directions for future products (e.g. Davila, 2005; Brown and Eisenhardt, 1995). Strategic objectives, however, are conflicting in nature. Cost leadership, for example, and high customer value may conflict in the development of components in which costs should be kept low and value should be kept high through materials and functions resulting in higher costs. Hence, managing conflicting objectives is a central problem for industrial organisations.

The scope of the product has furthermore emerged to allow for high value and higher margins through customer value. Organisations strive for product differentiation and leadership in product language (e.g. design, product greening). This leads to products consisting of more and more technologies. On the one hand, a deeper knowledge is needed within organisations to cope with the scope of technologies; on the other hand, expertise and greater knowledge of the technologies are required in order to handle these technologies. This creates a need on the one hand for more expertise in disciplines but on the other for more interdisciplinary work as it causes more interdependencies between constituents of the new product development network. The coordination and control of innovation and the heterogeneity in product development networks create another central dilemma for industrial organisations. Furthermore, the issue of coordinating and controlling strategy of an emerging research field becomes a factor.

Heterogeneous functions and views within organisations and strategic objectives thereby cause ambiguity and uncertainty in product development. Although innovations are associated with uncertainty, unexpected outcomes and new relationships of heterogeneous forms (e.g. Davila, Foster and Oyon, 2009, p. 282), it is the process of convergence that turns an invention into an innovation. To achieve a balanced set of strategic objectives and activities organisations strive for a more standardised and coordinated set of activities and towards more control efforts (e.g. Damanpour and Gopalakrishnan, 1999; Lynch and Cross, 1992; Nanni et al., 1990; Stringer, 2000). Management control should coordinate sets of innovation activities and the implementation of strategic objectives within different functions of organisations. Recent literature points to control and management accounting being productive in innovation. In their discussion, Davila, Foster and Li (2009, p. 327) summarise that management control systems "are viewed as flexible and dynamic frames adapting and evolving to the unpredictability of innovation, but stable to frame cognitive models, communication patterns, and actions."

In this thesis I will not argue for control and innovation as being either in a positive or negative relationship. Instead, I will elaborate on how conflicting strategic objectives and heterogeneous actors interact in innovative product development networks. Here, rather than focusing on how things fall apart, I focus on how things are constructed because this thesis is about product development: the generation of innovation. Two overlapping fields of research have been concerned with the coordination and control of product development: the literature on the relationship between management control and strategy, and the literature on control and innovation. As I elaborate in the coming sections, most of the studies in these fields are based on contingency theory, focusing on types of control, strategies, and e.g. product development structures and their fit (e.g. Chapman, 1997; Chenhall, 2003; Davila, 2000, 2005; Ittner and Larcker, 2005). Although some studies, such as practice-theory (e.g. Jørgensen and Messner, 2010) or actor network-theory (Christiansen and Varnes, 2007; Mouritsen et al., 2009), have taken a different approach there is still a gap in the understanding of the dynamics in product development networks in relation to control and the mobilisation of strategic objectives.

In the next two sub-chapters I will elaborate on the extant literature and its contributions in an effort to develop the gaps this thesis strives to fill. As this is an article-based PhD, the literature review provides a rather broad overview of the literature and its gaps and point to the overall contribution of the thesis through the four papers. A more detailed and more specific review is provided in the papers in relation to the underlying problem to be investigated in the relevant paper. Furthermore, in Chapter 2.3 the literature on aesthetical design and product greening is briefly reviewed as they both present specific problems in product development which are key elements of this thesis and research grounds that need further development.

2.1 The strategic nature of management control

2.1.1 Control and strategy – a generic issue

Management control systems (MCS) were initially defined as a means to transform strategy into action by providing information relevant for coordination and control (e.g. Anthony, 1965). Management control, strategic planning and operational control were distinguished from that perspective. Exactly this challenging task, the implementation of strategic objectives into practice, has provided an interesting setting for research in the field of management accounting and control. The discussions about management control systems and strategy have gained momentum after the call for more comprehensive systems that measure performance beyond the financial dimensions[5] and still provide interesting and unexplored grounds for research (e.g. Chapman, 2005).

On the one hand, MCS were often criticised as damaging flexibility and thus being incompatible with uncertain environments (e.g. Brownell, 1987; as discussed in Chapman, 2005), on the other hand, they are important for maintaining or altering patterns in organisational activities (Otley, 1999; Simons, 1995). Especially in recent research however, MCS are seen as enabling steering for strategic change in unstable environments (Chapman, 2005; Ahrens and Chapman, 2002, 2004; Simons, 1995). From the viewpoint of the simple implementation of strategy towards the viewpoint of a daily routine of making strategy (as discussed in Chapman, 2005), MCS may take on a more active role in strategy making.

The ways in which new strategic objectives are mobilised in MCS have been the

[5] Models such as the Balanced Scorecard (Kaplan and Norton, 1992), the Performance Pyramid (Lynch and Cross, 1991), or the Action-Profit-Linkage (APL) model (Epstein, Kumar and Westbroek, 2000) try to address the limitations of financial management control and to create a shift away from the financial dimension into other relevant dimensions that reflect the strategic objectives of an organisation.

focus of quite a considerable number of studies and have been discussed from different perspectives. In the discussion about strategy and management control the focus has mainly been set on the constellation and implementation of control systems and on the internal and external environment that have an impact on them.

Literature drawing on contingency theory, for example, focuses on the match between the kind of strategy and the form of management control in relation to organisational performance. Contingency theory has a long history in the study of management control and strategy: attempting to examine the most effective organisational design in relation to environmental factors, technology, organisational structure, culture and strategy (see Chenhall, 2003). In recent works (e.g. Burgelman, 2002; Davila, 2000, 2005; Ittner and Larcker, 2005; Bisbe and Malagueno, 2009) MCS are defined as tools that provide context for strategic change through the interaction and analysis with the strategic environment[6].

In the course of MCS and strategy studies, Ferreira and Otley (2009) provided a holistic approach in the form of a descriptive tool for the analysis of MCS (see also Broadbent and Laughlin, 2009). Their definition includes strategic formulation as well as strategic implementation[7]. They see the complete organisational network as relevant in analysing MCS. Strategic changes are thus to

[6] The configuration of the MCS plays a vital role to the integration of strategic objectives. Referring to Burgelman (2002), Davila (2005) who argue that MCS rather than dictating actions, enable actions within the defined strategic context. MCS may "provide the framework that people within the organisation refer to when acting" (Davila, 2005, p.45). Especially, as will be discussed later, MCS may shape and develop innovations in organisational contexts, interacting with (refining or replacing) strategy (e.g. Davila, 2005). Furthermore, Ittner and Larcker (2005) discuss strategic data analysis (e.g. strategic value drivers, target setting) and the role it may play in strategic implementation and redefinition. They argue that companies should put more emphasis on the analysis for selecting those control constellations that fit with the indicated strategic performance. Bisbe and Malagueno (2009) drawing on Simons' levers of control framework (Simons, 1995) investigated the relationship between management mode and innovation strategy and MCS. They found that the level of product innovation output depends on the way management control and strategy formation are configured.

[7] They view MCS as "the evolving formal and informal mechanisms, processes, systems, and networks used by organizations for conveying the key objectives and goals elicited by management, for assisting the strategic process and ongoing management through analysis, planning, measurement, control, rewarding, and broadly managing performance, and for supporting and facilitating organizational learning and change". (Ferreira and Otley , 2009, p. 264)

be discussed with regard to the management control systems' configuration and the complete organisational environment.

Conventionally, in contingency theory studies focus on collecting "aggregate information about organisation and their subsystems" (Ahrens and Chapman, 2007, p. 3). Thus, contingency approaches focus on rather static relationships between context, strategy and management accounting and control. They lack the examination of relationships and interactions between strategic objectives and management accounting (Chapman, 2005; Simons, 1990[8]). One approach that addresses this issue is practice theory. Studies of strategy and management control drawing on practice theory seek to understand strategy in action at the more detailed level of subsystems. Moreover, they seek to explore the relationships between human action and a global entity or system (Ortner, 1984). Social practices are defined through the social actions within space (the systems) and across time (routinised behaviour). In further process approaches to strategy, strategy is developed as strategising or strategy-as-practice (e.g. Jarzabkowski et al. 2007; Whittington, 2003, 2006). The social perspective suggests that actors within the organisation construct routines and intended practices, and that strategising is a proficiency that can be executed on the individual or the organisational level or both (Denis, Langley, and Rouleau, 2007).

In their work about accounting and strategising, Jørgensen and Messner (2010) argue that a practice perspective sheds light on how management accounting is "weaved into strategic considerations and debates" (ibid., p. 184) and how it is mobilised in the making of a strategy. In their study they find that managers may

[8] "The research underscores the importance of the dynamic relationship between formal process and strategy: competitive strategic positioning, management control and the process of strategy-making play one upon the other as the firm evolves and adapts over time. The analysis shows that interactive management control processes can be used to manage emergent strategy: rather than focusing on what the organization already understands and does well, these systems direct organizational attention to emerging threats and opportunities." (Simons, 1990, p.140)

mobilise strategic objectives with accounting information, which may act as "general understanding" and contribute to product development practices. Ahrens and Chapman (2004, 2005, 2007) discussed that MCS, rather than being an instrument of power at a distance, are functioning as an interactive bridge between diverse operational and strategic resources. Drawing on practice theory they argue that the usefulness of MCS depends on managers' experiences and whether they have the time to model the interdependencies between organisational processes, strategic priorities, and financial outcomes (Ahrens and Chapman, 2007, p. 121). They argue that the linkages between strategy and operational action "cannot rely on mechanical cause and effect relationships" (Ahrens and Chapman, 2007, p. 122). Control and management accounting should be used as a "framing device" rather than an "answer machine" (ibid.). In their case study of a restaurant chain, operational activities, management accounting and strategic messages were discussed at the same time as which strategising was executed through accounting and vice versa.

Although studies in strategy and control drawing on practice theory address the lack of dynamic interactions and relationships between strategy (and strategising respectively) and management control, there is further understanding needed of how strategic objectives may be mobilised by management accounting information. Management accounting information (calculations) may act on the process of strategising in that they may be a pre-condition or develop the context for existing or upcoming strategic objectives: displacing strategic objectives. Furthermore, there may be competition between non-calculative devices and management accounting information. Practices are thus not just shaped by "social" actors, such as managers (e.g. Whittington, 2003, 2006; Jarzabkowski et al., 2007), but also by actors such as management accounting information. As I discuss in Chapter 3, human actors may be only one of the many actors in strategising. From the actor-network perspective, strategising is not a purely social process but rather a process of mobilisation of and through different actors.

Discussing the issue of competition between calculative and non-calculative devices, Mouritsen et al. (2009) apply an actor-network perspective in their study of short and long translations. They study how competing calculations create context for innovation strategies (long translations) in that they mobilise alternative propositions about relevant entities, such as technologies. Their argument is that calculations, rather than reflecting the total of the organisation are just partial representations of the organisation. However, "the management accounting calculation is strong because it helps to develop context." (Mouritsen et al., 2009, p. 752). Here it would be interesting to investigate contexts which are not developed by calculations and how these contexts interact.

However, the research of management control and strategy is still interesting and only a few studies have focused on the interaction of strategy and control (Chapman, 2005 addresses this issue with contributions of several studies). Management control may not be an obstacle in undertaking strategic changes and operational innovations. Besides, as discussed, by providing a basis for strategic change, they may as well be vehicles of change. Here, management accounting information can examine the implementation of strategic objectives and it can be used to communicate the intentions and goals of the organisation (Chenhall, 2005). Thus it acts as a vehicle between action and strategy.

A deeper look into the interactions of strategy and management accounting is provided by the literature on performance measurements. This is explored in Chapter 3.

2.1.2 Performance measurements and calculations - a particular issue with control and strategy

One particular stream of research concerns the study of performance measurements as calculations. As discussed in the introduction of this chapter, strategic objectives may be ambiguous in nature. Besides competition of calculations, there may be problems of commensurability.

As discussed, studies discuss changes in strategic objectives in relation to the configuration of control systems. These changes are managed by creating transparency of strategic priorities and of connections of activities across the value chain (Nanni et al., 1992; Shank and Govindarajan, 1993). Here, transparency is created through the use of performance measurements; they “model performance *relations* among key value-chain activities and outcomes” (Malina and Selto, 2004, p. 442).[9] Performance measurements can be of a financial nature (such as internal rate of return ‘IRR’) or be more comprehensive: describing links between action and outcomes, providing feedback, supporting strategy development and implementation, such as models that include financial and non-financial measurements of operational and strategic performance (e.g. Epstein et al., 2000; Kaplan and Norton, 1996; Ittner and Larcker, 2001).

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[9] Here, I want to shortly define the definition of the verb to “model” and the noun “measurement”. I see performance measurements clearly as calculated, as measuring means here, counting something and relating it to a reference point. I see this process as an equation, and thus a calculation. Furthermore, steering through measurements means nothing less than calculating how to get to a deserved level, and thus, how to bring the equation into a deserved state. However, clearly, not every calculation is a performance measurement. A calculation becomes a performance measurement when it is related to a reference point. For example, a calculation can tell the weight of a particular car, e.g. 2.000kg. As long as we do not know whether this is heavy or not, it stays just a calculation. When broad into relation with *something* (let’s say the weight of a competitor car) we start to know whether we are performing better or worse as the related *something*; the calculation becomes then a performance measurement. It starts to act on decisions through being related to *something*. I will elaborate on that through the ANT perspective in chapter 3.2.2.1/p. 87-89.

The role and interdependencies of performance measurements provide an interesting research setting and is widely discussed in the studies of management accounting. Studies in management accounting that are dealing with the choice of performance measurements mainly focus on the characteristics of performance measurements and on how these may be influenced by organisational parts. Combining different theoretical perspectives (resource-based, systems-based and contingency-based strategy theories) Malina and Selto (2004), for example, focus on the importance of attributes that are influencing the consideration of performance measurements and argue that organisations have enough flexibility to choose the portfolio of performance measurements. They have to be continually reassessed to manage altering strategic objectives. It is the question of what influences this process. Chenhall and Langfield-Smith (1998) use a systems approach that shows how and to what extent management control strategies contribute to the development of performance measurements in organisations in a changing environment. Their study is a step towards describing the interactions within MCS in strategic change and of the factors that pervade the MCS. It gives an insight into the influences of accounting and addresses thus the question of which constellation best supports the operation of the MCS (see Ferreira and Otley, 2009, p. 273-274). Further studies on performance measurements and their choice focus mainly on the appropriateness of fit and the role of measurements (see Stringer, 2007). Rather than focusing on the overall organisational network (as suggested by Ferreira and Otley, 2009) they focus on the direct contingent link between organisational strategy and the use of performance measures within MCS (e.g. Tuomela, 2005).

Studying the attributes and appropriateness of performance measurements in relation to strategic and operational demands is of significant importance. However, as in the general studies of strategy and control, I see a perspective as relevant when it focuses on investigating and understanding the interdependencies and interrelations between performance measurements and strategic objectives and among performance measurements respectively. Measuring, for example, does not imply action, but the mobilisation of measurements are of importance[10] (Catasús et al., 2007). Although studying the process of measurement choice, current studies lack a more detailed perspective of the underlying influences through which measurements are created and under which they find application.

The discussed literature shares the view that organisations actively choose performance measurements to build a link between strategic objectives and the means by which the objectives should be realised. However, it needs to be considered that the links of the MCS in place may have a significant impact on these processes. Existing measurements, for example, may cause conflict or be in contradiction, which may have implications on the choice of new measurements in strategic change. Representational limits of accounting are of additional interest here as they influence the mobilisation of strategic objectives and calculations (this will be further elaborated on in Chapter 3). Consequently, the calculation processes of performance measurements and their interdependencies within the MCS are still an unexplored issue that is important because it defines the relationships within management control and the linkage between strategy and operations.

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[10] "Organizations should be aware that the acts of producing measurements are not enough to fuel the organization into acting" (Catasús et al., 2007, p.516)

2.1.3 A perspective on the relationships of strategy and control

"As Chapman (2005) points out, formal accounting and management controls can have 'valuable strategic roles'. At present, we do not have a strong sense of what those roles might be nor of how the specificity and contingency of time and place might influence the doing of accounting, the making up of strategy and the definition of 'value creation'. We might know, in general, on average, how firms said to be pursuing a particular strategy might budget in the face of assumed levels of certainty. But firms do not seek to be 'average', deviations from the norm may be normal and models of the past may be poor predictors of the future. Perhaps, greater engagement with the messiness of practice will enable us to understand it better and therefore teach more credibly. We would add much needed situated detail to current research in accounting that seeks to match accounting controls with abstract strategic archetypes. Such research would also complement recent research in accounting that is grounded in the actor-network theory of Latour and Callon. It would encourage us to devise new concepts that did away with distinctions between 'micro' and 'macro' levels of analysis; between action and structure/institutions." (Chua, 2007, p. 492)

With the ANT perspective of accounting as a technology, and calculation as an actor, a different perspective is chosen to discuss the topic of strategy and control. I will apply an actor-network perspective (discussed in Chapter 3) which helps to examine the dynamic interactions and relationships between strategic objectives and management control, and open the black box of the concept of strategy (Chua, 2007, p. 488). In these dynamic relationships, the making of strategy is not only being shaped by "social" actors such as managers (e.g. Whittington, 2003, 2006; Jarzabkowski et al., 2007), but also by actors such as management accounting information. This information creates context for strategic objectives.

In this thesis (and in the four papers respectively) I seek to provide an understanding of the mobilisation of strategic objectives through calculations and to contribute to the literature on strategy and control, and strategising. Especially concerning the heterogeneity among actors, such as strategic objectives, general calculations and performance measurements are of interest as controversies and conflicts occur that need to be settled throughout the strategising process. The role of calculations and performance measurements is an interesting research object, especially in product development environments, due to the complex and conflicting nature of product development. Product development finds itself in a dilemma, as it has to address conflicting strategic objectives such as increasing value and decreasing costs. Control systems that focus on cost (e.g. target costing, activity-based costing) may put pressure on development processes.

The issue between development and innovation, on the one hand, and management control, on the other, is discussed in the next section.

2.2 Management control in product development

As discussed in the introduction to this chapter, innovation through product development is an ambiguous task for mature industrial organisations. Especially in product development networks, MCS build an interesting research site as product development is an uncertain and complex process. Environments with "pluralistic demands and high uncertainty" (e.g. Jørgensen and Messner, 2010) place a challenge for organisations and lead to more product complexity (Nooteboom, 2000) and more criteria that need to be managed while uncertainty increases the need for flexibility. Fuzzy criteria in the early stages make this process even more demanding. Diverse and sometimes divergent strategic objectives, such as economic targets, time-to-market or quality are addressed in product development. In product development it is not about the articulation of these objectives itself nor their measurement, nor is the technical feasibility a problem in itself; it is about the orchestration of all relevant entities within the product development network through which an idea or an invention materialises (e.g. Ayers et al. 2001; Brown and Eisenhardt, 1995). Conflicts and contradictions arise out of the heterogeneity of actors (e.g. functions, disciplines, targets, strategic objectives, managers), which are mobilised to form the innovation and thus the final product.

The coordination and control of heterogeneity in product development build a central dilemma for organisations and provide an interesting research setting. Cost control in and of innovation, for example, is increasingly seen as important by practitioners and academics alike because key decisions about product design, manufacturing, sourcing and distribution may determine 70-80% of a product's lifecycle cost (e.g. Leech and Turner, 1985). Literature has been investigating the relationship between control and innovation for quite some time. Different perspectives have been applied to investigate positive and negative relationships and the contexts that management control provide for innovation.

Earlier literature on innovation management, and on control and innovation, points to limits and a rather constraining nature of control in product innovation (e.g. Damanpour, 1991; Dougherty and Hardy, 1996; Miles and Snow, 1978; Tushman and O'Reilly, 1997). Miles and Snow (1987), for example, argue that control builds an obstacle for creativity, and Tushman and O'Reilly (1997) point to motivational and cultural issues in control mechanisms. Bonner et al. (2002) point to reduced project performance and to less successful innovation outputs through formal control mechanisms in product development.

In more recent studies however, control is argued to be supportive in product development and innovation. Davila and co-authors, for example, contributed to the conceptualisation of the relationship between control and innovation (such as Davila, 2000, 2003, 2005; Davila & Wouters, 2004; Davila, Foster, and Oyon, 2009). He investigated the relationship from a contingency theory perspective and focused mainly on the issue of cost control and innovation. Financial measurements especially may play an important role in product development. Davila (2000) found that uncertainty and product strategy are related to the design of management control systems and that the design cannot be restricted to financial measurements but needs to incorporate non-financial measurements. Additionally, Davila (2003) found a positive relationship between the use of short term economic incentives and project performance in situations where the project group faces low levels of uncertainty, and a negative relationship between performance and short term economic incentives when uncertainty is high. Davila and Wouters (2004) discussed problems in relation to cost management and stated that cost may shift attention from other factors.

In this field, target costing is one of the most discussed financial instruments regarding control and innovation (Ansari, Bell & Okano, 2007; Cooper & Slagmulder, 1999; Ellram, 2006)[11]. They argue that target costing may lead to longer development time, that cost models reflect the present and not the future, and that cost shifts attention from (other) critical success factors. Furthermore, Davila (2005) proposes a framework in which MCS may respond to changes when they are used flexibly and dynamically while framing actions and communication patterns within product development.

Davila's studies thus point to both possible conflicts and consistencies between management control and innovation in specific settings and argue that "innovation requires formal tools that structure the execution process without becoming rigid mechanisms; these tools are flexible enough to take advantage of unexpected opportunities but strong enough to keep the direction" (Davila, Foster and Oyon, 2009, p. 287). Although being of immense value for theorists and practitioners alike, Davila's works are much focused on the effectiveness of management control of innovation using a broad empirical base. A more detailed perspective that focuses on the processes of control in interrelation with innovation would provide a greater insight into the interaction between both.

Other studies on control and innovation point to similar connections between innovation and control. Bisbe and Otley (2004) state, by discussing Simons' framework of levers of control (Simons, 1995), that interactive use of control systems may favour innovation in low innovating firms through the provision of guidance and legitimacy. Their study argues for the importance of formal MCS in innovation settings through a moderating effect. Bisbe and Malagueno (2009) add to that by arguing that the choice of interactively used MCS is associated with the

[11] For a comprehensive literature review on target costing see Paper 2 – *Calculating a Greener Future*

organisation's innovation management mode and that the innovation output relates to the correspondence between information needs of the innovation management mode and the information provided by the MCS. Both studies make important contributions to the levers of control literature by applying a contingency perspective. However, neither study provides an understanding of the process of interaction between control mechanisms and innovation management, and product development respectively. Mouritsen et al. (2009) study here, for example, the dynamic interaction between control and innovation from an actor-network perspective. They propose that management accounting calculations are, rather than just describing or representing innovation activities, linking them to organisational concerns and creating contexts for innovation activities. Their study provides a deeper insight into the interrelation between management accounting and control and innovation as it sheds light on innovation and accounting processes rather than on effectiveness of static organisational contexts.

Another perspective provides the research on coordination and structural approaches of innovation management. Cooper and Kleinschmidt (1996) argue that stage-gate processes may be the main pillars for success. Literature has come up with several "prototypes" or "blueprints" of stage-gate models (e.g. Cooper, 1990; Murphy and Kumar, 1995; Kuczmarski, 2000; Song & Montoya-Weiss, 1998). In these models, early stages are formed more by fuzziness (e.g. fuzzy front-end) and creativity, whereas the later development stages are more coordinated and controlled by criteria such as time, cost and quality constraints. However, these models are rather idealistic and may not reflect the complex issues that an industrial organisation (such as a car manufacturer) is facing in terms of flexibility, uncertainty and complexity.

Christiansen and Varnes (2007; 2009) focus on decision-making and rules of innovation, arguing that the work and relationships of actors prior to decisions are key elements in innovation (Christiansen and Varnes, 2007). Instead of applying a sequential perspective they apply a network perspective drawing on actor-network literature. Through this perspective it becomes relevant how innovations are generated prior to decisions and which role strategic objectives and their representations play. Furthermore, they argue that rules and means that steer innovation processes "in everyday practices are not the same as those that the companies officially declare and describe" (Christiansen and Varnes, 2009, p. 516).

Jørgensen and Messner (2010) studied product development activities in stage-gate processes and argue that formal structures may remind product development of the importance of profitability and thus help to mobilise accounting information together with strategic objectives in decisions as "rules and a general understanding" (Jørgensen & Messner, 2010, p. 185). Their practice theory approach provides a detailed perspective on the interrelations of innovation and control. However, their study does not provide insights into situations in which strategic objectives and management accounting are conflicting. Innovation activities may be affected by conflicts. In their case they found that the limits of accounting were not contested "because strategic objectives were not *translated* into numbers" (ibid., p. 201). Yet, this may be the case in specific settings in which, for example, accounting calculations are strong actors. Furthermore, they focus on two different product lines. In multi-project organisations many product lines may be at different stages at the same time and be affected by different practices and actions.

The literature on innovation and control thus points to the important and interesting issue of control being related to both, enabling and constraining innovation. Yet, a deeper understanding of how organisations approach this issue and which actors are important in this process is needed. Studies focus on problems and conflicts between control and innovation in relation to effectiveness. Still, there is a lack of understanding of how organisations specifically deal with these conflicts. An in depth study of these conflicts can reveal important details about the interplay of elements in innovation and control settings.

> *"Management control systems are important for the performance of the project, but the research does not reveal why, nor provides the detail on how these systems are designed. […] Additional empirical evidence and theoretical concepts are required to fully understand the implications of this research."* (Davila, 2000, p. 405)

The interplay of these elements may thus not be regarded as sequential or static due to their influencing nature on each other (e.g. Christiansen and Varnes, 2007). Management accounting calculations, for example, may play an important role here as they may be boundaries that set a limit on the "usability" of accounting in product development and decision making. The literature argues that there may be limits to the use of accounting in innovation especially in cases of great uncertainty. So far we lack knowledge of how these limits are pursued, encountered, created and explored, how they may be overcome and whether calculations in this process form collectives or more ambiguity among actors in product development. Calculations and strategic documents may not only be part of the decision process but also may accompany and interact with the generation of alternatives in product development (Jørgensen and Messner, 2010). A more detailed understanding is needed of how calculations and the generation of product alternatives interact.

In the next two chapters I will touch on the issues of product design and creativity, and product greening as key success factors that strategically emerge in contemporary product development and shape innovation processes.

2.3 Aesthetical design and greening in product development

Two issues are of high relevance in product development: Aesthetical design and product greening. Both build issues of strategic importance for organisations as both may create customer value leading to price premiums in the market. New strategic objectives may emerge or be developed through aesthetical design and product greening, and both may trigger new innovations. Heterogeneity, limits of measurability and uncertainty may be aspects that cause control problems in the integration of both. In the following sections I will briefly elaborate on the particular relevance of both in product development. A more specific review is provided in the four papers.

2.3.1 Design control in product development

I discussed the literature on innovation and control in Chapter 2.2. One specific aspect in product innovation is aesthetical design and creativity. The control of innovation literature focuses mostly on technological innovation in product development. Aesthetical design, however, is a rarely studied object in relation to control and product development, and is argued rather to be a "creative endeavour" of individuals (e.g. Verganti, 1999) than a controlled process of collectives. Aesthetical design from that perspective focuses on ergonomics, materials and surfaces, and aims to interpret and create societal trends. Aesthetics can be understood as visualisations of "semantic" or "sociocultural" innovations defined by materials or surfaces (e.g. Dell'Era & Verganti, 2009; Van Onck, 2000). Technological innovation, however, is described as the development of functions that are shaped more by control and coordination concerns. Design is argued to be an unmanageable and emotional process that is not "possible to reduce to a set of algorithmic steps" (Love, 2000, p. 311). This is specifically due to the limitations of measuring and accounting for design. The selection of and decision on alternative designs and concepts is therefore a complex task, which differs from technological innovation, and empirical insights and a deeper understanding of the processes of design are missing.

Abstract ideas of strategic objectives are interpreted and visualised in concept designs and anticipations of trends, forms and functions: all parts of this process (Verganti, 1999). The creation of concepts, however, is not a task performed by just creating one final concept; it is more of a finding process and involves the generation of alternative concepts. During the early stages many alternatives may be created to discuss the most suitable option, which may provide a major challenge for designers (Ayag, 2005). This is as well due to uncertainty and to difficulties in anticipating the future. In the literature on product development, there are lots of concepts discussed in which the "best combination of harmoniously conforming subsystems is selected in terms of highest performance and lowest cost" (Ayag, 2005, p. 693). This literature argues that (especially within the fuzzy front-end) different methodologies of screening and developing different alternatives take place (e.g. Smith and Herbein, 1999; Ayag, 2005; Reinertsen, 1999; Khurana and Rosenthal, 1998; Tatikonda and Montoya-Weiss, 2001). In these studies various criteria and methods for generating these alternatives are discussed and they aim at providing comprehensive and successful toolkits. As discussed earlier, criteria are often fuzzy in the early stages and design interpretations may vary. Besides cost, the value of aesthetical and technological innovation is often not graspable. That, what is often defined as "highest performance" is often vaguely anticipated in critical success factors and crucial roles and may even be incommensurable for decisions (Espeland & Stevens, 1998).

Thus, decisions may often be made based on "softer" targets or through discussions on strategic representations, such as physical visualisations or prototypes (e.g. Wouters and Roijmans, 2011). On the other hand and especially in technological innovation, calculations may be a critical part, in some cases, of making decisions "rational". Calculations may be needed to prove a point in decisions on alternatives. As Mouritsen et al. (2009, p. 751) stated:

> *"Mere cognitive interpretation of innovation is not collectively actionable; innovation has to be inscribed and made a calculation before it can be acted on. This is the context that the calculation develops and makes possible."*

It is thus crucial to analyse the tension between a "mere cognitive interpretation" and calculations within creativity in product development, and focus on the contexts that calculations develop. If a "calculation is stronger" than "mere mental interpretation" (Mouritsen et al., 2009, p. 751), the analysis of the effects of the "strength" of calculations on the creative processes of alternative generation and decision (in technological and sociocultural innovation) becomes an interesting research ground.[12]

The process of creativity within new product development projects thus faces, in the early concept stage, the following problem: different control mechanisms may be in place for design and technological innovation which may seek to control and integrate different strategic objectives. Furthermore, the mobilisation of strategic

[12] "Even if control systems are an important element in shaping the organization, its impact on creativity has been virtually ignored. The literature has not even answered how budgets – the traditional management control tool – impact creativity. Financial plans and budgets are often used as a diagnostic control systems setting financial and non-financial reference points that managers need to meet. However, in some organizations, financial plans are not used to control but to encourage people to project themselves in the near and far future, to identify new trends, to see new opportunities and threats, to adopt new strategic postures. Therefore, it is worth studying how financial plans can trigger creativity, how are financial plans designed and used to encourage people to come up with new radical ideas, is it possible to use financial plans simultaneously to think differently and to define the direction to follow?" (Davila, Foster and Oyon, 2009, p.296)

objectives may be different and decisions may be done differently due to the limitations of measuring and accounting for design. The ambivalence of creativity (in technological and sociocultural innovation) and the strength of calculations are important factors in the development process and in the mobilisation of strategic objectives. So far, these issues have not been subjected to research and more understanding through empirical insight is needed to fill this gap.

2.3.2 Product greening and calculations

2.3.2.1 Strategic opportunities of product greening

Debates about Corporate Sustainability and its implementation into corporate strategy and governance are becoming more and more the focus of organisational research (e.g. Delmas & Toffel, 2008; Gladwin et al., 1995; Hart, 1995; Hoffman, 2001; Sharma & Henriques, 2005; Shrivastava, 1995; Starik & Rands, 1995). In practice, corporate sustainability has gained serious attention among organisations during the last decade (see Bansal & Roth, 2000; Henriques & Sardosrsky, 1996; Sharma & Henriques, 2005; GRI Reporting[13]). Especially environmental sustainability should become a more and more important aspect in product development. A growing world population, scarcity of raw materials, governmental regulations, changing customer behaviour, sustainability reporting guidelines and indexes have become important drivers in this process. Competitive advantage through reducing cost, minimising risk and creating customer value may be enhanced through addressing these issues:

[13] (GRI = Global Reporting Initiative) The number of released sustainability reports based on the GRI guidelines increased from 50 in 2000 to 750 in 2005. In 2010 more than 1300 multinational companies released their reports based on the GRI Guidelines.

> *"Managers must start to recognise environmental improvement as an economic and competitive opportunity, not as an annoying cost or an inevitable threat… the early movers – the companies that can see the opportunity first and embrace innovation based solutions – will reap major competitive benefits." (Porter & Van der Linde, 1995, p. 130).*

The issue of managing product greening[14] can be related to the discussion of strategic issues in terms of the controversies of innovation and control (see Chapter 2.2). Strategic objectives move beyond regulatory compliance towards new strategic opportunities in achieving competitive advantage through greening (e.g. Banerjee, 2001; Bansal & Roth, 2000; Biondi, Frey, & Iraldo, 2000; Hart, 1995; Hoffman, 2001; McWilliams & Siegel, 2001; Porter & van der Linde 1995; Prakash, 2001; Sharma & Henriques, 2005; Shrivastava, 1995; Smith, 2003). Organisations need to develop relations between greening, innovation and cost if they wish to compare alternatives and optimise cost and value.

This means that in the early stages of product development, the improvement of ecological concerns needs to take place to go beyond "end-of-pipe" approaches and create green products. When organisations want to follow this strategy, strategic objectives need to be integrated and translated early in the development stages and thus be integrated with other strategic objectives such as cost control, profitability, quality, or time-to market (e.g. Dixon & Duffy, 1990). Interactions and interrelations of calculations and performance measurements play an important role (see Chapters 2.1 and 2.2) and need to be taken into account.

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[14] The implementation of the environmental perspective is often referred to as "corporate greening". Though the word "green" or "greening" cannot be precisely defined in practice or theory we refer to the term as the ecological aspect of sustainability and the relationship of a company's process and product activities to the natural environment (Bansal & Roth, 2000; Halme, 2002; Shrivastava, 1995; Winn & Angell, 2000).

Greening therefore becomes another value and function that needs to be incorporated into product development networks.

2.3.2.2 Barriers to making product greening operational

As discussed, greening is a new strategic objective: a value that companies need to account for. In studies about accounting and product greening, the focus is mostly set on determinants or on outcomes of environmental accounting and management[15]. Few studies investigate organisational practices and the relation between accounting and product greening. However, this relation may be important as management accounting shapes decisions on product substance and thus on the greening of products.

In this process, several barriers and drawbacks may occur for organisations. First, if organisations implement measurements for product greening, they may not be well developed due to a lack of experience and creativity (Porter & van der Linde, 1995) and due to the "rules of the game" such as management accounting processes that build barriers for their integration or invention (Perego, 2005, p. 235). Secondly, there is an issue with the assessment of cost and value. "Environmental and human resources are not assigned financial values, and as a result, their intrinsic values are not fully accounted for." (Bansal, 2002, p. 127). The value of greening may be hard to assess and grasp: such as with the customers' willingness to pay (e.g. Pedersen and Neergaard, 2006). Thirdly, the existence of strategic objectives concerning product greening does not automatically provide greener products (Perego, 2005). The links between

[15] For a comprehensive literature review see Paper 2.

environmental strategy, performance measurements and product development may be difficult to trace. Hence, organisations face problems with the integration of green strategic objectives into their product development network. They face the issue of incorporating environmental aspects while at the same time managing towards different strategic objectives and targets.

Further studies that look into the interaction of management accounting and environmental management, in organisations with functions in which financial calculations play an important role, find that, environmental projects may face difficulties in achieving acceptance (Fryxell and Vryza, 1999), professional beliefs may be potential obstacles as they conflict with dominant green values and activities (Harris and Crane, 2002), and single environmental projects are rather the outcome of environmental accounting practices than a comprehensive management of environmental aspects (Bartolomeo et al., 2000). Furthermore, control of environmental issues might have rather an indirect effect on economic performance through enhanced environmental performance (e.g. Henri and Journeault, 2008).

The literature thus points to limits of the translation of product greening through management accounting functions: pointing towards cultures and beliefs, functions, measurability and forms of measurements as likely barriers. "Management accounting may restrict green innovation or be sidetracked from decision making, due to organisational resistance and uncertainties related to greening of innovation" (Paper 2). If so, then accounting functions may be simply overcome through direct strategic decisions on product substance rather than through the use of MCS. I still see a lack of insights into how greening is translated in product development networks and how and through which means decisions are made in industrial organisations. Here, the focus should be more set on likely boundaries and controversies in this process.

2.4 Summary

Based on the discussion in this chapter, which reflects on the issues of control in relation to strategy and innovation and briefly highlights the two important issues of product greening and aesthetical design the following implications for this thesis can be summarised.

A considerable number of studies analyse static relationships between strategic objectives, organisational contexts and innovation in relation to control: arguing for best fit and effectiveness. These studies draw mostly on contingency theory and do not take a dynamic perspective into account. Moreover, further understanding is needed of the mobilisation of strategic objectives by management accounting and control, and of the contexts that are created for innovation. Still the ground of strategy and control is not fully explored (Chapman, 2005) and current studies lack a detailed perspective of the contexts that are developed and created through management accounting and control. Competition among and between incommensable strategic objectives and accounting calculations for example may both destruct and construct contexts for strategy and innovation. Although management control may act as "rules and a general understanding" (Jørgensen & Messner, 2010, p. 185) for overcoming complexity and uncertainty, it may however, limit larger strategic changes (e.g. Jørgensen & Messner, 2010). On the other hand, strategic changes may be initiated by control systems and create contexts for innovation (Mouritsen et al., 2009). Calculations may thus be defined as actors in organisations rather than just as intermediaries. I will clarify this distinction further in chapter 3.

One aspect is the limits of accounting, which are argued to be barriers for innovation activities and strategic change. We lack knowledge and empirical insight of how these are created, how they are explored and how they may be overcome in the course of strategic change and product development. Issues such as product greening and aesthetical design are main issues and key success factors that emerge in contemporary product development. For example, product greening, as a strategic objective, may face different barriers in management accounting and control to be implemented and aesthetical design may be subject to different control mechanisms than used in technological innovation because of its limits to accountability.

I seek to discuss these problems from a theoretical perspective on the different characteristics of product development and innovation, focusing on the role of strategic objectives and calculations. In this thesis, I investigate the use of calculations and control mechanisms in product development and focus on strategic issues (such as product greening) and development issues (such as aesthetical design). I aim to discuss the means by which a product development network is held together and by which product development converges into a final product. The overall research question of this thesis is therefore:

> *How do management accounting and control mechanisms interact with strategic objectives and heterogeneous innovation networks within product development?*

In summary, the research question addresses the following gaps. First, a perspective is needed that provides in depth details to understand the interdependencies in product development and innovation between control and strategic objectives. Calculations are here to be defined as actors in organisations rather than just as intermediaries. Secondly, barriers and boundaries for calculations and the ways they are created, explored and overcome need further investigation. Thirdly, heterogeneity especially among strategic objectives, calculations, performance measurements and organisational functions builds an interesting research ground in the complex and conflicting field of product development. Fourthly, the two specific issues of product greening and aesthetical design are two rather unexplored fields that are relevant in the context of the research question.

I will elaborate on the theoretical perspective of the overall research question of this PhD in Chapter 3: focusing on the actor-network perspective of the discussed and relevant literature. Furthermore, I will relate the papers through this perspective and explain how I organise their contributions and their coherence.

3 The theoretical perspective of the thesis

In this chapter I introduce the theoretical perspective of the thesis and of the papers respectively. Chapter 3.1 is an introduction to ANT. The chapter explains the foundations and main concepts of ANT from a Latourian perspective and serves more as guidance towards chapter 3.2 and the papers.
Furthermore, in Chapter 3.2 I relate this perspective to the concepts to be studied in the thesis. In Chapter 3.3 I develop the coherence between the papers and the overall research question.

3.1 The ANT perspective of sociology

The focus of this chapter is how we may perceive, choose and study research objects. Here, we have to go from stable and robust objects to unstable objects. We have to unfold what is behind the object, going from "ready-made science" towards "science in the making" (Latour, 1987, p. 4), and thus from the fabricated into the fabrication of things.

3.1.1 The sociology of ANT

The motivation for choosing actor-network theory in the study of technology and management accounting lies exactly in this point; not studying the fabricated and already made objects, but studying how things are in the making: are in fabrication. Thus, how does it happen that a machine (like a car) goes "from a paper world to a messy, greasy, concrete world" (Latour, 1987, p. 253)[16]? Actor-

[16] "Machines for instance, are drawn, written, argued and calculated, before being built. Going from 'science' to 'technology' is not going from a paper world to a messy, greasy, concrete world. It is going from paperwork to still more paperwork, from one centre of calculation to another which gathers and handles more calculations of still more heterogeneous origins. The more modern and complex they are, the more paper forms machines need so as to come into existence. There is a simple reason for

network theory is a theory of studying black boxes; it is to study how through the construction of single parts, of actors of a machine, a collective disappears and becomes a darker and darker black box. For studying technological projects, the paths of the "incarnation" of the mechanisms and automatisms of humans and non-humans (Latour, 1996, p. 207) need to be traced and extracted.

Which sociology (sociological standpoint), which philosophy of science, frames the perspective of studying technological projects? In the following section, I describe how actor network theory positions itself in relation to ontology and epistemology. Moreover, I describe what was meant by Latour stating that "to study technological projects you have to move from a classical sociology – which has fixed frames of reference – to a relativistic sociology – which has fluctuating referents" (Latour, 1996, p. 169).

In the "modernist settlement" questions can only be attempted and answered all at the same time; the questions of epistemology, ontology, psychology, politics and theology. For actor-network theory, there is no sense in talking independently of these questions (Latour, 1999, p. 14). When we do not distinguish between these questions, what are we asking? We need to escape fixed frames and try to find the "hideout in which science has been held since being kidnapped" (Latour, 1999, p. 212).

In this settlement, where and what is reality when studying science? Can we describe science like a photograph as an exact copy of the world? No, we can't. Latour (1999) describes that it is not possible to verify the link between the mind and the world, rather, one can, through the study of science, trace the chain of

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this: in the very process of their construction they disappear from sight because each part hides the other as they become darker and darker black boxes." (Latour, 1987, p.253) transformations that circulates "verified reference" through "constant substitutions" (Latour, 1999, p. 79). Thus, reality is not a fact, a given, but moreover, it is something that is generated through translation and transformations[17]. External reality (out there) is thus a consequence of science rather than its cause.

> *"If [...] no dissenter is able to modify the shape of a new object, then that's it, it is reality, at least for as long as the trials of strength are not modified." (Latour, 1987, p.93)*

This means that realities are constructed, not by humans, but by science. Still, reality exists so far ANT is still a realist – it is however constructed by science in a process of constructing facts, which are its products[18]:

> *"First, facts need a theory if they are to be made visible, and this theory is rooted in the previous history of the research program – it is 'path dependent' as economists would say – but then, facts may be judged independently of earlier history. Once again the mystery of the two opposed meanings of the little word 'fact' is reiterated." (Latour, 1999, p. 129)*

Reality may be described as subject, or put differently, be dependent on scientific practices. With this dependency, scientific worlds are created that can become

[17] "Our philosophical tradition has been mistaken in wanting to make phenomena the meeting point between things-in-themselves and categories of human understanding. Realists, empiricists, idealists, and assorted rationalists have fought ceaselessly among themselves around this bipolar model. Phenomena, however, are not found at the meeting point between things and the forms of the human mind; phenomena are what circulates all along the reversible chain of transformations, at each step losing some properties to gain others that render them compatible with already-established centers of calculation. Instead of growing from two fixed extremities toward a stable meeting point in the middle, the unstable reference grows from the middle towards the ends, which are continually pushed further away." (Latour, 1999, p.71-72)

[18] "Realism would be misleading, for it would construct plausible settings for its narratives on the basis of specific states of science and technology, whereas what I want to show is how those states are generated." (Latour, 1996, p. VIII)

"possible worlds in conflict that move and shape one another" (Latour, 1996, p. IX).

Leaving classical sociology behind with its reference frames, norms, laws, morality, rules, cultures, classes, the nature of power relations and pursuing a rather relativistic theory with no fixed references, with no knowledge about classes or cultures, with its own version of facts is the perspective of ANT. It is not "more scientific than the actors" (Latour, 1996, p. 200).

For the researcher this means that instead of being cut off entirely from the world outside while at the same time being realistic about the outside world, s/he needs to "reconnect through as many relations and vessels as possible within the rich vascularisation that make science flow" to speak about the world (Latour, 1999, p. 113). Hence, the more connected science is, the more verifiable and solid it is. How this is to be pursued is discussed in the next section.

The epistemological question of what our representation of the world is must therefore not only be confused, but also mixed with the ontological question of what the world is really like (Latour, 1999, p.93). I discussed the reality not as a state of affairs, a state of order, but as something that is being constructed. It is not that social structures or sources emit power that diffuse through and order society. Rather, translations of actors construct associations. ANT is thus a "sociology of associations" (e.g. Latour, 2005, p.9) in which power is mediated through actors that "transform, translate, distort, and modify the meaning of the elements they are supposed to carry" (Latour, 2005, p. 39). Thus, there is no state of affairs, no state of order but only translations that generate associations.[19] As Elder-Vass (2008, p.

[19] "To be sure, the social environment can either hinder or encourage their development, but it never forms or constitutes the very content of the sciences [...] Science studies follows those implausible translations which mobilise in completely unexpected ways fresh definitions of what it is to make war and fresh definitions of what the world is made of." (Latour, 1999, p.91-92)

465) stated about ANT: "In addition to its neglect of realities beyond the empirical domain, it also strives to ignore the existence of emergent social structures." Thus, by doing that, epistemological and ontological questions are tied to one another (Latour, 1999, p.98).

ANT is more of a methodological stance in that it, rather than categorising or frame-working something, takes on the explanation of how things are formed, how they hold together, or how they fall apart. In the following sections I seek to explain this methodological stance of ANT as a study of "science, technology and society".

As already discussed, instead of talking about science, technology and society, my perspective is focusing on the weaker and stronger associations (Latour, 1987, p. 140). One needs a starting point for studying technology and society. Do we have facts or objectives *(3.1.2)*? Furthermore, what are objects and are they constructed, and moreover, by whom? Is it only by humans *(3.1.3)*? When we focus on "in the making" who are the actors and what are their actions *(3.1.4)*? What is mediated in these actions (e.g. intermediaries or mediators) *(3.1.5)*? How do we understand translations and what are their outcomes *(3.1.6, 3.1.7)*? Finally, what do we need the answers to these questions for *(3.1.8)*? I will discuss this in the next section.

3.1.2 From facts and where to begin to study

One should always begin by tracing associations. But by doing this, aren't there then pre-existing entities? Latour (2005, p. 166) talks about virtual entities that should "at least for now" not be followed. What does "at least for now" mean? Well, if one considers what reality is in ANT terms, namely "if [...] no dissenter is able to modify the shape of a new object, then that's it, it is reality, at least for as long as the trials of strength are not modified" (Latour, 1987, p.93), then it might be clear what "at least for now" means. Where the trials of strength are not modified, the tracks are not interesting to study. Where the social aggregates are modified, one should begin to trace the associations. By doing this, the researcher may on the one hand, not define in advance "what sorts of building blocks the social world is made of" (Latour 2005, p. 41); "let the actors do the job for us. Don't define for them what makes up the social" (ibid., p. 36). On the other hand, what is called "virtual entities", are actors that are present in researching the traces of creation, recreation, formation and dismantling. If one then traces the associations of the constantly modified social aggregates, one must trace actions, following actors generating these associations. Thus, by following actors and tracing associations, actors that modify the trials of strength have to be described[20].

3.1.3 General symmetry: humans and non-humans

Thus one important method in ANT is to "follow the actors". But who are the actors? If society in ANT terms is not socially constructed, who is constructing it if not humans? Society is constructed from humans and non-humans; "humans, for millions of years, have extended their social relations to other actants with which, with whom, they have swapped many properties, and with which, with whom, they form collectives" (Latour, 1999, p. 198).

Things only exist if humans and non-humans are holding them continuously together. What are the forces then? Not "social forces" because then objects are

[20] Describing actors may as well mean describing groups as actors (see e.g. the "fishermen in Callon, 1986, p.204; Latour, 2005, p.34)

leaving the stage and "the magical and tautological force of society is enough to hold *every thing* with, literally, *no thing"* (Latour, 2005, p. 70). Objects, things too, have agency. The forces of holding together controversies that modify, form and deform groups are the ties of humans and non-humans. "…*any thing* that does modify a state of affairs by making a difference is an actor" (Latour, 2005, p. 71). Everything is a *full-blown actor* and objects too now explain the relations of power, and that they are *active*. Either things are made to act or they act themselves.[21] "On the one hand, it [the thing] can be said to hold people together, but on the other hand it is people who hold it together" (Latour, 1996, p. 213); starting from this symmetry between humans and non-humans towards asymmetries through their relations and through their actions. No asymmetry may be presupposed. In the next sections I discuss the actions and the controversies between the actors.

3.1.4 Focus on actions and actors. Why?

When we talk about associations rather than structures, we have to ask ourselves who is then acting. Leaving out the assumption that structure may determine actions, as "society", "culture", or "classes" determine agency, we need to shift our view towards the actions first. Action can be thought of as a "node, a knot, and a conglomerate of many surprising sets of agencies that have to be slowly disentangled" (Latour, 2005, p. 44). Action alone is here not possible; the question is what and who is acting: while somebody, "we" are acting. An actor is thus not acting alone, it has no force of inertia (Latour, 1996, p. 176), it is "what is made to

[21] One example of this is the one of Pasteur and his yeast. Frames of reference are starting points and enablers for actions: "An experiment, as we just saw, is an action performed by the scientist so that the non-human can be made to appear on its own. [...] The experiment creates two planes: one on which the narrator is active, and a second on which the action is delegated to another character, a non-human one. [...] An experiment shifts out action from one frame of reference to another. Who is the active force in this experiment? Both Pasteur and his yeast. More precisely, Pasteur acts so that the yeast acts alone." (Latour, 1999, p.129) Also see Figure 4.1. p 130

act by many others" and actors are "constantly engaged by others in group formation and destruction" (Latour, 2005, p. 46-47).

> *"The actors in a technological project populate the world with other actors whom they endow with qualities, to whom they give past, to whom they attribute motivations, vision, goals, targets, and desires, and whose margin of manoeuvre they define. It is precisely because of this work of populating that they are called actors. For a given actor, this is the way the strategy of the other actors is interdefined." (Latour, 1996, p. 163)*

When the researcher now focuses on the course of action, these (associations) become uncountable and information of controversies is unlimited. Thus the empirical domain provides the researcher with endless entities: all of them heterogeneous. But what should the researcher then do while focusing on action and following actors? Latour (2005, p. 47) states that the researcher has "to ignore the queerest, baroque, and most idiosyncratic terms offered by the actors, following only those that have currency in the rear-world of the social". This may look like a craft, the art of doing research, but only through feeding off these controversies, only through discovering which actors fill the *social* world and keep us from making use of a priori settings through actions and group formation.

How do you feed off controversies? Well, agencies are always changing the state of affairs, "transforming some As into Bs through trials with Cs" (Latour, 2005, p. 52-53). Thus, the social is there, where change is happening and thus, it has to be assembled anew each time. Hence, for gathering data on actions, one needs to constantly compare courses of actions: "recording not filtering out, describing not disciplining" (Latour, 2005, p. 55). In this course, actors may constantly add or withdraw other entities, formulating the empirical trace (what is acting and how?) for the researcher. S/he then shifts from certainty about action to uncertainty.

"Following the actors" is the way to trace social connections. Concreteness in this course comes "from the increase [...] of the relative share of mediators over intermediaries" (Latour, 2005, p. 61). I will elaborate on intermediaries and mediators as entities of actions in the next section.

3.1.5 Intermediaries and mediators or "give me the cause and I will have the effect"[22]

When talking about "making someone do something" we may have a cause and effect relationship. Does input predict output? No, not in the way we discussed action in terms of mediation. For an intermediary the connection between cause and effect is clear as effect is already in the cause, but for mediators this is not the case. "Causes do not allow effects to be deduced as they are simply offering occasions, circumstances, and precedents. As a result, lots of surprising aliens may pop up in between" (Latour, 2005, p. 59); uncertainty and unexpected action enter the stage!

Intermediaries can be defined as a "black box counting for one" (Latour, 2005, p. 39) whereas mediators are specific, and their outcome and output unpredictable. "Mediators transform, translate, distort, and modify the meaning or the elements they are supposed to carry" (ibid). ANT thus describes the means and tools for construction as mediators and not as intermediaries:

[22] Latour, 2005, p.58

> *"For ANT, there is no preferable type of social aggregates, there exist endless numbers of mediators, and when those are transformed into faithful intermediaries it is not the rule, but a rare exception that has to be accounted for by some extra work – usually by the mobilisation of even more mediators!" (Latour, 2005, p. 40)*

The transformation by the "mobilisation of even more mediators" may thus lead to intermediaries: to a black box. This concept is described in the next section, which deals with the process of translation.

3.1.6 Translation, alignment, and convergent networks – from extreme weakness to the greatest strength[23]

We discussed that objects have agency too, that humans and non-humans are actors without discrimination. We learned that uncertainty and controversies are the sources of constructions and that "the identity and the respective importance of actors are at issue in the development of controversies" (Callon, 1986, p. 199). These principles are the starting point for the sociology of translation. "No one lives in a 'culture', shares a 'paradigm', or belongs to a 'society' before he or she clashes with others. The emergence of these words is one consequence of building longer networks and of crossing other people's paths" (Latour, 1987, p. 201). In the study of ANT, we are searching for this consequence. "Something more is needed to turn the temporary juxtaposition of interests into a durable whole" (Latour, 1987, p. 122).

[23] Latour, 1987, p.121

The question then is, what is happening when humans and non-humans interact, from the perspective of no a priori distinctions in social dimensions, and when uncertainty and controversies are in action? Actors having contradictory and/or disputable arguments; how then do they interact and how is group formation done? How may alignment between actors occur? Well, the observer has to follow "the actors in order to identify the manner in which these define and associate the different elements by which they build and explain their world, whether it be social or natural" (Callon, 1986, 201). Callon (1986) introduced the four moments of translation in which the *world* is *built* and *explained* by actors. These are problematisation, interessement, enrolment, and mobilisation (Callon, 1986).

Problematisation refers to the determination of a set of actors and the definition of their identities in a way where one actor becomes an obligatory passage point for the other actors. In this process that actor becomes indispensible (Latour, 1987, p. 120). Why would the one actor do this? Because there is this one question of what the problem is and how to solve it. This single question "is enough to involve a whole series of actors by establishing their identities and the links between them" (Callon, 1986, p. 205).

The second moment of translation concerns interessement. Entities are not formulating their goals and identities independently. Action is needed to adjust the goals and identities. In this course, interessement "is the group of actions by which an entity [...] attempts to impose and stabilize the identity of the other actors it defines through its Problematisation" (Callon, 1986, p. 207-208). IF A interests B, then it needs to cut or weaken the links between B and other entities (e.g. C, D, E) that are striving to link B to themselves:

“The properties and identity of B [...] are consolidated and/or redefined during the process of interessement. B is a ‘result’ of the association which links it to A. This link disassociates B from all the C,D, and E’s [...] that attempt to give it another definition” (Callon, 1986, p. 208).

As discussed, agencies are always changing the state of affairs, “transforming some As into Bs through trials with Cs” (Latour, 2005, p. 52-53). In this course, a system of allies is constructed.[24]

Enrolment, the third movement, is achieved through successful interessement. The actors that are made interested now accept the roles that are defined and attributed to them. “To describe enrolment is thus to describe the group of multilateral negotiations, trials of strength and tricks that accompany the interessements and enable them to succeed” (Callon, 1986, p. 211). The translation of the individual goals of two agents results in a composite goal that is different from the original ones. (Latour, 1999, p. 179)

Mobilisation, as the fourth moment, is the process of rendering entities “mobile which were not so beforehand” (Callon, 1986, p. 216). Actors form an alliance and act as a unit force. The actors that were not mobilised together beforehand and that occupied different spaces and times are now displaced and assembled in the same space and time. “To translate is to displace” (Callon, 1986, p. 223). In other words, diverse actors have been mobilised to act as one.[25] A composite goal out of more subgoals becomes a common achievement of each of the agents (Latour,

[24] “In the geometric sense of translation it means that whatever you do, and wherever you go, you have to pass through the contenders’ position and to help them further their interests.” (Latour, 1987, p.120)

[25] “It is necessary to consider more generally the mobilisation of resources, whereby I meant the ability to make a configuration of a maximal number of allies act as single whole in one place.” (Latour, 1987, p.172)

1999, p. 181). The result is action, "action is a property of associated entities" (Latour, 1999, p. 182)

"Now at the end of the four moments described, a constraining network of relationships has been built" (Callon, 1986, p. 218). A shared space has been created in which heterogeneous actors are *aligned* through common goals (Callon & Muniesa, 2005). When these networks are coordinated (i.e. the extent to which rules guide interactions) these networks are *convergent* (Callon, 1992; Callon & Muniesa, 2005). Thus, in summary, *translation* leads to *alignment* of a network with heterogeneous actors. When the network entails coordination through "the existence of numerous conventions and local procedures" (Callon, 1992, p. 94) it is strongly *convergent*.

Heterogeneity has been aligned and is now a black box, a punctualised network. "When many elements are made to act as one, that is what I will now call a black box" (Latour, 1987, p. 131). Thus, in doing research we need to focus on the contradictions that are mediated and to build up black boxes and we also need to focus on black boxes that fall apart because of the contradictions. Depunctualisation, and thus opening black boxes, is the perspective, the methodology which will be applied and pursued in this thesis.

3.1.7 How to use ANT in the thesis now?

As I will be analysing product development networks and thus how machines (technology) are becoming durable I will analyse how diverse actors are made to act as a whole, how concepts, technologies, innovations and components are becoming what they are. "A machine, as its name implies, is first of all, a machination, a stratagem, a kind of cunning, where borrowed forces keep one another in check so that none can fly apart from the group" (Latour, 1987, p. 128-129). I discussed what we understand by *borrowed forces*: namely, the process of translation. We need to follow the actors, their heterogeneity, and their contradictions and should trace how efforts that enrol humans and non-humans are mediated and how controversies are settled (Latour, 1987, p. 144).

However, ANT is not only the methodology of how to analyse the empirical accounts. Moreover, ANT is the perspective of how this thesis contributes to science. It should help to penetrate "from the outside the inner workings of science and technology" and then "to explain to the outsider how it all works" (Latour, 1987, p. 15). This process is divided into the following steps.

First, as in Chapter 2 the relevant body of literature is revised and gaps that arise for further research are identified. Open questions and doubts lead us from the "world of literature to Nature as it is" (Latour, 1987, p. 67). The literature or rhetorical resources are the starting point for finding controversies in the rhetoric resources themselves and in the empirical domain. We do not start off with *facts* or *building blocks* but with doubts and questions about quasi-facts. Quasi-facts referring here to the scientific work inscribed in the publications I discuss.

The second step is to discuss the concepts that have been touched by the gaps through the lens of ANT. This is discussed in Chapter 3.2. I focus mainly on the concepts and instruments[26] that are needed to form technology, such as calculations and control; thus, I focus on the tools that are needed to adjust durability.

[26] "When science in action is followed, instruments become the crucial elements, immediately after the technical texts; they are where the dissenter is inevitably led." (Latour, 1987, p.69)

Thirdly, in Chapter 4, the research methods need to be discussed in relation to the perspective by which I strive to make a contribution.
Fourthly, in Chapter 5, as this is a paper-based thesis, the papers with their perspectives, methodologies, theoretical underpinnings, empirical work and their conclusions are presented: each based on the perspective of ANT and dealing with the questions ”Why and in what conditions do controversies occur? How are they ended?” (Callon, 1986, p. 219)

In Chapter 6, following the paper presentation, I discuss the conclusions of the papers together with the earlier introduced overall research question and contribute back towards the body of literature and to the discussions and applications of ANT studies.

3.2 The ANT approach to strategy, control, mechanisms, innovation and fabrication

If everything is constructed and we wish to unfold the constructed facts, then we may end up infinitely opening black boxes. Thus, we have to discuss facts, such as theories and studies, and we have to ask the formal questions and accept (although to a certain degree) that we believe in something or not; the fate of facts is in our hands (Latour, 1987, p. 29).

If a product is a fact, something that is in front of us and that is working, we may ask ourselves why? Furthermore, the same kind of products may differ significantly. Cars, for example, although being in the same sector, competing for the very same customer, are varying in design, function, price, volume, quality and so on. That is, a car is not simply a fact; it is something that is made a fact. The question about the "made" or "fact-making" is thus the one we need to discover and break down the black box of a car as an example. I discussed earlier the foundations of actor-network theory and how things are in the making. Now I wish to elaborate on the concepts I discussed in the literature review through a sociological lens: *strategic objectives, calculative and non-calculative devices, control and innovation*. This perspective assists in understanding relations and influences of actors within the network of management control and product development. It helps to understand how products become durable by providing themselves with a context and by how they change this context over time. This involves looking at the space and its relations as if they were not pre-given (Callon, 1986, 1991; Latour, 1987).

To study management control and product development a more systematic approach, that focuses on interdependencies between different actors in the organisation, is suggested to avoid ambiguity in results and conflicting findings (Abernathy and Brownell, 1997; Chenhall, 2003; Ferreira and Otley, 2009). But rather than using "snapshot" perspectives (e.g. Ferreira and Otley, 2009, p. 276) for the analysis of the study I strive to analyse how things are in the making. Especially if the analysis is striving for a "complete description of the totality of a control system" (Ferreira and Otley, 2009, p. 263) then the framework might serve on the one hand, as a tool for documenting certain practices. However, on the other hand, strategic objectives, calculative and non-calculative devices, control and innovation can only be accessed while tracing the changes in all possible spaces and by analysing how resources are mobilised: thus, by focusing on time *and* space.[27] In the following I discuss these concepts, from a sociological perspective, focusing on actor-network theory.

3.2.1 Strategic objectives and inscriptions

> *"'Oh around the sixties. The Kennedy era. Private cars were on the way out – that's what everyone was saying.'" (Latour, 1996, p. 15)*

This is an example of Latour's story on Aramis (1996). Ideas such as private cars being "on the way out" are mediated within organisations. These main ideas may be initiators of change or act as guidance in decisions about change or preservation. Inscribed in documents (e.g. as mission or vision), they are mediated throughout the organisation and by referring to them, allies that combine different parts of the organisation are drawn together and mobilised[28]. Through inscriptions

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[27] Here it is important to look at the space and its relations as if they are not pre-given. The question is how things are related within that space and time. Latour (2005, p.71) states that "any thing that does modify a state of affairs by making a difference is an actor". The relationship between actors thus build up a network and they produce spaces and times and the actors "mobilise, cumulate and recombine the world" (Latour, 1987).

[28] "It is necessary to consider the mobilisation of resources, whereby I meant the ability to make a configuration of a maximal number of allies act as single whole in one place." (Latour, 1987, p.172)

in e.g. documents or calculations, these strategic perspectives are translated into "more concrete" objects and provide a "routine basis" (Ferreira and Otley, 2009, p. 269). Through these objects, acting at a distance becomes possible by:

> *"Devising inscriptions that retain simultaneously as little and as much as possible by increasing either their mobility, stability, or combinability. This compromise between presence and absence is often called Information. When you hold a piece of information you have the form of something without the thing itself. [...] As we know, these pieces of information [...] can be accumulated and combined in the centres" (Latour, 1987, p. 243).*

In this definition, the inscriptions, the information act as a representation of something (human or non-human entities). This can be a strategic document, a calculation, a prototype, or a shareholder. Each of these objects represents something as something is inscribed into them; a strategic document may represent the customer; a calculation may represent a shareholder or a design model the creativity of an individual.

Influence on behaviour, on decisions, is furthermore a vital part of representations. They may ,for example, make things profitable that weren't beforehand and vice versa (e.g. Latour, 1996, p. 184). They can, like the "sleeping policeman" in Latour's collective of humans and non-humans (Latour, 1999, p. 186), modify behaviour, shift meanings and display goals. An engineer, for example, may not believe in profitability as much as a CEO, but more in technologies; however, within a frame of business cases that calculate his inventions, the goal of the engineer becomes displaced and is redirected towards profitability, albeit through technology.

Thus, to discuss strategy and strategic objectives we have to search for devices that represent human and non-human entities and in which these are being inscribed. Through this perspective, maybe every representation become "strategic"; we do not know yet. But by following these representations as actors, we may get an idea of what strategy is and how it is done. In the next section I will discuss in which form these representations may appear, how they translate decisions, and how they control are networks.

3.2.2 Representations, control, mechanisms

3.2.2.1 Representations – non-calculative and calculative devices

Representations are able "to sum up, to summarise, to totalise – as the name 'total' indicates – to bring together elements which are, nevertheless, not there" (Latour, 1987, p. 234). This is the principle of representation. Representations can only make a difference once the networks behind them are in place (e.g. Paper 2). These representations can be devices of calculative or non-calculative nature.

Non-calculative devices refer here to representations that are not calculated. Texts or technical objects for example are non-calculative devices. They "can be vital expressions of core values, signalling to people how they should act toward those things. "Identities and crucial roles are often defined with incommensurable categories" (Espeland & Stevens, 1998, p. 327). For example, strategic documents may contain texts with words such as *dynamic*, *family-oriented* or *aggressive*. These may represent strategic objectives and act on engineers, designers or managers while developing a product. These non-calculative representations are present as actors in product development networks.

On the other hand, there are "calculative devices"[29]. Calculations are built on how things are and should be commensurable. The process of calculation is the process of commensuration. Calculation may therefore be conceptualised as a process of searching and overcoming boundaries to calculation: through commensuration (Espeland & Stevens, 1998). Commensuration is the transformation of qualities into quantities, into common metrics (Espeland and Stevens, 1998). Such a calculation entails a three step process (Callon & Muniesa, 2005). First, a calculative space needs to be created in which entities can be moved, arranged and ordered based on common principles. Secondly, the entities become associated with one another. Here, Valorimeters are tools that translate entities into numbers (Caliskan & Callon, 2010, p. 17). This commensuration is the "expression or measurement of characteristics normally represented by different units according to a common metric" (Espeland & Stevens, 1998, p. 315). In the end, the calculation is finalised by summarising the results.

Used for decision making, and thus of immense interest to this thesis, calculations are argued to mechanise decision making. Especially "value" plays an important role in the process of commensuration and decision making[30]. Through becoming part of a network, and being set in relation to other calculations or actors, calculations become measurements of performance. They become *valued* in the sense that they display *good* or *bad value*. In footnote 9 I already introduced an example in which the weight of a car was calculated. The arising question in product development could in this case be: do we have to decrease weight? As

[29] "I refer to calculative devices as devices that "a) circumscribe the group of calculative agencies that are to be met, by making them identifiable and enumerable; b) organize their encounter, that is, their connection; and c) establish the rules or conventions that set the order in which these connections must be treated and taken into account (formats, queues, etc.)." (Callon & Muniesa, 2005, p. 1242) The three step process is further described in the text.

[30] "When used to make decisions, commensurated value is derived from the trade-offs made among the different aspects of a choice. Value emerges from comparisons that are framed in terms of how much of one thing is needed to compensate for something else. In complex choices, commensuration often occurs at several levels of analysis." (Espeland and Stevens, 1998, p.317)

long as this calculation stands for itself, we don't know. But if it is linked to other calculations, for example, to the weight of competitors, or to consumption-levels based on weight, one can relate the weight performance to better or worse, good or bad. A calculation thus becomes a performance measurement when it is put into a context; when it is linked with other actors.

3.2.2.2 Conflicts of non-calculative and calculative devices

As discussed, in product development, various interests of multiple departments need to be coordinated; heterogeneity and conflicts arise in the process of mobilising strategy. The mobilisation may also lead to tensions and inconsistencies through being mobilised differently throughout the organisation. Heterogeneity is cause and effect of possible conflicts. "Cause" as different parts of the organisation add different perspectives on strategies (representations) and "effect" as the mobilised representations lead to contradiction and tension among different parts of the organisation. For example, cost reduction strategy and customer value strategy may lead to conflicting views through the generation of cost reduction measures that are in conflict with customer functions which add value. Thus, it becomes crucial to analyse how these heterogeneous perspectives (and thus strategies) are mobilised in organisational networks.

I will follow the call of Espeland and Stevens (1998) to shift attention to the processes of commensuration and calculations to get novel insights into fields of sociological inquiry. To focus on the making of calculations and on making things calculable is furthermore to focus on obligatory passage points, as "calculators whoever they are, sit at a central point inside the centres because everything has to pass through their hand" (Latour, 1987, p. 244). How we may define these "centres" and what the actions are within them is to be discussed in the next section.

3.2.2.3 Control systems and mechanisms

When talking about management control, in Callon's (1991) view, the use of calculations would be defined as intermediaries put into circulation by actors. This view provides insight into the world that circumscribes the calculations. Here, I consider both calculative and non-calculative devices intermediaries. What is happening now in the centres in which these devices are accumulated? The centres may be called systems (such as management control systems, MCS) in which calculative and non-calculative devices are translating other actors. A strategic document, for example, may problematise something, interest and enrol other actors (such as managers). and mobilise them towards a new, common goal. Latour's definition of the centres of calculations can be used to define MCS:

> *"How to act at a distance on unfamiliar events, places and people? Answer: by somehow bringing home these events, places and people. How can this be achieved since they are distant? By inventing means that (a) render them mobile so that they can be brought back; (b) keep them stable so that they can be moved back and forth without additional distortion, corruption or decay, and (c) are combinable so that whatever stuff they are made of, they can be cumulated, aggregated, or shuffled like a pack of cards. If those conditions are met, then a small provincial town, or an obscure laboratory, or a puny little company in a garage, that were at first as weak as any other place will become centres dominating at a distance many other places." (Latour, 1987, p. 223)*

(a), *(b)*, and *(c)* were discussed in the previous section, where each is considered a step towards representation. But we can only start talking about MCS, if *alignment* through these processes is met. *Domination*, in terms of MCS in product development, has only occurred when durability in terms of product development and the finalised product is an end result of the development process. Thus, *alignment* in and through management control leads to product decisions and the finalised product. There are the many traces that are cumulated in the MCS and through which "everything can become familiar finite, nearby and handy" (Latour, 1987, p. 230). Oversight[31] is created. The MCS is like a machine and can thus be studied as such. "We were well aware that thousands of sightings, 'looks', sensors, feelers, signals, alarm bells make it possible to transcribe by sight on a control panel what the mechanism seals up. No machine without its control panel" (Latour, 1996, p. 222). Thus, only through opening the black box of a MCS, can one understand what is represented and how, and, more importantly, why decisions are made towards the outer world and for shaping new objects, such as cars, through product development. Space and time are reversed and are inscribed into the MCS to oversee and control space and time. Through this oversight and control we may become superior to the outer world and construct it. With MCS "we are able to gather together synoptically all the actions that occurred over many days and that we have since forgotten" (Latour, 1999, p. 64). Revealing them or, put differently, *ungathering* them from the MCS is to discover the actions carried out to develop a product and that is the research that has to be done to understand the process of product development, which is exactly what I attempt in this thesis.

[31] "In a beautiful contradiction, the English word 'oversight' exactly captures the two meanings of this domination by sight, since it means at once looking at something from above and ignoring it." (Latour, 1999, p.38)

When I said that a MCS is like a machine, then one may ask for its *mechanisms*. Callon and Latour are talking here about formalisms. The more representations are accumulated in the system "the more formalism they will require simply to stay together" (Latour, 1987, p. 245). But what is meant by formalism here? As discussed, Callon (1991) describes a strongly *convergent* network as one that entails coordination. In this network, heterogeneous humans and non-humans (technical objects) evolve predictably through conventions and procedures "as if acted on by rules to which they conform" (Callon, 1992, p.94); "despite the heterogeneity of the assembled entities, they work in unison" (Murdoch, 1998, p. 363). It is exactly this process (the one that creates coordination) which I will refer to as *control mechanism*. Although the word mechanism sounds as if something is done over and over again it is nothing stable but is a result of the links that are assembled and reassembled in every moment. Thus, a *control mechanism* is the translation of representations (such as strategic documents, calculations, prototypes) within a MCS that leads to alignment of respective actors. From this perspective, control mechanisms include decisions, incentives, rewards or punishments. Every translation that leads to an aligned and coordinated network is a control mechanism.

The process of alignment and the combination of the worlds' representations within the MCS becomes interesting when "forms coming from completely different regions" (Latour, 1987, p. 243) interact in the MCS; thus, when new strategic objectives are mobilised within the MCS. "Unexpected connections"(ibid.) are what happen in innovation and what cause uncertainties in the process of product development.

3.2.3 Innovation and uncertainty

"But the more the fate of the project is bound up with these new participants, the more room they take up, comparatively speaking. The only thing a technological project cannot do is implement itself without placing itself in a broader context. If it refuses to contextualize itself, it may remain technologically perfect, but unreal. Technological projects that remain purely technological are like moralists: their hands are clean, but they don't have hands" (Latour, 1996, p. 127).

Here the "broader context" for a product can be defined as the market with its customers, costs, technologies, production facilities, suppliers and so on. I discussed how, through calculative and non-calculative devices and their connection, product development networks are assembled and held together. The result is this "broader context" into which innovation is fabricated. Different actors have divergent interests in the very beginning of the process of innovation. With the process of translation towards a "common" project, a project that has a "good agency of translation" (Latour, 1996, p. 48), goals become common ones and the product development network starts off with the fabrication of a product: of an innovation.

Latour describes the degree of innovation as follows:

"Here is the difference between a project that is not very innovative and one that is highly innovative. A project is called innovative if the number of actors that have to be taken into account is not a given from the outset. If that number is known in advance, in contrast, the project can follow quite orderly, hierarchical phases; it can go from office to office, and

every office will add the concerns of the actors for which it is responsible. As you proceed along the corridor, the size or degree of reality grows by regular increments. Research projects, on the other hand, do not have such an elegant order: the crowds that were thought to be behind the project disappear without a word; or, conversely, unexpected allies turn up and demand to be taken into account. It's like a reception where the invited guests have failed to show; in their place, a bunch of unruly louts turn up and ruin everything." (Latour, 1996, p. 72)

For studying innovation and product development respectively, one therefore needs to follow unexpected events, and the discussed unexpected connections that are made. If one were to only study processes on the blueprint, one would end up just studying the blueprint and not what is really *developed*. Things, products, are being *developed* and thus *develop* over time, and as they do, unexpected, previously unseen actors enter the stage. As with research work (like this thesis) it cannot be written from a blueprint, as it needs to come up with something new and yes, something unexpected; a product is not being developed from numbers and actions that are known in advance: at least not innovations. Uncertainty and controversies are the sources of social constructions and "the identity and the respective importance of actors are at issue in the development of controversies." (Callon, 1986, p. 199). Uncertainty is thus a concept that is inherent to ANT (See Appendix 2). Certainty may only be achieved through alignment of different actors and their interests; hence, through translation.

When focusing the research on management accounting systems and innovations, Latour is very concise about the relationship between both, as accounting systems decide the fate of innovations:

> "*Of course you have to 'take into account' all the elements, as people say naively, but only the not very innovative projects know in advance which accountant to believe and which accounting system to choose. We use the term 'innovative' precisely for a project that requires choosing the right accountant and the right accounting method, in order to decide which actors are important and which ones are dangerous." (Latour, 1996, p. 73)*

Here, and in the discussion of minimising uncertainty and representing the outer world, management accounting is held accountable for the "success" of an innovation, as it decides which actors to choose. Because innovation needs to grow, control and innovation are not separated but tied together. Furthermore, heterogeneous actors and controversies are settled through the process of innovation and control. The innovator deals with uncertain and heterogeneous things. They have to assemble them, they need to be "recruited, seduced, modified, transformed, developed, brought on board" (Latour, 1996, p. 57), in order to get to the fabrication of an object. "The innovation [...] will make it possible to "translate" and to "reconcile" contraries in order to establish chains of translation and to situate [...] expertise as the obligatory passage point that will resolve the great problems of the age. The work of generating interest consists of constructing these long chains of reasons that are irresistible, even though their logical form may be debatable." (Latour, 1996, p. 33) It is thus not about the logic of action but about the translation and enrolment of all actors. If such a thing as logic were to be responsible for product development, then why, for example, does every Automotive Company produce different cars? And why are some called innovative and others not?

Of course, if we stay with the example of cars, some actors are well known beforehand and some processes as well. Maybe a new model will never hold to be called a "radical innovation". Think of all the customers already enrolled and inscribed in current as well as future car projects. They are already a reality in existing cars (e.g. volume and price, positioning, and so on) and are easier enrolled into future car projects through estimations. Through tying estimations to past numbers they become more real[32]: more realistic, and uncertainty decreases.

Still there are controversies and uncertainties about future markets, future customers and about technologies. New actors and objectives become part of product development and provide a project with a context[33]; the network is developing through these actors and it is exactly these actors that are to be studied. New customer demands, new technologies, new laws, new management technologies and creativity are all to be taken into account. "Innovation always comes from a blending of redistribution of properties that previously had been dispersed." (Latour, 1996, p. 36) We need to trace where they come from and how they are acting to understand the translations they are causing within product development and thus how fabrication takes place. "In order to follow a technological project, we have to follow simultaneously both, the narrative program and the degree of 'realisation' of each of the actions." (Latour, 1996, p. 81) The many compromises, the settlement of uncertainties and controversies that increase a project's reality are of interest.

[32] "Anything can become more real or less real, depending on the continuous chains of translation". (Latour, 1996, p. 85)

[33] "A technological project is not in a context; it gives itself a context, or sometimes does not give itself one. What is required is not to 'replace projects in their context,' as the foolish expression goes, but to study the way the project is conceptualised or deconceptualised. To do that, the rigid, stuffy word "context" has to be replaced by the supple, friendly word 'network'. [...] The impression of a context that surrounds the project comes from the fact that one forgets to count the handful of mediators who speak in the name of money, Official Bodies, chips, or voters." (Latour, 1996, p.133-134)

3.2.4 A brief summary of strategic objectives, calculative and non-calculative devices, control, and innovation

The in Chapter 3.1 discussed actor-network theory provides a perspective on the concepts of strategic objectives, calculative and non-calculative devices, control and innovation. Uncertainty and controversies are sources of social constructions (Callon, 1986, p. 199). Heterogeneity is one important aspect as, instead of becoming homogeneous, networks are convergent through the alignment and coordination of heterogeneous actors (Callon, 1986). This process defines how the *world* is *built* and it is *explained* by actors (Callon, 1986). Diverse and heterogeneous goals become a composite objective: a common achievement of the actors (Latour, 1999, p. 181). The result is action which "is a property of associated entities" (Latour, 1999, p. 182). The actor-network perspective (as examined in Chapter 3.1) conceptualise the product development as a network that "describe[s] a coordinated set of heterogeneous actors which interact more or less successfully to develop, produce, distribute and diffuse methods for generating goods and services" (Callon, 1991, p. 133).

Strategic objectives are mobilised and are cause and effect of heterogeneity. Their mobilisation is a process of conflicts by which new networks are developed and constructed. Representations (calculative and non-calculative) and control mechanisms are here important actors as they are translators and align heterogeneity towards innovation. They settle controversies and conflicts in the fabrication of innovation by displacing goals. The result of the discussion so far is the fabrication of the future. Decoupled interests, goals, objectives and things are made durable; they are fabricated into an innovation. In the next section, I discuss how this perspective relates to the research work of this thesis

3.3 Analytical strategy and paper coherence

I have come a long way from discussing the relevant literature on control, strategy and innovation, and on greening and design, the sociology of ANT, and finally from discussing the relevant concepts of this thesis. The literature review pointed to several gaps that I intend to fill with the four papers of this thesis. I argued that in studies of control of strategy and innovation, a perspective that focuses on the dynamic relationships of control and innovation is needed to investigate the rather unexplored ground of control and strategy (Chapman, 2005) and that current studies do not provide a detailed perspective of the contexts that are developed and created through management accounting and control in product development networks. Furthermore, calculations play an active role in organisations, and in product development networks respectively. Knowledge and understanding is needed about the role of calculations and the limits of accountability in innovation activities and strategic change. I strive to contribute to the literature on control of strategy and innovation through the discussion of different characteristics of product development and innovation, focusing on the role of strategic objectives and control mechanisms with calculative and non-calculative devices. I develop the contribution through investigating the use of these devices and control mechanisms in product development and focus on strategic issues (e.g. product greening) and development issues (e.g. aesthetical design). Through discussing the coherence of the four papers and their relation, I strive to shed light on the overall research question:

How do management accounting and control mechanisms interact with strategic objectives and heterogeneous innovation networks within product development?

Here, particularly the heterogeneity among actors (e.g. strategic objectives, calculations, and managers, technologies) is interesting to study, as it needs to be aligned through the settlement of conflicts and controversies.

The ANT perspective assists here in understanding the interrelations between heterogeneous actors and helps us to understand how products become durable; in that, strategic objectives, calculations, or control mechanisms are not defined as pre-given (Callon, 1986, 1991; Latour, 1987). Thus, interrelations can only be studied through tracing changes in time and space. This perspective unravels unexpected connections that are drawn throughout product development and that are responsible for innovation; thus, providing a dynamic perspective of innovation, strategic objectives and control mechanisms. Following the actions carried out to develop a product is the research that has to be done to understand the process of product development and this is exactly what is to be developed in the four papers.

3.3.1 Links and relationships of performance measurements in strategic change

Focusing on the dynamics in the mobilisation of strategic objectives, we lack insights about the particular interactions of management accounting calculations and strategic objectives. Here, specifically the issue of the choice of accounting calculations and performance measurements become interesting areas of research. There is a further understanding needed in relation to strategic objectives and their implementation and mobilisation by management accounting calculations. As discussed in Chapter 2.1.2, studies in management accounting that deal with the choice of performance measurements are mainly focusing on attributes and characteristics of performance measurements and on how these may be influenced by organisational parts or strategic objectives (e.g. Malina and Selto, 2004; Chenhall and Langfield-Smith, 1998; Tuomela, 2005). However, I here see the actor-network perspective as relevant for understanding the links between and among performance measurements and strategic objectives and how this influences how measurements are created (Malmi and Brown, 2008). Studies drawing, for example, on contingency or practice theory assume that managers actively choose performance measurements to implement strategic objectives, neglecting the perspective that the links that are drawn by existing calculations may be of specific importance. Performance measurements are not simply intermediaries that are put in circulation to implement strategic objectives (Callon, 1991) but are actors in the sense that the links and contexts they establish impose the design and choice of new performance measurements within strategic change. Hence, interdependencies of performance measurements and the implementation of strategic objectives are still an unexplored issue that is important for the literature on control and strategy as the relationship defines the linkage between strategy and operations. Therefore the research question that is explored in Paper 1 is:

How are new strategic objectives (such as reducing product complexity) translated into the new product development process and which role do existing performance measurements play in relation to the choice of performance measurements?

3.3.2 Creating and exploring calculative spaces for innovation and the environment

In addition to the problem of interdependencies between calculations in strategic change, it becomes interesting to investigate the specific process of mobilising new strategic objectives through calculative processes in product development. Here, for example, calculations are, rather than just describing or representing activities in product development networks, creating contexts for activities and strategic change (e.g. Mouritsen et al., 2009). If so, then, as discussed in Chapter 2.2, strategic objectives may be transformed into numbers, or simply be represented by calculations: especially in settings where calculations are strong actors. Limits on accountability and commensurability are here often argued to hinder strategic objectives from being either transformed into numbers or from being implemented at all. The literature of product greening points, for example, to limits on management accounting, which argues that product greening and green innovations may be restricted by management accounting functions or processes. But here we lack general knowledge of how limits on accountability and commensurability may be encountered or handled and if and how they may be overcome. Insight into the translation processes in product development networks is missing, in which strategic objectives are incorporated that are argued difficult to commensurate.

Here, it becomes interesting if through the introduction of new strategic objectives calculative processes may fall apart. These objectives may weaken the alignment of a network, yet create a need for the network to be realigned. One aspect here may be that not everything is represented by calculations but that calculations form collectives through the process of translation (Latour, 1987). Or, furthermore, through a process of commensuration, objectives may be represented by a common metric (Espeland & Stevens, 1998, p. 315). A study focusing on these processes would fill the previously discussed gap and would contribute to the literature of control and strategy, innovation and product greening. The emerging research question, which is posed in Paper 2, therefore is:

How is greening calculated in heterogeneous product development networks?

3.3.3 The translation of strategic objectives in the process of aesthetical design

In some cases strategic objectives may be primarily mobilised by other means than calculations, however they may still interact with them over time. In Chapter 2.3 I pointed towards the issue of aesthetical design and technological innovation as two different routes towards innovation, although possibly separated, yet with the need to be integrated. In aesthetical design, strategic objectives are thus likely to be mobilised differently and decisions may be taken based on different objectives due to the incommensurable nature of aesthetics. However, accounting calculations as strong control mechanisms may play a role in the process of aesthetical design. This has so far not been a subject for research and more empirical insight is needed. With the focus on strategising: as the process of the mobilisation of strategic objectives, calculations, and other actors within the product development network develops a deeper insight into this issue may be granted. Instead of talking about strategy as practice focusing on social actors (e.g. Jarzabkowski et al. 2007; Whittington, 2003, 2006), I seek to develop an ANT perspective of strategising and exploring the process of strategic mobilisation in design as a process of translation. Calculations may displace strategic objectives (Latour, 1999), although objectives may also act as guidance or reference in decisions about change or preservation. Thus, the mobilisation may also lead to tensions and inconsistencies through first, being mobilised differently throughout the organisation, and secondly, through calculative and non-calculative devices being in the same space. Thus, the research question investigated in Paper 3 is:

How are strategic objectives translated in the process of aesthetical design?

3.3.4 Controlling, separating and converging design and product development

Building on the previous problem, technological innovation and design may have different control mechanisms in which strategic objectives are mobilised. However, at some point there is a need for integration of both throughout product development. In this process, there are controversies and uncertainties about future markets, future customers and about technologies so heterogeneous contexts need to be converged towards the final product. The convergence of design and technological innovation thus plays an important role in the development process. Divergent interests are translated into a "common" project with "good agency of translation" (Latour, 1996, p. 48) and goals are displaced and common ones are created through decisions. If management accounting decides which actors to choose, and if abstractions of relationships and heterogeneous relationships between actors are impacted by calculations on the one hand, and if accounts such as design may have different control mechanisms than in technical product development, then we need to have insights about the convergence of these mechanisms. Contributing to the literature on control and innovation and aesthetical design, the research question to be investigated in Paper 4, therefore is:

How is design and technological innovation controlled, when both separation and integration of design and product development is demanded?

3.3.5 Summary

Through the four presented research questions, I strive to make a contribution to the discussed literature by applying a more detailed perspective on calculations and control in strategy and innovation. The papers relate to each other in the discussed form and make a rather specific contribution to the field. Although each paper discusses particular problems and cases within product development networks, they make an overall point, which is developed in Chapter 6. I see this form of contribution to the literature as an advantage due to the lack of in-depth studies in this field. Furthermore, product development is, due to its complex and diverging nature, an issue that is hard to study and may present conflicting and ambiguous findings (e.g. Chenhall, 2003). With an actor-network perspective, I strive to point to particular issues in product development and to conceptualise a contribution and further implications, rather than developing a framework. Links and relationships of calculations in mobilising strategic objectives (Paper 1), the role of calculations in the process of mobilisation of objectives (Paper 2), the role of calculations in the strategising process of aesthetical design (Paper 3), and the different mechanisms in product development and their convergence (Paper 4) are thus relevant in studying the question of how management accounting and control mechanisms interact with strategic objectives and heterogeneous innovation networks.

4 Research methods applied in the PhD

The focus on calculations, MCS, and product development guided the assembly of the empirical material and the data collection methods of this PhD thesis. The empirical domain is a European car manufacturer that has been studied for a period of three years. I have thus studied the company in a longitudinal study, while I was employed in the department of product development, controlling and product cost steering. Here, I participated in the calculation of cost and value of functions and components. Through this, participant observation, access to relevant documents and information, and insights into the product development network and cases were granted.

I strongly focused on episodes in which product decisions were prepared and generated, and in which innovation, design and the environment played an important role. To discover and understand these episodes I had to understand the product development network, the control mechanisms and the general ways in which calculations were performed within the product development network. Thus, rather than focusing on how things fall apart, I focus on how things are being constructed.

In order to understand how controversies occur and how they are settled in the realm of innovation and calculation, I have studied "unpredictable and heterogeneous associations that are revealed by the growing intensity of the controversies [...]:

(a) how causes and effects are attributed;

(b) what points are linked to each other;

(c) what size and strength these links have;

(d) who the most legitimate spokespersons are;

(e) and how all these elements are modified during the controversy" (Latour, 1987, p. 202).

I did this in a cumulative study of special cases and divided this thesis into four papers, which will be discussed in Chapter 5. In the following sections I will first describe how I chose the cases, secondly how and why I collected the data, and thirdly, I will close with a brief summary on methods and methodology. However, this is rather a broad overview as the methods are described in the papers in more detail.

4.1 Selection of cases and papers

All four papers cover a broad range of issues in relation to the central research question. Each paper is a step to understanding how control mechanisms interact with strategic objectives and heterogeneous innovation networks. Paper 1 focuses on product complexity reduction and the choice of performance measurements. It specifically investigates the role of calculations in the process of the translation of new strategic objectives within product development. Paper 2 deals with calculating greening and innovation, and focuses on different modes of calculations that are used to translate previously incommensurable objectives into commensurable ones thus translating greening and innovation into the product. Paper 3 focuses on the mobilisation of strategic objectives in aesthetical design processes and how objectives interact and emerge within these processes. Paper 4 addresses the issue of controlling and managing design and technological innovation, which have both the need to be kept apart and the need to be integrated. It investigates the mechanism by which design and technology are controlled and converged. All four papers address the different issues and provide diverse angles to the research question. The diversity of the papers enables a more complete picture of the different issues in product development. I found that all papers were highly concerned with the research question as new product specifications had to be decided upon and developed. Furthermore, I searched for episodes in which controversies through new strategic objectives (such as product greening or product complexity reduction) and aesthetical demands arose within the cases and needed to be settled. However, this is discussed in Chapter 6.

The cases enable theorisations that add and extend extant literature and frames by providing unique and convincing insights (Eisenhardt, 1989). By focusing on important particular episodes, actors and their relationships can be traced while being de- and constructed and complex situations become more transparent.

The choice of the cases and the episodes was to a certain extent influenced by the time available for this thesis. Within the three years, these cases were present and pertinent, and in these three years, interviews, participant observation and material could be gathered.

My employment in the company presented challenges and advantages for conducting research for this thesis. The employment granted insight about actual cases and facilitated case selection by enabling the choice of the for the thesis and research question relevant cases. Furthermore, throughout the employment, complete access to relevant data, material and persons was granted. This would have been inaccessible for researchers outside the company due to confidentiality. The limitation (discussed in the final chapter) of the employment is that it may have led to bias, causing omissions of likely relevant actors or processes within the data (Hermanowicz, 2002). Bias might influence the choice process of the data and may direct the research away from neutrality towards unconscious direction. Furthermore, while conducting interviews, the interviewer may have sought to probe and develop meaning, steering the interview in a specific direction. One means to address this issue and improve the focus on the empirical material was the co-authorship of Papers 2 and 4. As, e.g. interviews are local accomplishments, meaning that the interviewer affects the interviewee through her/his behavior and interpretations (e.g. Alveson, 2003), or as the choice and interpretation of company material is dependent on the collector, co-authorship and the involvement of more researchers leads to more diverse material and enhances opportunities of interesting findings (Miles and Huberman, 1994).

4.2 Data collection and analysis methods

The papers have used multiple methods for gathering data on the discussed issues. First, 71 interviews were conducted with key respondents in the firm (see Appendix 1). Secondly, participants of relevant meetings were observed and thirdly, access to all relevant documents was granted. Fourthly, a questionnaire for Paper 2 was conducted with 52 respondents from R&D, finance and marketing. The chosen approach, of using multiple data collection methods (survey, documents, observation and interviews) and through the co-authorship, enabled the use of triangulation between the different data sources. This supported further insights into processes and how actors were involved in them and specific inferences of the material could be made (e.g. Flyvbjerg, 2001). The methods are briefly discussed in the next section and in more detail in the papers where they apply.

Interviews

All interviews except 20 were recorded and transcribed verbatim. A list of the profile of the interviewees is presented in Appendix 1. The transcribed interviews were coded using thematic and pattern codes (Miles & Huberman, 1994), and great care was taken in the analysis in order to gain a broad picture and discover the links and ties between the actors in the product development network.

Company material

Company material, such as meeting minutes, presentations and documents about methods and processes could be accessed. In relation to the cases I chose materials from key decisions to follow the actors that were involved in the decision process. Furthermore, where possible, I observed meetings in which decisions were either prepared or taken in order to get a deeper understanding of the specific cases, their network and the relations.

Questionnaire

As discussed, a questionnaire was conducted in Paper 2. Here, the level of differences and views on calculations, greening and innovation is measured. The analysis feeds into our qualitative interpretation of the level of heterogeneity in PDN and does not reflect a quantitative analysis of hypotheses. Specifically, the understanding of the positions of how the groups (accounting, R&D and marketing) see greening in relation to market and customer preferences and how the different groups see calculations in relation to product decisions should be increased.

The contradiction between a questionnaire assessing groups and actor network theory is here evident. ANT could be argued as a pitfall in the methodological application in relation to a questionnaire. In ANT groups are not existent: only group formation. Through a questionnaire causes are interpreted rather than outcomes:

> *"Analysts who use groups endowed with interests in order to explain how an idea spreads, a theory is accepted, or a machine rejected, are not aware that the very groups, the very interests that they use as causes in their explanations are the consequence of an artificial extraction and*

purification of a handful of links from these ideas, theories or machines." (Latour, 1987, p. 141)

In Paper 2 the heterogeneous views that were the result of the questionnaire were however not used as causes to explain how product development advances but were used to discuss the process of alignment of heterogeneous actors through calculations. Heterogeneity as one main element in the process of translation and one main pillar in the sociology of ANT is more of a prerequisite of the same process (Callon, 1986, 1991). If heterogeneous actors become aligned through calculation it is important to understand their views on relevant "entities" in the study, i.e. greening, calculation and innovation. A questionnaire was conducted to make these diverse views transparent.

4.3 Discussion of methods and methodology

> *"How are we to study these unpredictable and heterogeneous associations that are revealed by the growing intensity of the controversies? Certainly not by dividing them into 'knowledge' and 'context', or by classifying them into 'primitive' or 'modern' ones [...] All actions like 'dividing', 'classifying' or 'ranking' do not do justice to the unpredictable and heterogeneous nature of associations. The only thing we can do is to follow whatever is tied to the claims." (Latour, 1987, p. 202)*

ANT searches in the studies of technology to follow how causes and effects are attributed, which actors are linked together, the durability of these links, and how these elements are modified and translated prior to, during and following controversies. Thus, boundaries and controversies (as discussed in Chapter 4) are in the focus of this research work. Interviews and qualitative methods (e.g. Miles and Huberman, 1994) are setting (as in every study) limits to the scope of the research work, but in following these methods, boundaries are set by the interviewees and the material itself. "This will let the actors add whatever they choose to the framework; it will let them take it as far as they care to go." (Latour, 1996, p. 19) The material will open up, while following the translations they are going through, while being in other hands. The study of statements, as Latour (1987) called it, is starting off from the stage it is in and then goes through all the actors that make a fact or not out of it. Following all contradictions, controversies, break-downs and evolvements opens up the complete process of translation. This, however, is only possible through triangulation, following statements from interviews, participant observations and company material: as through coding the traces of translations become visible (Latour, 1987, p. 59-60).

Going into a company and studying the process is the same as following and studying scientists in their laboratories. “If the scientists we shadow go inside laboratories, then we have to go there, no matter how difficult the journey.” This is exactly what was striven for in this thesis. Although it appears that my journey was short because I worked on site already the opposite might be the case. I had to travel away from my position as a worker and travel back as a researcher.

5 Paper Section

Paper 1	Berhausen (2011)	*Mobilisation of strategic objectives – The role of performance measurements in their design and choice process*	Second Submission to: *Management Accounting Research* in October 2012 (planned) Published at the 9th International Conference on Corporate Social Responsibility, 16.06.2010-18.06.2010 Zagreb, Croatia
Paper 2	Thrane and Berhausen (2011)	*Calculating green innovation: Creating and exploring calculative spaces for innovation and the environment in the automotive industry*	Resubmission to: Accounting, Organizations & Society - 2nd review completed, allowed for 3rd submission Published at 34th Annual Meeting – European Accounting Association, 19.04.2011-22.04.2011 Rome, Italy (Contribution Statement Appendix 10)
Paper 3	Berhausen (2012)	*The translation of strategic objectives in the process of aesthetical design*	Submission to: *Creativity and Innovation Management* in October 2012 (planned)
Paper 4	Berhausen and Thrane (2012)	*Controlling, separating and converging design and product development*	Submitted and published (Parallel session) at 35th Annual Meeting – European Accounting Association, 09.05.2012-12.05.2012 Ljubljana, Slovenia (Contribution Statement Appendix 10)

Table 2 – Overview of the four papers

5.1 Paper 1 – Mobilisation of strategic objectives – The role of performance measurements in their design and choice process

This paper shows how the mobilisation of new strategic objectives is influenced by existing links of management control systems. Interviews and internal documents from a case company in the carmaking industry provide the empirical data. In the organisation the introduction of the new strategic objective "reduction of product complexity" was firstly addressed by a new performance measurement. Failing to steer with this measurement, the company chose another way. Through the calculation of a price tag, which could be included in the existing measurement "IRR calculation", the strategic objective could be mobilised in the product development process. Drawing on actor-network theory, the paper finds that the design and choice of performance measurements are influenced by performance measurements already in place. It adds to the literature in that it displays the relevancy of contexts in the choice of performance measurements that are created through existing performance measurements. Performance measurements are influencing: the way information flows and how systems and networks are configured and linked. Besides the accuracy of performance measurements, the role of the measurements and the networks in place may be important in the choice process of performance measurements. Organisations facing strategic change and searching for the most appropriate connection between strategy and control may find connections by using the working links of their existing performance measurements.

5.1.1 Introduction

The implementation of strategic objectives into practice is a challenging task for organisations and provides a challenging setting for research in the field of management accounting and control. In a framework that distinguishes the levels of management control, strategic planning, and operational action (e.g. Anthony, 1965), management control is characterised as the link between strategy and action. A performance measurement system (PMS) is argued to translate strategic objectives into practice by providing relevant information and it maintains or alters patterns in organisational activities (Otley, 1999; Simons, 1995). If strategic objectives should be carried by control systems then changes in strategic objectives change the configuration of these systems (e.g. Malina and Selto, 2004; Morecroft et al. 2002). These changes are argued to be managed by organisations by using information that creates transparency about operations in relation to strategic priorities and about connections of activities across the value chain (Nanni et al., 1992; Shank and Govindarajan, 1993). One key aspect for this transparency is the use of performance measurements. Performance measurements are designed to coordinate decisions and activities to achieve a balanced set of strategic priorities (Lynch and Cross, 1992; Nanni et al., 1990). Thus, to cope with issues in the current environment and to address changing strategic objectives an organisation must be able to change the configuration of its performance measurements.

Performance measurement is an interesting research area, particularly in product development networks. Product development is a complex process which is managed with multiple performance criteria (e.g. Davila and Wouters, 2004; Chenhall, 2003; Malina and Selto, 2004; Otley, 1980, 1999). In product development environments, performance measurements may deal with different strategic foci such as customer value, target costs or activity improvements (e.g. JIT/JIS, lean manufacturing) (e.g. Abernethy and Lillis, 1995; Perera et al. 1997). Thus, industrial organisations face challenges with the management of multiple performance measurements and with the implementation of new measurements. Dealing with both, existing and newly introduced performance measurements may result in several issues for organisations such as ineffective management, confusion or a lack of focus (Ittner and Larcker, 1998; Jensen, 2002). The design of accurate measurements that link strategic objectives to action, and their integration into existing networks are two important issues in strategic change (e.g. Malina and Selto, 2004). However, few studies provide a deeper look into the specific choice and implementation issues while focusing on existing links of new performance measurements (Lillis, 2002, Stringer 2007).

Perspectives including elements such as culture, reward systems, or planning systems (e.g. Malmi and Brown, 2008; Ferreira and Otley, 2009) may provide holistic views for studying PMS within organisations. However, I strive to focus on performance measurements as actors which tie organisational networks and mobilise resources. This study investigates the interplay of existing performance measurements and the effect it has on the choice and implementation of new performance measurements that are derived from new strategic objectives. The paper explores the research question:

> *How are new strategic objectives (such as reducing product complexity) translated into the new product development process and which role do existing performance measurements play in relation to the choice of performance measurements?*

Drawing on actor-network theory I try to understand relations and influences of actors within the network of management control. The ANT perspective helps to understand how performance measurements evolve and get established, by providing a context, and how they change this context over time. It looks at the space and its relations not as if they were pre-given (Callon, 1986, 1991; Latour, 1987). Contradictions, controversies and uncertainty are conditions between actors. I strive to follow "the actors in order to identify the manner in which these define and associate the different elements by which they build and explain their world" (Callon, 1986, p. 201). This process is the process of translation (Callon, 1986) in which a network is built by creating a forum in which, in turn, other actors enrol and are mobilised through problematisation and interessement. Thus, by following controversies and following how they are resolved through enrolment and mobilisation of actors, a perspective opens up through which the choice and the influence of performance measurements can be analysed and explained. I analysed the mobilisation of the strategic objective and the related creation of new performance measurements. Hereby, I focused on the configuration and influences of performance measurements which were already in place and how these had an influence on the choice of new measurements.

To follow the suggestion of Ferreira and Otley (2009) a case study was conducted to understand the complexity of interdependencies in PMSs in the process of performance measurement choice (see also Dent, 1990; Eisenhardt, 1989; Langfield-Smith, 1997). The study is a longitudinal study that was carried out over a period of two years. The company is an international car manufacturer (which I call hereafter Automotive Company) where I was employed during the study. Automotive Company is a medium sized car manufacturer that is known for its innovative and design driven products. At Automotive Company a new strategic objective of reducing product complexity (part numbers and variants) was introduced. The case concerns the management of product complexity in new product development and how this can be reduced while still creating value for the company.

The paper contributes to the literature of management control systems configuration and to the literature on the choice of performance measurements by making the interplay of performance measurements more transparent and by connecting performance measurements in place with the choice and implementation of new measurements. The study finds that the by existing performance measurements created contexts play an important role in the mobilisation and choice of new performance measurements. It suggests focusing more on how performance measurements are mobilised, and how strategic objectives are translated in studies on the choice of performance measurements (e.g. Malina and Selto, 2004; Chenhall and Langfield-Smith,1998; Lynch and Cross, 1992; Nanni et al., 1990).

The paper is organised as follows. First, I discuss the literature on the role of performance measurement choice and PMS. Secondly, I briefly discuss the literature on product development in relation to performance measurements. Thirdly, I discuss the theoretical perspective drawing on ANT. Fourthly, the empirical study is presented. Fifthly, the findings are discussed, and sixthly, I conclude the paper and discuss its limitations.

5.1.2 Theoretical discussion - Performance measurement choice and PMS

Performance measurement may help firms achieve a balanced set of strategic priorities and objectives (e.g. Lynch and Cross, 1992). It supports firms when implementing and describing strategic objectives; it guides decisions through influencing behaviour, and by providing a basis for rewards or punishments. Performance measurements are used in the organisational context and are organised as models that "model performance relations among key value-chain activities and outcomes" (Malina and Selto, 2004, p. 442). These performance measurement systems (PMS) can be of a financial nature (such as IRR) or be more comprehensive describing links between action and outcomes, providing feedback, supporting strategy development and implementation (e.g. APL from Epstein et al., 2000; BSC from Kaplan and Norton, 1996; Value based management from Ittner and Larcker, 2001). These comprehensive models include financial and non-financial measures of operational and strategic performance.

When organisations face strategic change, new strategic priorities and objectives need to be described and implemented (e.g. Lynch and Cross, 1992). Simply said, the gap between the operational level, with existing links of performance measurements, and the strategic level, with new strategic priorities, needs to be closed. New performance measurements are then designed and implemented to mobilise the new objectives. Here however, two problems arise. First, organisations have to derive and design accurate measurements that link strategic objectives to operational action (Malina and Selto, 2004; Stringer, 2007) and secondly, the new performance measurements need to be integrated into the existing links of the performance measurements already in place. The links and interrelations that performance measurements build within organisations are thus important in the implementation process of performance measurements. A deeper look into the networks of performance measurements reveals thus further insights about the design and choice process of performance measurements during strategic change.

Theories of the choice of performance measurements are focusing, for example, on the characteristics of performance measurements and on organisational parts that influence these characteristics. Here, studies often characterise the organisational setting as an important factor for the choice, e.g. entrepreneurial vs. conservative settings (e.g. Malina and Selto, 2004), or they evaluate the environmental situation (either stable or unstable) as an important factor for choosing performance measurements. As Malina and Selto (2004) state, it is rather interesting to focus research on the importance of attributes that are influencing the consideration of performance measurements. They argue that besides organisational and environmental characteristics, organisations have enough flexibility to choose the portfolio of performance measurements and that they use this freedom to decide which measures best fit their actual situation. Performance measurements have to be continually improved to manage changing strategic objectives and to create and/or maintain strategic advantages and positions. In this process organisations choose: which performance measurements are continued and which are discontinued; which to create and which to dismiss. Malina and Selto (2004) discuss attributes that are relevant in this process. They analyse the trade-off of attributes in deleting or retaining performance measurements. They found that measure-attributes are important in the choice-process of performance measurements and that design attributes are more important than use attributes. What is interesting here is how these attributes are defined and shaped in organisations. Further insights can be revealed by taking a closer look into how these attributes may be influenced by existing links and the interrelationships of performance measurements already in place. The use of the performance measurements may thus be influenced by these links and interrelationships, and may thus play an important role.

As not only human beings have an influence on the choice but all elements of the PMS, attributes and their evaluation are implicitly incorporated into the PMS in place. It is the question of what in the network influences the process of choice. Chenhall and Langfield-Smith (1998), for example, analysed how and to what extent management accounting in companies contributed to the development of performance measurements in organisations undergoing change programs. Their study is not concerned with the appropriateness of measurement attributes, it identifies rather the role that the accounting function plays in the process of change and, hence, in a process of performance measurement choice. The study is a step towards explaining constellations of PMSs and of the factors that influence PMSs. It gives insight into the influence of a certain function (accounting) of the organisation and addresses thus the question of which structures and functions are in place to support the operation of the PMS (see Ferreira and Otley, 2009, p. 273-274). A focus here on the existing links could provide further insights about how these relevant actors (such as existing performance measurements, decision processes or strategic objectives) may have an influence on the choice of performance measurements.

Furthermore, Merchant (1996) discusses how congruence with objectives, controllability, accuracy, intelligibility and cost effectiveness are important qualities for performance measurements. Further studies on performance measurements and their choice focus on the role of the measurements, their appropriateness of fit and their use in PMS (see Stringer, 2007). These studies are analysing organisational strategy and their relation and fit with the use of performance measurements within PMS (e.g. Tuomela, 2005). What would extend and add to the literature on the choice of performance measurements would be a field study on performance measurement choice that follows specific cases throughout the organisational network (e.g. Stringer, 2007). The choices of performance measurements in relation to existing links of measurements is still a rather unexplored issue that is important as it defines the relations within the PMS and their interdependence in the choice-process of performance measurements. To focus on existing performance measurements and their links reveals conflicts and tensions that might exist among performance measurements. Although these conflicts may improve cross functionality and may result in improving shared outcomes (Simons, 1995, Kaplan and Norton, 1996), the links that are tied between them may result in conflicts for the implementation of new performance measurements (Jensen, 2002). Although studies have discussed solutions of how organisations may avoid these conflicts (e.g. Ittner and Larcker, 1998; Lillis, 2002; Mc Noir et al., 1990), there is little empirical insight about how conflicts between existing and new performance measurements have an impact on possible solutions. Especially in product development environments the role of performance measurements makes for an interesting research aspect due to their complex and conflicting nature[34].

However, the decision making context plays an important role in the use of information internally and on the choice of performance measurements (Booker, Drake, Heitger, 2007, p. 20). Performance measurements mobilise distant places and build up the organisational world (Robson, 1992). Thus, performance measurements influence the networks and the (re-)production of time and space. They have an influence of how PMS are designed and how new performance

[34] Management control over product development is struggling with focusing on cost and value at the same time. Especially strategic objectives such as profitability and efficiency play an important role in industrial organisations. Means such lean manufacturing, design to value or target costing thus may play important roles in the PMS and product development environment. Product development and innovation is a complex field in which not only costs but other key success factors are mediated, such as time-to-market and customer value. Thus, multiple performance measurements lead to trade-offs in product development (e.g. Booker, Drake, Heitger, 2007). How these trade-offs are made is related to the way, information and performance measurements are designed and provided. "Designers need a comprehensive cost model to balance trade-offs involved." (Kaplan and Cooper, 1998, p.214). Both, relatively accurate information on product costs and useful and comprehensible information for engineers for product decisions are needed in new product development. It is thus important for managers to choose information or performance measurements that fit not only the engineer's terminology, but also the decision systems in place; accuracy and comprehensiveness need to be balanced (e.g. Kaplan and Cooper, 1998, p.216-217).

measurements are created and selected. The discussed literature shares the view that organisations design the PMS, and that they select the performance measurements to link their objectives and the means by which the objectives should be realised. However, the existing performance measurements may have significant impact on these processes. The research question is thus:

> *How are new strategic objectives (such as reducing product complexity) translated into the new product development process and which role do existing performance measurements play in relation to the choice of performance measurements?*

5.1.3 Research approach - Performance measurements and actor networks

For studying performance measurements a systematic approach, which focuses on interdependencies between different actors in the organisation, is suggested to avoid ambiguity in results and conflicting findings (Abernathy and Brownell, 1997; Chenhall, 2005; Ferreira and Otley, 2009; Malmi and Brown, 2008). Malmi and Brown (2008) argued for understanding management control as a package in which subsystems build an interrelated whole. They point towards the need for studying elements, such as cybernetic control measurements and their interdependencies within the package and towards a lack of studies that analyse these interdependencies. Ferreira and Otley (2009) furthermore address this issue by providing a framework for description that "allows researchers to obtain a holistic overview in as efficient a way as possible" (ibid, p. 264). The framework should help discuss the issues that pervade or influence the whole PMS. Their intention is to provide a more holistic perspective on the system, its interrelations and its design. These perspectives (e.g. management as a package or MCS framework) argue for holistic approaches and for including elements such as culture, reward systems or planning systems (e.g. Malmi and Brown, 2008; Ferreira and Otley, 2009). While I agree that these elements are important actors in studying performance measurements I strive to focus on performance measurements as actors which tie organisational networks and mobilise resources. I will elaborate this argument a bit further in this section.

Furthermore, rather than using a "snapshot" perspective (Ferreira and Otley, 2009, p. 276) on the analysis of the study, I strive to analyse how things (performance measurements) are in the making. Especially if the analysis is striving for a "complete description of the totality of a control system" (ibid, 2009, p. 263) then a framework might serve, on the one hand, as a tool for documenting certain practices. However, on the other hand, the choice and design of new performance measurements can only be accessed while tracing the changes in all possible spaces and by analysing how resources are mobilised; thus by focusing on time *and* space.[35]

Miller and O'Learly (1993) discuss how and by what means accounting expertise is problematised in relation to "particular demands"; the selection of performance measurements is to be discussed from a perspective of problematisation and involvement. If one talks about the selection of performance measurements within PMS, one needs to understand how they evolve through the network of the organisation and how they establish an organisational context. Here, the actor network perspective provides an approach through which the relationships within organisational networks can be revealed by tracing changes in all possible spaces. Mouritsen et al. (2009) study here the dynamic interaction between performance

[35] Important is here to look at the space and its relations not as if they were pre-given. The question is how things are related within that space and time. Latour (2005, p.71) states "any thing that does modify a state of affairs by making a difference is an actor". Thus, the relationships between actors build a network and produces spaces and times, and the actors "mobilise, cumulate and recombine the world" (Latour, 1987).

control and innovation from an actor-network perspective. They propose that performance calculations link activities to organisational concerns and create contexts for innovation activities. Their study provides a deeper insight into the interrelation between management accounting and control and innovation.

Strategic objectives should be the guidance for organisations in their decision about change or preservation. Inscribed in documents, they are mobilised throughout the organisation and by referring to them, allies that combine different parts of the organisation are drawn together and mobilised. “It is necessary to consider more generally the mobilisation of resources, whereby I meant the ability to make a configuration of a maximal number of allies act as single whole in one place.” (Latour, 1987, p. 172). Callon (1986) introduced four moments of translation in which this “single whole” is built and explained by actors, namely problematisation, interessement, enrolment and mobilisation. In the process of problematisation one actor becomes indispensable by determining other actors’ identities and links. Through interessement the actors’ identities and goals are adjusted; it is “the group of actions by which an entity [...] attempts to impose and stabilize the identity of the other actors it defines through its problematisation.” (Callon, 1986, p. 207-208). Through the adjustment, links to other identities are displaced towards one goal and a single actor. The other actors are enrolled by accepting their roles through successful interessement. The translation of individual goals of two (or more) actors results in a composite goal that is different from the original ones (Latour, 1999, p. 179). By acting towards the composite goal, actors act as one unit as they are displaced from their previous locations and are assembled in the same time and space (Callon, 1986, p. 223). “Now at the end of the four moments described, a constraining network of relationships has been built” (Callon, 1986, p. 218); heterogeneity is aligned.

The process of translation is especially interesting for studying the choice of performance measurements in relation to new strategic objectives. Strategic objectives may lead to inconsistencies and tensions through being mediated differently throughout the organisation (Ferreira and Otley, 2009, p. 268). Here, performance measurements play a crucial role as they may either cause or settle inconsistencies and thus become the actors that translate strategic objectives. Therefore, I will analyse the case by discussing the four moments of translation – *problematisation, interessement, enrolment, and mobilisation.* This adds to the development of analysing and explaining controversies and how "a constraining network of relationships has been built" (Callon, 1986, p. 218).

Performance measurements are intermediaries that are holding the network and its actors together. Rather than talking about causality between strategic objectives on the one hand and performance measurements on the other hand, it is the alignment of heterogeneous actors through the latter that defines the PMS. Thus, performance measurements could be defined as intermediaries, put into circulation by actors (Callon, 1991). This view provides insights about the world that surrounds the performance measurements. Here, I also consider performance measurements mediating actors and not just intermediaries. Performance measurements have a role in PMS that have an impact on the organisational networks and its environment. It is therefore interesting to ask how performance measurements have an impact on their use and how this is related to the choice of performance measurements when new strategic objectives arrive. They are involved in anticipating changes in the organisation and its environment thus providing the initiative to change. Extent and type of change is not only initiated by performance measurements but are also influenced by them. In the course of change, new actors, different ones, are entering or leaving the network, causing breakdowns of alignments, new translations and new alignments between parts of the PMS. From an actor-network perspective a network is inherently unstable because it has to be assembled and reassembled in every moment. Relationships and links are constantly under construction[36]. One has to look for relationships and links that last and thus for actors that may construct, reconstruct, or deconstruct the network. To find these actors one has to follow the translations and their episodes within the network.

Rather than seeing an outcome and thus an end, or a function (e.g. Power, 2004) in performance measurements I understand performance measurements as actors that create, that do something. I go beyond the call from Power (2004) to open up the black box of performance measurements and to "recover the social and political work that has gone into their construction as instruments of control".

In summary, the ANT approach attempts first, to describe a case in detail in which a new strategic objective is translated. The four moments of translation help here in the discussion about how controversies arise and how they get settled. This provides the literature on the choice of performance measurements with further insights into how the choice and design of performance measurements is influenced by existing links. Secondly, by performance measurements being defined as actors rather than just intermediaries, much more respect is given to existing measurements which may have an important role in influencing the extent to which PMS are altered, or the introduction of new performance measurements. Thirdly, ANT shifts the view from a more static, snapshot view on the status quo towards a view in which things are in the making. Through describing how measurements and their links are in the making, important factors in the

[36] "Thus, the object, the real thing, the thing that acts, exist only provided that it holds humans and nonhumans together, continuously. Slightly out of phase, it resides neither in the social element (it is made up of chips and hinges, shock absorbers and pairs of subway cars) nor in technologies (it is made up of passions, transported people, money, Communist ministers, and software). On the one hand, it can be said to hold people together, but on the other hand it is people who hold it together." (Latour, 1996, p. 213)

mobilisation process of new strategic objectives become apparent. This may give new implications for further research on the choice of performance measurements.

5.1.4 Research methods

The empirical domain is the international car manufacturer (Automotive Company) where I was employed, at the time of the study[37], in the department of product development and innovation controlling. For this longitudinal study empirical material was gathered over a period of two years.

I gathered relevant empirical material and attended related business meetings within that timeframe and focused on new product development. The material consists mainly of product cost calculations (business cases) as a basis for decisions, documents about related product decisions and related strategy papers. I attended more than 50 meetings and management decision circles in which product decisions were made and discussed. I focused on input measures of product decisions and how they were related to product decisions. Furthermore, I conducted twelve interviews ranging from thirty minutes to one hour of which eight were recorded and transcribed. An overview of these interviews is provided in Appendix 3. The interviews were conducted with managers and engineers of the product development network. The interviews were semi-structured focusing on the choice and the reasons for the choice of performance measurements as well as on their use. I focused strongly on episodes in which performance measurements were discussed, chosen, and in use to understand the translations and to research the PMS and relations to performance measurements (Eisenhardt, 1989).

[37] The employment in the company at the time of the study may have led to bias (e.g. Hermanowicz, 2002). Validity and reliability was enhanced through collecting and analysing data, interviews and documents, through coding and integrating all collected data.

The material was organised to follow the calculations that influence the product development network and to analyse how performance measurements change the decision network and its relations. Focusing on the change of management accounting calculations and performance measurements within a specific organisational network creates visibility of aspects of the change process (Burns and Scapens, 2000). The employment in the company may have led to bias in leading the interviews and choosing material. To overcome this limitation I made use of the triangulation of all data (interviews, participant observations and documents) through which I could follow the episodes and get in-depth insights (e.g. Flyvbjerg, 2001).

First, I had to understand the product development network and how calculations and performance measurements act in this network. Secondly, I had to trace the process of the choice of performance measurements and the interrelation with the product development network. Thirdly, I had to analyse how the change in performance measurements translated action and changed the product development network.

5.1.5 PMS and new product development: The complexity case

5.1.5.1 Introduction to Automotive Company

Automotive Company's vision is to enhance profitability, create value and ensure its future through international success. Automotive Company strives towards the goal of being the leading car manufacturer in its sector. The goal for its product portfolio is to have clear and pure product lines and provide excellent mobility for its current and future customers. These statements are inscribed in official company documents, internal company documents and presentations.

In new product development managers can refer to these documents, and interpret them towards the statements, when describing strategic objectives. By doing this, tensions arise in conflicting strategic objectives. Enhancing profitability is described through customer value, efficiency improvements and lowering costs. More efficient component design, new supplier markets, and improved assembly and manufacturing processes are objectives in product development. On the other hand, the focus is set on value and the customer, focusing on quality, innovation and sustainability. These strategic objectives are sometimes contradictory in product development, as in cases where increased product value results in higher component costs.

Different units and departments within the product development networks explicitly advocate strategic objectives. These are inscribed explicitly in documents and could provide a basis for departments to argue for specific decisions in new product development. As discussed, tensions and conflicts arose through these different objectives, because they were advocated for by different departments (e.g. marketing advocates for innovative materials while finance argues for cheaper materials).

The new product development process was structured through car projects, each having its own development teams and its representatives from the divisions, units and departments. Thus, car projects had a rather autonomous position, being guided by the different strategic objectives of Automotive Company, such as market views, quality standards, cost targets, innovation, time, weight, manufacturing, social and environmental standards, law, capacity and other factors. Thus, the product development network was a very complex network that included interests from all areas of the organisation, having a matrix-kind, decentralised management in terms of projects and in terms of units.

Performance measurements derived from strategic objectives are mobilised in the product development network. These are based on strategic objectives, such as bringing down costs, improving efficiency in design and production, and creating more value for customers through quality, innovation and sustainability. Performance measurements concern mainly customer value (price and volume), weight (kg), quality (ppm), CO2 Emissions (g/km), engineered hours (h), assembly time (h) and costs ($). Costs are split between logistic costs, proportional costs per vehicle, development costs, investment cost and overhead cost within the product development network. Furthermore, an overall project business case is calculated resulting in a rate of return (IRR), which is reported as performance measurement. All performance measurements are agreed upon from project management and targets have to be reached at the start of production. The targets are set based on experiences and tests of current products, and results are incorporated into the targets. Targets are redefined and adjusted when new results and findings point towards a different route of product configuration. The actual level versus the targets is sometimes reported on a daily basis to project management. Thus constant changes can be reported, traced and acted upon by project management[38]. The managers are rewarded based on all performance measurements and their achievement. Monetary, as well as non-financial rewards in the form of career portfolio remarks are rewarded. As long as the product development network accepts the performance measurements and as long as project management is held accountable for the measurements and the targets, decisions can be taken towards these targets and with the performance measurements.

[38] Systems are designed to carry and visualise performance measurements. They are visualised in an intranet IT application in which all units report their status on a weekly basis. This tool can be used throughout the organisation and is organised with information access limitations to address the information needs of managers at different levels. The information is thus provided from the operational level and is organised to provide management with performance measurements and the actual status on a weekly basis. Furthermore, when product decisions are made, the actual status could be made transparent instantly in meetings.

5.1.5.2 Performance measurement and decision in new product development

Decisions in the projects are made based on the evaluation of all relevant performance measurements. To address all factors and to minimise the complexity of the decision a standardised decision making process is inscribed into the company's documents. There are decisions without alternatives, i.e. law restrictions or concept-feasibility; but besides these "no-go" decisions all concept changes are concerned with the impact on performance. Decisions on the project level are mostly concerned with cost, quality, weight, engineered hours and CO2. Furthermore, customer value and innovations are discussed and calculated at project level. For these decisions, specific meetings are held on a regular basis. In these decision circles representatives articulate their interests and present them through the means of performance measurements and their calculations. In this process, the change is visualised to managers by an IT tool and they base decisions on the visualisation: on the information provided to them. Performance measurements were thus used interactively in the decision process of product development.

In the studied organisation every product related decision in the development process is evaluated under the aspects of cost and value. For every decision there is a business case giving transparency about the financial impact of the decision, which should ensure the objective of profitability. These calculations guide all decisions around the configuration and development of a car project. Business cases are here IRR calculations based on predicted cash flows generated by alternatives. These calculations build a very strong argument in product decisions of the project manager:

"When the financial target is tough, which is basically the case in all our projects, we decide mainly based on positive business cases. At least as long as there is not a generic strategic decision or as long as we are not having serious problems with achieving our other targets." [Project manager]

Performance measurements to meet quality, weight, engineered hours and CO2 are always discussed under the aspect of cost, and the related business case that is visualised through the performance measurement of IRR. Decisions to meet or at least to lower the gap to these targets are often postponed or even dismissed, as long as there is a negative business case. This should generate alternatives and foster innovation. A project leader commented in a decision circle on a weight-reduction alternative:

"I don't want to decide, now let's check and see if there are other possible alternatives..." [Project manager]

But, when time becomes critical, product related decisions to meet other targets have to be made. A project manager stated in a decision process:

"We have no alternatives... We need these features to meet our CO2 goal I don't see any alternatives..." [Project manager]

As long as meeting non-financial targets is not time critical, the business case is the actor that has a strong impact on this network. Even finding solutions to meet non-financial targets are influenced by cost concerns. An engineer stated:

"We really have to make sure that there are positive business cases to ideas, otherwise we can't decide." [Coordinating Developer Car Components]

When meeting non-financial targets is critical, these targets gain more momentum but are still strongly evaluated under the aspect of cost. Alternatives become heavily discussed when the target IRR of the alternative is not met or is even negative. The steering and controlling of non-financial targets are thus extremely difficult and financial measurements play an important role in the product development network. However, although the financial dimension is strong in the process, other performance measurements still play an important role in the final decisions on product concepts, as targets in these dimensions have to be met as well.

In the following I describe how first, a new strategic objective of reducing product complexity was initiated, secondly, how it struggled to enter the product development network, and thirdly, how it was mobilised.

5.1.5.3 Product complexity in new product development

The product development network was facing a new strategic objective of *reduction of product complexity* and started struggling with the implementation of a new performance measurement.

The issue was that while focusing on efficiency, the reduction of "product complexity" in the supply chain and the management of part numbers became important. In Automotive Company *product complexity* referred to the number of parts generated through additional derivatives or variants. Automotive Company stated in strategy documents that on the one hand, the idea of producing the least product complexity reflects the most efficient production, referring to Henry Ford ("Any customer can have a car painted any colour that he wants so long as it is black"). On the other hand, addressing customer needs and therewith the individualisation of a car leads to high *product complexity* and may even lead to "incontrollable" complexity, as it was stated in a strategy document. Thus, there was a range between high efficiency and low cost at one end, and high customer value at the other. It was described in the documents, that the individualistic character of a customised and high value car was still the objective, but that product complexity had to be reduced.

A program was initiated to strengthen operations to be prepared for future events such as market crises. An external consulting company brought the information into the organisation that the organisation had a problem with the complexity of its products, referring to the strategic objective of efficiency in product design. The problem the organisation was facing was that *product complexity* had grown relatively higher than sales and profit. The analysis by the external consulting agency showed that these inefficiencies do not fit with Automotive Company's objectives of being efficient and profitable while providing customer value. The argument was that benchmarked competitors are able to provide similar customer value while having less *product complexity*. Pointing towards the objective of efficiency (in product design and production) and profitability, plus keeping the customer value focus, a new strategic objective namely *reduction of product complexity* was derived, which was translated into the product development network.

The *reduction of product complexity* along the supply chain and management of part numbers to bring down cost was a central concern of that program and was introduced as a new strategic objective in the management of resources, value and cost. To implement this strategic objective a separate initiative was set up that was concerned with the implementation of a management process, and with the design and choice of performance measurements. The initiative was concerned with the product development network where decisions about the configuration and thus about the complexity of a product were taken.

5.1.5.4 The strategic problem of product complexity – Problematisation

The *reduction of product complexity* initiative was implemented and managed by a team of 5-10 members[39]. The problem of reducing product complexity was displayed with the chart of the consulting agency stating that parts had grown relatively higher than sales and profit, and that Automotive Company's competitors had less parts compared to their sales and profit. Through attaching part numbers to the strategic objectives sales and profit, the problem was visualised to managers and while using the common goal of increasing sales and profit, a new goal (strategic objective) of *reduction of product complexity* was introduced. Thus, *product complexity* was problematised through its relation to sales and profit.

5.1.5.5 Interessement and enrolment

A target was set by the team for the managers of the product development network to reduce part numbers and thus *product complexity*. Every car project had a target

[39] The exact number of participants is disguised due to confidentiality but lies somewhere in between.

regarding part numbers and the objective to initiate ideas to reduce them. A manager from the team explained:

> *"Yes, the project managers are responsible for generating ideas of how to reduce complexity and they have to close the gap to the part number target. They didn't do anything, because they never had a target. Now, since top management had decided to do something, they are urged to do something. They have to come up with ideas to reduce complexity."* [Manager of complexity initiative team]

A new performance measurement was created; namely, the *number of parts per car project*. The status quo in development of planned part numbers was reported and measured against the target. A new performance measurement was thus created that should be managed within the PMS of new product development. Although project managers agreed on the target and on reducing the *number of parts per car project,* there were problems with the new performance measurement in the projects and decisions, which I discuss in the following section.

5.1.5.6 Limits of translation – Product complexity as a value driver

It became apparent that the product development network did not successfully steer the complexity because the set of limitations couldn't be met. In the product development network, business cases had a strong position. When alternatives were generated, adding new product substance, then *product complexity* was a revenue driver for the business cases because often with higher product substance, customer value was added and market prices could be increased. Furthermore, the complexity initiative team was struggling to reduce part numbers, and reach the targets with ideas: as they often generated lower margins through a loss of product substance that came with the market price decrease. These alternatives generated negative business cases. A controller stated:

> *"There is no chance that we reduce part numbers when we have a negative business case to that idea. Project management will never decide on that basis."* [Controller]

No project manager decided a decrease in part numbers, when the business case told him not to do it. Although the complexity initiative team argued with relatively higher growing part numbers in relation to sales and profit, the link between decreasing part numbers while increasing profitability was not apparent in the decisions. This was due at that time to product complexity being understood rather as a revenue driver instead of a cost driver. The problem was that costs that were tied to the complexity of the car couldn't be measured for single decisions and thus couldn't be implemented in the business cases. Costs such as overhead or step costs, or other relevant complexity drivers couldn't be directly measured but had a long-term impact on performance. These are discussed later in more detail.

In Figure 1 the performance measurements for management decisions are displayed. On the one hand, there is the financial performance measurement (business case) and, on the other hand, there are non-financial performance measurements including the *number of parts*. The business case, weight, CO2, engineered hours per vehicle, quality and number of parts are measurements which were provided to management for every product decision. Furthermore, it is visualised how cost and value are input for business cases. Value drivers such as additional functions, individualisation, optional equipment, more colours and materials provided, on the one hand, positive input for business case calculations.

On the other hand, as shown in Figure 1, functions, optional equipment and other drivers for customer value increase the *number of parts*. Thus, these drivers of value resulted in positive (business case) and negative (number of parts) indications for management decision through the mobilisation of performance measurements.

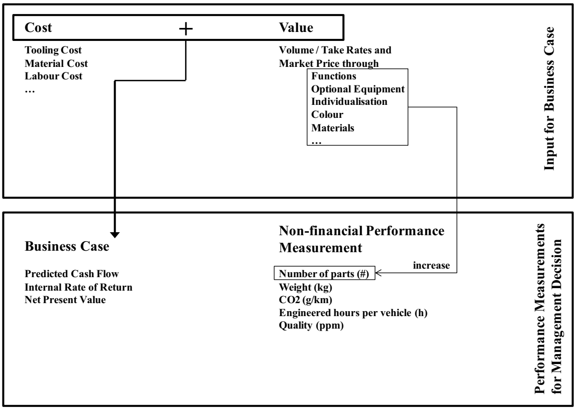


Figure 1 – Cost, Value, and Performance Measurements – Product Complexity as number of parts

Even though managers had agreed on the target and the performance measurement, action towards the reduction of parts was not taken. Furthermore, reporting structures and rewarding processes were focused on the current performance measurements. Due to the problem of steering the process, the part number targets did not gain acceptance and thus did not change decisions towards product complexity reduction. The dilemma was here that the strategic objective was not translated into action and decisions. A manager of the initiative explained:

"Yes, we had given them a target. And now, I can't say I reduce the part numbers in a car project by X in the development process with no appropriate tool. You would have to generally limit the number of parts and that is not possible. How would you steer it, it's too complex." [Manager of complexity initiative]

The performance measurement *number of parts per car project* was apparently not an "appropriate tool". I will discuss in the next section, how the strategic objective was translated into action.

5.1.5.7 New interessement and enrolment - Product complexity as cost driver

After recognising the previously described dilemma, the initiative team decided to analyse how many indirect "costs" were tied to one part number. The team analysed the supply chain and found three kinds of costs related to one cost driver, that were thus far not considered in cost calculations. These were step costs, indirect/non-assignable costs and "forgotten" costs, all of which couldn't be directly measured but had significant impact on performance. Step costs refer to costs that occur through a sum of decisions (part number increase), which then result (in sum) in a cost jump (e.g. a sum of decisions leading to complexity so that parts, rather than being provided to assembly in separate boxes, now need to be delivered in sequence, which is costlier and requires more assembly space). No assignable or indirect costs refer to costs that come with part number increases (such as quality measures or higher administration efforts). "Forgotten" costs refer to costs that are direct but that occur outside the focus: without being measured and incorporated in business cases (e.g. due to more parts, more boxes are needed). The cost driver is thus *number of parts* with costs assigned from all three kinds of costs. The price tag for every part number was thus derived from the indirect resources a part number generates along the supply chain. Interviews, KPIs, and other relevant data were evaluated by the initiative team and the result was an average cost per part number that reflected the efforts it generated through *product complexity*. The goal was to incorporate these costs "adequately" into the business cases to change the decision making process and thus to reduce *product complexity*. The result of an extensive analysis was a price tag that was incorporated into the calculation of the performance measurement business case (IRR calculation). This price tag was then to be incorporated into all business case calculations, whether it was an alternative to reduce part numbers or to augment the substance of the car. If the alternatives to be decided increased the number of parts, a *malus* for every new part was incorporated; if decreased a *bonus* was incorporated. With this price tag, the strategic objective was translated into practice by monetising resources that reflect present and future consumption of *product complexity*. The business case (IRR calculations) was shown with and without the price tag for the part number through a sensitivity analysis (see Figure 2).

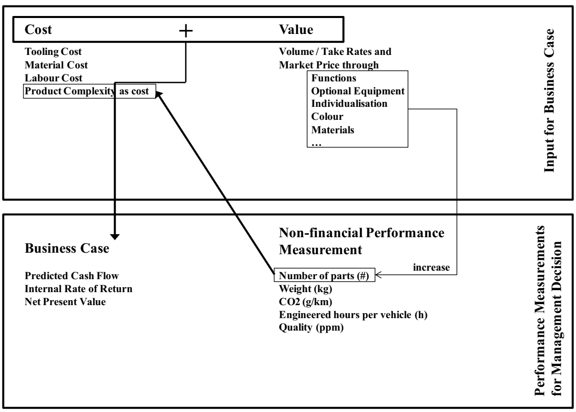


Figure 2 – Cost, Value, and Performance Measurements – Product Complexity as cost

Thus, *product complexity* was now not only steered through the absolute number of parts and the target, but through being incorporated into another performance measurement, namely, IRR calculations. Product complexity became a cost driver. The dilemma of prior competing performance measurements *number of parts* and customer value in *IRR-calculations* was addressed by understanding product complexity as a cost driver, which was in turn fed into *IRR-calculations.*

5.1.5.8 "New" mobilisation – Translation of strategic objective into decisions

A number of cases in which the reduction of part numbers so far had shown a negative business case were recalculated right after the introduction of the price tag. The business cases showed both the outcome without, and with the price tag. In some of the cases the business case shifted from being negative to being positive: including the price tag. Though still highly discussed in the product development network and critically analysed by project management, the decisions skipped and the reductions of part numbers were decided. A financial controller described:

> *"It was highly discussed and it took quite some time to being decided but in the end project management accepted the price tag and decided for the reduction measure. It was decided top-down to calculate with the price tag so that they had to accept it."* [Controller]

The price tag became institutionalised and got incorporated into every business case calculation shortly after the first decisions were made. The initiative stressed this topic in car projects and forced a quick implementation. A manager of the initiative said:

> *"Project management have to implement it now, because their boss told them so. They have targets. We say it has to be implemented immediately because the experience shows us that you can only reduce part numbers in the early development stages or in a complete revision of a project. After the start of production part numbers are more increasing due to changes in parts and the offer."* [Manager of complexity initiative]

The implementation of the price tag had an impact on some substance related decisions that, as an effect, increased or decreased the number of parts. But the price tag and the business case calculations didn't just have an effect on the decisions. A manager of the initiative stated his thoughts:

> *"The leverage is that the engineers produce less part numbers. Through that leverage you are only able to reduce part numbers, straight from the head of the engineers. The price tag sensitised from the beginning on."* [Manager of complexity initiative]

In various meetings in which alternatives were discussed for the first time (before the calculation of a business case), the increase or decrease of part numbers became more and more an argument, and was always discussed in combination with the price tag attached to the alternative. An engineer commented on an alternative:

> *"No, I don't want to follow that solution. We are producing a high amount of new part numbers. The malus for the business case would be too high. Let's focus on something else."* [Coordinating Developer Car Components]

Though every alternative was calculated, engineers were sensitised concerning the augmentation of part numbers when constructing concepts or finding alternatives. Through the current position of the calculation, the price tag gained momentum and was translated through business cases as well as through sensitising engineers. Though already implemented and an influencing measure in business case calculations, the price tag was highly discussed. Project managers were concerned about the validity of the price tag, and they did not agree completely to implement costs that occur indirectly in the life cycle of their project in their business case. But not only project managers had concerns with the correctness of the price tag and its evaluation. A controller criticised:

> *"I cannot accept that you have the same price tag for generating an additional colour as for generating an additional front axle. The price tag does not say the truth then."* [Controller]

As far as the management of that initiative could argue for the price tag they admitted:

> *"Of course you can question the validity of the price tag. It might be that in some cases the price tag does not say the truth and that because of this some decisions might go in the wrong direction. But at least the price tag gives transparency about complexity to some extent. People here need clear targets and everybody needs to understand that. That might lead to a car with fewer options, yes, but we cannot deal with the complexity anymore, we have to reduce complexity, that's what our competitors have been doing since quite a while."* [Manager of complexity initiative]

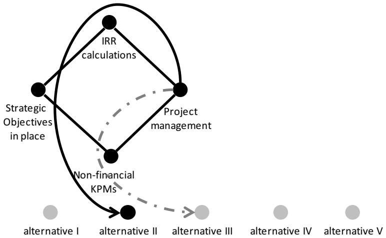
Since mostly project management and controlling raised concerns about the validity and correctness of the price tag, and not about the existence of the price tag itself, management started discussing the amount of the price tag and whether this would need to be adjusted. However, as time was limited, the issue of the "correctness" of the performance measure could not be empirically evaluated.

In summary, the following observations can be made from the empirical material. First, new strategic objectives were derived from calculations that are based on existing strategic objectives (increasing number of parts in relation to profit and sales). Secondly, new performance measurements (number of parts) were based on these calculations. Thirdly, links of existing performance measurements (IRR calculations in decisions) were a boundary for new performance measurements. Fourthly, by using existing performance measurements and links, new strategic objectives were translated into decisions.

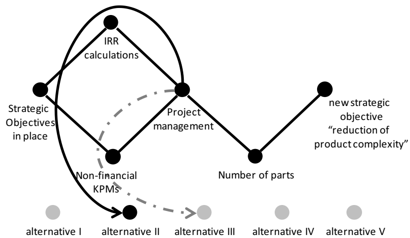
5.1.6 Discussion

A “snapshot” perspective (Ferreira and Otley, 2009, p. 276) may help to get a “complete description of the totality of a control system” (ibid., p. 263). This may serve as a tool for documenting certain practices (see Appendix 4 – this table shows the structured findings in the choice process of the performance measure of complexity, the price tag). Although this perspective may describe certain categories and processes, such as organisational structure, strategies and plans, or information flows and systems, it does not provide insights about how things are in the making and why the snapshot looks as it does. I added two columns (Appendix 4) to display the change that occurred in the product complexity case over time. Although this may serve to get a comprehensive overview about certain levels and how they change over time, the links between performance measurements and strategic objectives and how action may influence both may not become transparent. Initiatives to change, failure, disruptions, translations and convergence are happening in between these levels and shed light on problems and solutions as they occur in performance measurement systems. I will try to apply another perspective to overcome this problem. The actor-network perspective adds here in that it helps to trace changes in time and space, and by analysing how resources are mobilised. Rather than talking about causality between objectives (key success factors, and strategies and plans) on the one hand, and the key performance measurements (and target setting, performance evaluation, and reward systems) on the other hand (Ferreira and Otley, 2009; Malmi and Brown, 2008), it is rather the process of translation of heterogeneous actors that builds up the links in an organisation. In the coming sections I elaborate on the translation of strategic objectives and on how performance measurements interact in that process.

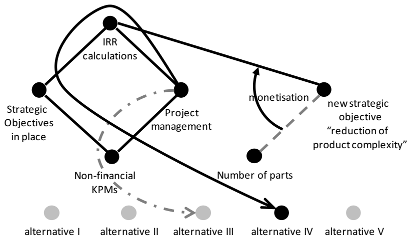
In the case company, IRR calculations have a strong position. In Automotive Company the calculations are the most important decision basis for product relevant decisions. Although other performance measurements are in place, such as weight or CO2, these non-financial measurements merely play a role when they indicate that decisions have a critical impact on these dimensions. With the new strategic objective (*reduction of product complexity*), a new performance measurement (*number of parts*) was introduced. This measurement, however, had no impact on product decisions, and IRR calculations were still the main decision basis. Thus, for Automotive Company the link between the new strategic objective and operational product decisions was not built. The measurement "*number of parts*" could not mobilise decisions nor alter decisions towards reducing the amount of part numbers and thus product complexity. Thus, the initiative derived a price tag which was then implemented into IRR calculations as these were the main decision basis. This step linked the *number of parts* with the IRR calculation, and by referring to IRR calculations the strategic objective of reducing product complexity could be mobilised. In conclusion, the IRR calculation is the actor at Automotive Company that everybody has to go through. By using the linkages the calculation builds up, new strategic objectives can be mobilised through simply being attached to the calculation. I will discuss the findings in the next sections.



Stage 1: Before introduction of new strategic objective "reduction of product complexity"



Stage 2: New strategic objective "reduction of product complexity" translated into non-financial measure "number of parts"



Stage 3: New strategic objective " reduction of product complexity" translated into financial measure "price tag"

Figure 3 – Translations in the Product Development Network

In Figure 3 the different stages before and after the introduction of the strategic objective "complexity" are illustrated. The graphics are schematic visualisations of the decisions of the product development network. The three (3) stages illustrate the product development network and the process of decision making of product alternatives. Strategic objectives are represented by performance measurements that act on project management. The strategic objectives are positioned on the left and right end of the figure; the strategic objectives in place are on the left-hand side and the new strategic objective of "*reduction of product complexity*" is on the right-hand side. Performance measurements are then connected to the strategic objectives, as they should link these to the operational decision processes of project management. Connected to the strategic objectives in place are financial and non-financial performance measurements; connected to the new strategic objectives is the non-financial performance measurement "*number* *of parts*". All performance measurements are connected to project management which then links alternatives to the project through decisions based on measurements.

The alternatives, proposed by engineering, represent product alternatives that are/get measured [40]. The arrows represent the decisions that are either made around financial IRR calculations (bold arrow) or non-financial (dotted arrow) performance measurements. As discussed in the empirics, decisions were mostly made around IRR calculations; the bold arrow illustrates the choice of the product alternative. At times decisions were made around the other non-financial performance measurements, which are shown with the dotted arrow.

5.1.6.1 Problematisation through connecting things

The basis of the initiative for reducing product complexity were efficiency improvements, efficient design and enhanced processes as strategic objectives. A new actor, the consulting firm, problematised the issue of product complexity and made it a strategic objective. Arguing that product complexity had grown relatively higher than sales and profit and through benchmarking competitors, two arguments were calculated for the interessement of the executive committee enrolling them into the issue of *reduction of product complexity*. Sales and profit, both being strategic objectives and inputs of the performance measurement *IRR calculation*, were used to demonstrate that *product complexity* (in part numbers)

[40] The proposed alternatives are different technological solutions for a specific problem. Alternative II in this figure is the one that has a positive business case with the highest rate of return and no critical technological issues. Alternative III is an alternative with strong importance on non-financial measurements such as weight, CO_2, or quality and no critical or negative business case. In both alternatives the number of parts may be critical. This is shown in Alternative IV which becomes the one with the highest rate of return when the part numbers become monetised. Alternative IV is thus chosen when the price tag is included in the business case and product complexity is incorporated as a cost driver. Alternatives I and V both neither have the highest rate of return (with or without price tag) nor are these alternatives with critical technological solutions. The decision process and the alternatives are further described in the next sections.

had grown relatively higher. This calculation provided the initiative for a new strategic objective (and thus for change) based on existing strategic objectives directly (efficiency improvements), and performance measurements (IRR calculation) indirectly. A calculation was here mobilised for problematisation (compare short-/long-translations, Mouritsen et al., 2009). The process of calculation mobilised existing strategic objectives towards the issue of *reduction of product complexity* and drew the first connection between the performance measurement and the strategic objective.

Strategic objectives become measured and mobilised in and through calculations. Connections between activities across the value chain and strategic priorities are to be made visible (Nanni et al., 1992; Shank and Govindarajan, 1993) to maintain or alter patterns in organisational activities (Otley, 1999; Simons, 1995). Thus, calculations are strong actors in the process of problematisation in which other actors' identities and links are described and determined. Part numbers, projects, profitability, sales and competitors were subsummarised in a calculation that proplematised the issue of product complexity.

5.1.6.2 Boundaries for new performance measurements – Existing links of performance measurements

Depending on the context a measurement defines for itself, it can have more or less influence on the links between actors and intermediaries. Furthermore, a measurement can gain or lose influence in certain stages of time. Within the choice process in the product complexity case, the first proposition[41] was to establish a performance measurement that measured the number of parts and

[41] As Latour (1999) described it, propositions are occasions given to different entities to enter in contact. They can be found in time and space with different durability in time and certain interdependence in space. Performance measurements reflect such propositions.

related them to a target. The connection towards the strategic objective was clearly expressed through the enumeration of parts and through striving to control the absolute amount of parts. Used in the problematisation, part numbers (in relation to profitability and sales) became a non-financial performance measurement (as illustrated in stage 2 in figure 3). Thus, the design of the performance measurement was dependant on the calculation used in the problematisation and directly linked to it. As there was no impact regarding the decisions on product alternatives, the arrows did not change[42]. The measures that were already in place were stronger propositions and lasted throughout stage 2; while the performance measurement of product complexity (number of parts) did not have an influencing position. Thus, alternatives with a high amount of part numbers were still chosen because these had either the business case with the highest rate of return (Alterative II), or strong importance on other non-financial dimensions such as weight or CO2 (Alternative III).

As shown in the product complexity case, the mobilisation through the performance measurement failed due to several reasons. First, the performance measurement of *number of parts* was subject to existing performance measurements. This means, secondly, that the new performance measurement could not enrol all actors: as value and cost were often jeopardised by managing the reduction of product complexity. This was expressed in business case calculations (IRR) that evaluated product complexity reduction measures. With the new performance measurement of *number of parts* the decision circle had to incorporate one more dimension into their decision. Managers were provided with the number of parts that were generated additionally with the product decisions, and were provided with an overall target per car. The decision circle had problems

[42] I created two dots of non-financial performance measurements and "number of parts" to show that the existing non-financial performance measurements had a certain impact on decisions on product alternatives, whereas the "arriving" performance measurement of number of parts had none.

deciding product relevant options, as business cases (IRR calculations) were often negative and thus other performance measurements more important. Thirdly, although *reduction of product complexity* was targeted and measured in number of parts, the information received was more important than the action towards reaching the target (see Booker, Drake, Heitger, 2007, p. 35). Conflicting targets and the information in the decision circles were thus prioritised in favour of existing performance measurements and not of reduction of product complexity. The fit of performance measurements in development networks thus depends, not on the attributes of a measurement itself, (e.g. Malina and Selto, 2004) but on the links with other, existing performance measurements.

Managers were enrolled and agreed upon the *reduction of product complexity*; however, the strategic objective could not be mobilised in the product development network. Decision making and choosing between alternatives may here become a problem through multiple and new measurements because managers do not know "the tradeoffs between the multiple measures, they cannot know whether they are becoming better off" (Jensen, 2002, p. 249). However, conflicts and trade-offs shaped the decision processes as they generated cross-functionality, shared outcomes and new alternatives as discussed in chapter 5.1.5.2 (e.g. Simons, 1995, Kaplan and Norton, 1996).

5.1.6.3 Mobilisation – Fitting with existing performance measurements

The mobilisation of the strategic objective *reduction of product complexity* was in this case dependant on the existing performance measurement (IRR calculation). The information that was provided to management in the form of additional part numbers was not used for the decisions as the IRR calculations were still considered a strong basis for decisions. Steering the product development through

IRR calculations should lead to higher long-term profitability of the organisation. In stage 3 (Figure 3) it is illustrated how the new strategic objective *reduction of product complexity* was transformed through "understanding the complexity of a car as cost". The initiative decided to "adequately incorporate" product complexity into IRR calculations. It changed the outcome of decisions without changing the performance measurement system in place (visualised in Figure 3 through the arrow going from alternative II to alternative IV). To mobilise the strategic objective, product complexity was calculated as cost: to become part of the performance measurement IRR calculations and to become comparable with other financial measures. A strong composite goal of all actors was, prior and throughout the performance measurement IRR calculations, understood as cost; product complexity became part of that goal, becoming displaced from the previous definition of the number of parts. The strategic objective was translated by being displaced and mobilised together at the same time and space as IRR calculations (Callon, 1986). Thus, it is not the goals and performance measurements of the product development network that were different from the original ones, but through *product complexity* being integrated into an existing goal (IRR calculations), it was translated into action.

The extent and type of change may depend on the performance measurements in place and their working links. Existing performance measurements might have a position that can be used by new strategic elements. In this case the mobilisation was enabled through monetising. In place performance measurements thus have an effect on extent and type of change within PMS, as they already have a position and links that can be used by new strategic objectives. The constellation of the propositions in place thus had an effect on the mobilisation of the new strategic objective as first, the propositions in place (time dimension) were stronger in the network than the first proposition of product complexity (non-financial measures) and secondly, the powerful actor financial measurement had an impact on the choice of the second proposition (the monetisation of complexity). The goal of profitability through IRR calculations was used as a *mobiliser* of the strategic objective product complexity for altering product decisions. As Malina and Selto (2004, p. 66) stated, the use of performance measurements is influenced by the relation of "performance measurements (e.g., some non-financial measures) that cannot be measured or audited as objectively or accurately as financial measures." Rather than seeing the accounting function responsible for influencing the choice of performance measurements (e.g. Chenhall and Langfield-Smith, 1998), it is the position of the IRR calculation and the context it creates that contributes to the development of the performance measurement.

There may, on the one hand, be limitations to financial management control models (e.g. Kaplan and Norton, 1992; Lynch and Cross, 1991; Epstein, Kumar and Westbroek, 2000); however, if the constellation of the PMS has an influence towards financial measurements, an organisation may use financial measurements to mobilise strategic objectives into its operations by using financial management control. More generally, existing performance measurements may provide a space for new strategic objectives by displaying goals. Thus, it is not a question of the design or the use of attributes (Malina and Selto, 2004) of performance measurements, but of the contexts they create and act in. Accuracy is not tied to the performance measurement itself but calculations and evaluations within existing contexts may determine whether they are mobilised and whether strategic objectives are mobilised. Furthermore, achieving a balanced set of strategic priorities through balancing decisions (Lynch and Cross, 1992; Nanni et al., 1990) may be subject to the configuration of performance measurements in place.

5.1.6.4 The "imperfection" of the price tag

The price tag was still in discussion as there were some actors in the network that saw the performance measurements as "logically calculated", and other actors that did not agree on the calculation or the principle of monetisation itself. Although the adequacy of the price tag may be discussable and was discussed in the complexity case, the method of incorporating the price tag in calculations reduced uncertainty in decision processes and was "sufficiently simple that the product engineers understand it immediately" (Kaplan and Cooper, 1998, p. 217). Product complexity became present in product decisions and comparable to other financial dimensions. But the monetisation did not only become present in calculations, but also in the product development network of head-engineers, at the very beginning of a construction and development process. It altered the way alternatives were generated and avoided imminent complexity from the onset. It sensitised the product development network to reducing the complexity of their products.

Adequacy of measurements is thus not defined by the design of the measurement itself (Malina and Selto, 2004) but by the way the measurement is used. Through being mobilised by the IRR calculation, the price tag had an effect on the calculation of cost and value. Number of parts became comparable through being monetised. This effect is the reason why the price tag worked on alternative product decisions. Product complexity can thus be managed through the mobilisation of the price tag.

Although it is not a perfect calculation it is however accepted due to the transparency it provides. The use of performance measurements may be thus more important than its design. It is the mobilisation which the measurement creates that made the strategic objective present in decisions. As long as through this the price tag becomes mobilised, decisions are being altered and the measurement is, so to say, functioning; as long as it is mobilised, it is getting managed (e.g. Catasus et al., 2007). What comes and goes, what stays, and what develops is to be defined in the product development network and through propositions (Callon and Latour, 1981). As the strategic target stays, the durability of propositions of translation depends on the position of actors within the network. For how long measures are constructing or even exist depends on when the next actor changes the networks and provides another powerful tool to work with. Nonetheless, as not only one actor and thus not only one performance measurement is part of the network, interacting measurements lead to different propositions. These propositions in turn influence the way strategy is inscribed in future measurements and how these measurements are visualised.

5.1.7 Conclusion and limitations

Conclusion

Organisations that introduce new strategic objectives are facing a problem when adding new performance dimensions into operations. New measurements that strive to implement strategic objectives and to provide management with a basis for decision making are interacting and competing with existing measures. The studied organisation was struggling with the introduction of a new performance measurement that should reflect the direct link to the strategic objective "*reduction of product complexity*". They overcame this problem by introducing a price tag using the IRR calculations to influence the decisions and the output of the product development network. In that way, product complexity could speak the language of the product development network.

The configuration of performance measurements in place and the tied links were important as they provided a vehicle for transporting the strategic objective. This study shows how performance measurements that are already in place influence the design and choice of new performance measurements. The choice and translation of performance measurements do not only depend on the objective itself, but on the network it acts in. Performance measurements in place are embedded in information flows and systems, and link relevant parts in the PMS and the organisational network. They are much more than intermediaries in this case; existing performance measurements act upon the choice of new performance measurements and create coherence through the translation process in which heterogeneous actors converge (Callon, 1991, p. 144). To what extent a PMS is altered or new performance measurements are introduced, and which type or configuration of PMS and performance measurements are chosen thus depends on the role of performance measurements that are already in place.

The study adds to the literature in that it is not only interesting to focus on accuracy and attributes of performance measurements (e.g. Malina and Selto, 2004; Chenhall and Langfield-Smith, 1998; Lynch and Cross, 1992; Nanni et al., 1990) but on how they are mobilised and how strategic objectives are translated. They mobilise distant places and create the organisational world (Robson, 1992). The contexts that performance measurements create in decision-making play an important role in the mobilisation and choice of performance measurements (Booker, Drake, Heitger, 2007, p. 20). Furthermore, contexts shape the configuration and design of new performance measurements. Existing literature points to functions or attributes that influence the choice of performance measurements, and analyse the links between strategic objectives and the means by which the objectives are implemented. Furthermore, it adds to the analysis using a framework such as the one of Ferreira and Otley. It is not only the answers to the twelve questions that may be important in studying PMS but also the focus of ties and links within the overall organisational network and their relation to change: not focusing on a status quo or snapshot, but on the changes and new relations that occur throughout the PMS.

Organisations that are facing a strategic change and that are asking for the “most appropriate” connection between strategy and control may answer this question by using the working links of their in place performance measurements. Theorists and practitioners have to take existing actors and ties that may provide the translation of new strategic objectives into consideration.

Limitations

There are two main limitations to this study. First, employment with the company may have led to bias and to preoccupation in conducting interviews and choosing material. This limitation was addressed by integrating and triangulating all data (interviews, participant observations and documents), and via the access I had during the study, which might not have been granted to researchers outside the company. Secondly, the time for the study limited the analysis of further translations that may have occurred due to the doubt that was cast on the price tag.

5.2 Paper 2 - Calculating green innovation: creating and exploring calculative spaces for innovation and the environment in the automotive industry.

This paper analyses how cost, value and the environment are calculated in innovation processes, focusing on the specific calculations that translate "green" concerns, functions and technologies into cost and value. Specifically, the study analyses how a medium sized European car manufacturer (Automotive Company) calculates green options and technologies in innovation processes, managed through a comprehensive target costing system. The approach is longitudinal and has made use of multiple data sources, i.e. interviews, surveys, observations and document analysis, to track the development and significance of "green calculations".

The paper adds to the literature in several ways. First, it adds to the literature on environmental management and accounting by analysing how greening can be enumerated and affects operational decision making and design choices. Secondly, it details, to a larger extent than extant literature on target costing and control of innovation, how links and relations between cost, greening, value and functionality are established in and through calculations. Thirdly, it adds to the literature on control of innovation and the making of markets by conceptualising specific modes and ways of overcoming perceived calculative limits. These modes entail both calculative and social elements and they create and explore calculative spaces through attaching, valorising, packaging, imaging, solidifying and projecting.

Much controversy existed concerning the value, calculability and necessity for greening in Automotive Company. The cases illustrate how greening, rather than being in opposition to the rationalising force of accounting, was in a process of being enrolled and incorporated into calculations. This makes greening a much more mundane issue than often posited, which on the one hand, may not overthrow established structures and values in a post capitalistic, ecological society, but may quite contrarily give hope for a greener future through its incorporation into the everyday affairs of firms.

5.2.1 Introduction

The relationship between accounting and the environment (Burritt & Schaltegger, 2010; Gray 1992; Henri & Journeault, 2008; Perego, 2005), and control of innovation (Davila, 2003; Davila & Wouters, 2004; Jørgensen & Messner, 2010; Mouritsen, Hansen, & Hansen et al. 2009) are two lines of inquiry receiving increased attention from academics and practitioners alike. The two subjects are important, as the consequences of energy consumption are increasingly perceived as generating excessive societal risk and as innovative activities that become more important to firms.

These two concerns, management of innovation and the greening of industry, are closely interrelated, because green innovation enables the creation of new innovative paths with the potential to generate cost reduction opportunities and customer value. Porter and Van der Linde (1995) argue that "Managers must start to recognise environmental improvement as an economic and competitive opportunity, not as an annoying cost or an inevitable threat… the early movers – the companies that can see the opportunity first and embrace innovation based solutions – will reap major competitive benefits" (Porter & Van der Linde, 1995: 130). When organisations explore these new strategic opportunities a shift from only regulatory compliance towards the anticipation of regulations, and towards the implementation of environmental strategies and policies that go beyond compliance can be recognised (e.g. Banerjee, 2001; Bansal & Roth, 2000; Biondi, Frey, & Iraldo, 2000; Hart, 1995; Hoffman, 2001; McWilliams & Siegel, 2001; Porter & van der Linde 1995; Prakash, 2001; Sharma & Henriques, 2005; Shrivastava, 1995; Smith, 2003). Firms seeking to achieve competitive advantage through greening need to develop connections between greening, innovation and cost, if they wish to compare alternatives and optimise cost and value. Greening therefore becomes another value and function to be calculated in innovation networks.

While there is literature investigating how firms should disclose and control environmental and social issues and how firms manage and control innovation, there is less knowledge about how firms are seeking to represent and calculate environmental concerns and about how calculations are carried out within the product development process. This may be important because the power of environmental concerns within firms' decision-making processes may increase as these concerns are monetised, calculated and rationalised (Kadous, Koonce & Towry, 2005).

The literature on target costing and control of innovation is only a partial help here. The literature on target costing (Ansari, Bell & Okano, 2007; Cooper & Slagmulder, 1999; Ellram 2006) argues that the value of functionalities are developed through a process where target costs (equalling market price minus profit) are allocated to functions based on customer valuation (using e.g. conjoint analysis), and that "expert judgment of engineers" divide the cost of functions into components (Ansari, Bell & Okano, 2007: 515). The literature on target costing thus points to translations of non-monetary preferences into a value, which is then further divided into functions and components, but how this is specifically accomplished is a black box. In parallel, the general literature on innovation and cost (e.g. Jørgensen & Messner, 2010) argues that there are limits to representations and calculations, especially in relation to uncertainty (Knight, 1921) and there are situations where accounting should not be used (Davila and Wouters, 2004) or where accounting is limited and other activities are more important (Jørgensen & Messner, 2010).

Basing our study on writings in economic sociology (Callon, 1991, Weber, 1980; Knight, 1921) and following Callon and Muniesa (2005), a key concern in this paper is how calculations meet, translate and supersede perceived uncertainty and calculative boundaries and how calculations are performed in innovation processes under pressure from environmental and profit concerns, through a process of "isolating objects from their context, grouping them in the same frame, establishing original relations between them, classifying them and summing" (Callon & Muniesa, 2005: 1232).). More specifically, we investigate the research question:

> *How is greening calculated in heterogeneous product development networks*?

This research question helps us understand how greening is integrated into innovation calculations, how calculations increase the power of greening and how greening as an actor affects the integration and convergence of a product development network. We do this through a study of a medium sized European car manufacturer, hereafter called "Automotive Company", focusing on how perceived uncertainties and limits to calculability are pushed and superseded so that effects of green policies on product development may be calculated.

In the automotive industry, concerns for environment, cost and value intermingle and interact in innovation processes because car manufacturers make decisions in product development that are responsible for a large part of the world's CO2 consumption, and car manufacturers are under pressure to produce more environmentally friendly cars, whilst generating adequate profits. The industry is furthermore one of the prime examples of the use of target costing, making Automotive Company a good site for studying how greening is calculated.

Automotive Company is renowned for its focus on corporate social responsibility and has generated large profits for many years. Yet, margins have recently been under pressure and the Company has therefore sought to control cost in development through the instalment of an improved target costing process. We have studied Automotive Company in a longitudinal study, where one of the authors was an active participant in the calculation of cost and value of (environmentally friendly) functions and components, we have had full access to all relevant documents, interviewed key respondents in the firm and performed a short survey to test views on the relationship between calculations and greening.

The paper seeks to develop three contributions. First, we contribute to the literature on environmental management and accounting through illustrating how links between innovation, the environment, competitiveness and cost are established and how through this calculations of greening become embedded in decision making processes. Secondly, we contribute to the literature on control of innovation and target costing: by, analysing and theorising how value and cost for specific functions and components are established through the creation and exploration of calculative spaces. Thirdly, we add to the increasing literature on the mechanics of calculation (Rowe, Birnberg and Shilds, 2008; Kadous et al, 2005; Lillis, 2002) and the making of markets (Callon & Muniesa, 2005), through a more explicit and detailed focus on calculations, theorising how uncertain green entities are made calculable, and potentially optimised, through the creation and exploration of calculative spaces. We argue that attaching, projecting, valorising, packaging, solidifying and imaging are among the modes that facilitate first, how greening become embedded in decision making processes, secondly, how value and cost for specific functions and components are established and thirdly, how uncertain green entities are made calculable. These modes build on Frank Knight's theorisation concerning ways of meeting uncertainty through focusing on the issue of uncertainty and calculability, and extend it through incorporating a more explicit social theorisation and through the suggestion of new categories.

Specifically, we argue that greening in Automotive Company, rather than being a purely altruistic, uncertain and incalculable constraint on product development, was rationalised through a set of mechanisms and modes of calculation, which made it an integrated part of product development networks. Calculating greening was a contested subject, as greening was, to some extent, viewed as an incalculably and incommensurable item, especially by management accountants who choose to be spectators in some calculative processes. The calculations of "green" concerns in innovation were thus input to processes that decreased convergence in the network. Despite resistance to moving greening from the strategic apex to the operational and calculative level, projects succeeded in converging the network and calculating green options in innovation projects, through innovative processes and modes that helped the firm create and explore uncertain and "green" calculative spaces.

The paper is organised as follows. First, we briefly review the literature on accounting and the environment followed by the discussion of the literature on cost management in innovation. Secondly, we develop our theoretical perspective, drawing on the writings of Knight, Callon, Weber and others on the making of markets. Thirdly, we analyse Automotive Company in two distinct ways. The first approach in our analysis is to trace the development of CSR and environmental concerns in the firm as well as we detail the overall structure and processes of calculating and designing the future cost of cars. We end this section with a brief questionnaire that we conducted to trace perceptions of greening, innovation, customers and calculations. The second approach is to follow modes of calculations and to study specific episodes where value, and cost of "green" components and functions are calculated. This helps us detail the use of calculative tools and translations of value, cost and environmental concerns. Finally, we discuss findings and conclude the paper.

5.2.2 Management Accounting and Environmental Management

Greening is a new value and factor that firms need to account for and translate into numbers[43]. It is envisaged that management accounting may play an important role in shaping decisions towards greening. However, the literature argues that there are barriers and drawbacks to successfully integrate environmental concerns in management accounting processes. Four issues are pertinent. First, companies seem to lack experience in "handling environmental issues creatively" (Porter & van der Linde, 1995) and performance measures are argued not to be well developed. The creation of a working and sophisticated measurement system may take time and seems to be problematic. There are "rules of the game" (e.g. management accounting functions) that keep the measurements not only from being integrated but also from being "invented" (Perego, 2005). Secondly, "true" costs and benefits of greening are difficult to estimate. Though costs are somewhat calculable based on estimates, profits are more difficult to grasp (e.g. Pedersen and Neergaard, 2004). In estimating profit, for example, customer behaviour plays an important role. Companies have limited ability to answer the question of "willingness to pay" and predict impacts on benefits. Thirdly, the link between

[43] Following the call from Gray (1992), studies of accounting and greening have been focusing on determinants or on outcomes of environmental accounting and management Some studies of the determinants have been concerned with the underlying factors that make organisations disclose their environmental performance (e.g. Deegan & Blomquist, 2006; Gray et al., 2001; Lehman, 1999; Neu, Warsame, & Pedwell, 1998) or that make organisations adapt environmental management practices, studies of the outcomes have been concerned with the relation of disclosure and environmental and/or financial performance (e.g. Al-Tuwaijri, Christensen, & Hughes II, 2004; Clarkson, Richardson, & Vasvari, 2008) or the relationship between environmental management and environmental and economic performance (e.g. Christmann, 2000; Melnyk, Sroufe, & Calantone, 2003; Roy, Boiral, & Lagacé, 2001). The approach we take here is different as we are interested in how greening is calculated rather than disclosed or affect outcomes.

environmental strategy, performance measures and product development may be difficult to trace. Bartolomeo et al. (2000) found, by analysing eighty-four companies in four countries, that although organisations might claim environmental management accounting activity, this often represents only singular experimental projects, rather than a systematic and comprehensive approach. Fourthly, the existence of an environmental strategy may not be sufficient to ensure its implementation (Perego, 2005). Firms face problems integrating greening in overall firm objectives, and into calculations and performance measurement systems. Similarly, Henri and Journeault (2008) discuss to what extent eco-control as the integration of environmental matters within MCS influences environmental and economic performance. They distinguish between direct effects of eco-control on economic performance and indirect effects through environmental performance, and conclude that eco-control has no direct effect on economic performance, but indirect effects through enhanced environmental performance. From the perspective of organisational structure, for example, Fryxell and Vryza (1999) examined the integration between corporate environmental departments and other functions such as accounting. They focused on most critical areas in the integration process and on the mechanisms of integration. They found that environmental projects face difficulties in getting acceptance in functions that use monetary measures to evaluate projects, more precisely, accounting functions. In relation to this, Harris and Crane (2002) discuss how green culture changes organisations and what factors act as barriers or facilitators. Professional beliefs, e.g. in accounting functions, emerge as potential obstacles as they conflict with dominant green values and activities.

The literature on management accounting and greening thus points to issues of integration, between management accounting functions and environmental management, as an important element in furthering greening in firms. Firms' cultures and difficulties in measuring and calculating effects of green policies act as a barrier to the acceptance of environmental management within accounting and finance functions. Management accounting may restrict green innovation or be sidetracked from decision making, due to organisational resistance and uncertainties related to the greening of innovation. In such a case management accountants may be spectators rather than participants in decision making and innovation processes. “Greening” is thus a new, uncertain value that faces resistance when incorporated into future product projects and thus into the calculations, negotiations and discussions of product development networks. The literature however provides little insight into how greening is calculated in product development networks and how it affects decision making in industrial organisations.

5.2.3 Target costing, translations and innovation

If greening is to be integrated into the operational processes of firms, it must be integrated into the calculations and control systems in product development. The literature investigating this has followed two paths. One path is the literature on target costing, counting at least 177 articles (Ansari, Bell, & Okano, 2007), the other is a more general literature trying to conceptualise how accounting affects innovation processes, competencies and organisations. In the following we discuss this literature.

Target costing is a system that seeks to plan profits through processes of translating value into numbers and redesigning products[44]. Target costing is

[44] The literature on target costing is predominantly occupied with advocating for the system and sorting out technical issues (see e.g. Ansari et al, 2007; Bernstein & Macias, 2002; Cooper & Slagmulder, 1999; Elramm 2006; Ibusuki & Kaminski, 2007; Swenson et al. 2003). However, a few studies look into wider effects and Mouritsen et al. (2001) e.g. found that the implementation of target costing and outsourcing of production had effects on the strategy of their case firm. Carlsson-Wahl et al. (2009) examined what happens when the hierarchically oriented target costing system is inserted into an uncertain and

argued to be important because key decisions about product design, manufacturing, sourcing and distribution are made, which may determine as much as 70-80% of a product's lifecycle cost. The basic mechanics of the system is a process of allocation or assignment of cost and value to functions and to components. Target costs for a product are found by deducting a target profit from the market price and target cost (allowable cost), and are then allocated to functions based on perceived customer value. This is followed by a process where target cost (allowable cost) for functions is allocated to specific components. Cost targets are compared to estimated costs of production and development and hence problem functions and components are identified. Target costing is thus a system that involves several translations from overall customer preferences to product value to function/feature value and to component value. Target costing thus seeks to control and calculate uncertainty through a series of translations that ends up consisting of clear and unambiguous targets that can be compared to current cost levels.

The literature on target costing argues that two translations are especially difficult. First, the customer valuation of a feature must be estimated using conjoint analysis or Likert Scales (Ansari et al., 2007). Bernstein and Macias (2002) illustrate how discrete choice analysis (a variant of conjoint analysis) can be used to generate customer valuation of specific attributes in a product through quantitative testing of product attributes, where a software program pairs attributes, and respondents choose a product. In this way, ideas about customer preferences can be translated into a concrete valuation of attributes, features, functions.

interactive world. They argue that target costing defines problems that development should solve. The solution of problems however happens in an interactive mode involving suppliers and sub suppliers.

The second translation or assignment of value has to do with estimating how much several different components contribute to the value of a function. Ansari et al 2007 argue, "how engineers or product engineers distribute the relative importance that the customer places on a feature, such as safety into product components like brakes or seat belts is largely judgmental" (p. 515). Thus, translation is key to understanding how target costing works, and both techniques and judgements are important. There is however little knowledge of how these translations and assignments of cost and value to functions and components are performed in actual innovation processes.

In the more general literature on control of innovation (Davila, 2003; Davila & Wouters, 2004; Davila & Forster 2005; 2007), control and innovation are often conceptualised as two opposing objectives. On the one hand, the accounting literature typically argues for the relevance of control in innovative organisations, e.g. departing in Simons' finding that prospectors rely more heavily on management control (Simons, 1987), the literature however also focuses on the issue of how and when accounting should be supplanted by other concerns. Davila (2003) investigated the relationship between short term economic incentives and performance of development processes and found a positive relationship between the use of short term economic incentives and project performance in situations where the project group faces low levels of uncertainty, and a negative relationship between performance and short term economic incentives when uncertainty is high. Davila thus found a U-shaped relationship between short term economic incentives, uncertainty and performance. In a study of different types of translations (short and long), Mouritsen et al. (2009) found that the contradiction between innovation and control somewhat dissolves by arguing that long translations create contexts for innovation (i.e. control systems add to innovation through the effects on the innovation strategy). Jørgensen and Messner (2009) illustrate how their case firm was strongly committed to an "enabling form of control" based on flexibility, transparency and repair actions that facilitated search processes and made room for experimentation and errors. The approach with enabling controls however was problematic in relation to the implementation of larger strategic changes. In another paper Jørgensen and Messner examine how accounting affects new product development activities, arguing that accounting in some cases works as "rules and a general understanding", (see Schatzki, 1996; 2002), it becomes a powerful means that allows managers to move forward despite high degrees of complexity and uncertainty". (Jørgensen & Messner, 2010, p. 185; see also Ahrens & Chapman, 2007), while in other cases, the "representational limits of accounting" (Jørgensen & Messner, 2010, p. 185) made strategising more important. Control, therefore, may both enable and constrain innovation and the literature argues that there may be limits to the use of accounting in innovation, especially when uncertainty is high.

The literature on target costing, and on innovation and control thus points to several important and interesting issues. The role of management accounting in innovation is contested; it may be unable to inform decision makers in situations of high uncertainty and the management accounting systems used may decrease uncertainty through calculations translating cost and value. In the following we theorise on these issues.

5.2.4 Calculations, uncertainty and networks

Greening and innovation are uncertain activities because firms have limited knowledge of the translations and relations between greening, innovation and customer preferences. The relation between accounting, greening and innovation may therefore be conceptualised as a problem of measurability or calculability of new green functions, options and technologies. Frank Knight (1921) analysed the problem of measurability or calculability in his work on risk, uncertainty and profit, arguing that "calculability" of economic situations (probability situations) can be divided into three groups. The first group is a priori probability, which is absolute certainty about calculations based on "Absolutely homogeneous classification of instances completely identical" (Knight, 1921, p. 224). A priori probability is distinguished from the second category of calculability (statistical probability) through the latter's reference to empirical datum. Knight illustrates this through the following example: "an illustration of the first probability we may take throwing a perfect die. If the die is really perfect and known to be so, it would be merely ridiculous to undertake to throw it a few hundred thousand times to ascertain the probability of its resting on one face or another. And even if the experiment were performed, the result of it would not be accepted as throwing any light on the actual probability." (Knight, 1921, p. 215). This first form probably cannot be found in calculations of green innovations, whereas the latter is dependent on knowledge and systems in place within the firm. The third form consists of estimates, and here "there is no valid basis of any kind for classifying instances" (Knight, 1921, p. 225). This last form is what characterises true uncertainty and what, in Knight's discussion, is the basis of profits, where the two other types of probability are risks that are less problematic to deal with for business. Knight further argues that risk is more objective, whereas uncertainty is more subjective (Knight, 1921. P. 233).

While Knight analyses the three forms and uncertainty and risk as distinct forms, he argues that uncertainty can be managed and made calculable through various means: “It goes without saying that rational conduct strives to reduce to a minimum the uncertainties involved in adapting means to ends... In attempting to act "intelligently" we are attempting to secure adaptation, which means foresight, as perfect as possible” (Knight, 1921, p. 238). We therefore suggest that calculability refers to the extent to which calculations are believed to be true representations of the object that is calculated.

Therefore, an important question is how firms seek to reduce uncertainty and thereby increase the “calculability” of greening. Knight argues that there are six ways of dealing with uncertainty 1) grouping, where the key issue is the homogeneity of classes 2) specialisation, in order to facilitate judgment 3) control of the future, e.g. through the use of marketing to manipulate the future 4) increased power of prediction gaining better knowledge of the future through e.g. outside experts 5) diffusion of uncertainty and risk on more people/firms to minimise consequences and 6) avoiding or staying out of uncertain business. In our treatment 5) and 6) are generally irrelevant and 2) is related to the functional specialisation within the firm, this makes consolidation and grouping, increased prediction and controlling the future key ways of addressing uncertainty for firms and individuals attempting to “act intelligently” in the face of uncertainty.

The calculation of green policies may move ecological concerns from the realm of values (and estimates) to the realm of instrumentally rational actions and calculations. The calculation of green policies is therefore related to rationalisation, because accounting and calculation is an impetus to rationalisation:

> *"All rational calculation and double entry bookkeeping, [insert authors] Through the system of accounts creates a fiction of exchange relationships between different departments or individuals or accounts which enables the optimal control of the profitability of all alternatives and options. The investment calculation in the most formally rational mode presupposes fight between people... In rational enterprises all alternatives are calculated with estimated profitability as the target." (Weber, 1980, p. 49 & p. 58)*

Calculation is at the core of (rational) firms' effort to improve profitability. In Weber´s groundbreaking work, calculations are a key pillar and impetus to the rationalisation, demystification and modernisation of the world (Habermass, 1999; Weber, 1980), as well as producing tensions and potential conflict.

Parallel to Weber's and Knight's perspective, current economic sociologists view calculability not as a trait of the "thing" in itself but as a process by which things become calculable. Calculation of green options in product development may therefore be conceptualised as a process of searching and overcoming boundaries to calculation, through commensuration (Espeland & Stevens, 1998). In such a process, calculation of "green innovation" entails a three-step process (Callon & Muniesa, 2005). First, a calculative space has to be created where, based on common principles, entities can be moved, arranged and ordered. Secondly, the entities are translated and associated with one another. In this process Valorimeters are the tools, procedures etc. that translate entities into figures and monetary amounts (Caliskan & Callon, 2010, p. 17). This is a process of commensuration, which is the "expression or measurement of characteristics normally represented by different units according to a common metric" (Espeland & Stevens, 1998, p. 315), i.e. a process of grouping and translation of units into a common (monetary) metric. Finally, the calculation is finalised through summarising the result. Thus, there are two moves involved in making a calculation. First the calculative space has to be created and secondly the entities have to be associated, i.e. the calculative space has to be explored through various means.

In product development, especially when controlled by target costing, the commensuration process involves the coordination of multiple departments, groups and relations with customers and suppliers. We therefore choose to conceptualise the innovation process as an innovation network that "describe[s] a coordinated set of heterogeneous actors which interact more or less successfully to develop, produce, distribute and diffuse methods for generating goods and services" (Callon, 1991, p. 133). Such networks exhibit varying degrees of convergence, which is "the extent to which the processes of translation and its circulation of intermediaries leads to agreement" (Callon, 1991, p. 144). A network is strongly convergent when it is aligned (i.e. a shared space has been created and things are commensurable) and coordinated (i.e. the extent to which rules guide interactions). A converging network is not equal to a homogenisation of actors, their interests, knowledge and cognition, but is a temporary stabilisation of the network around specific approaches to innovation and calculation. In the process of aligning and coordinating networks, calculative tools may be important because things that act as money "become greatly accessible" (Caliskan & Callon, 2009, p. 389); their circulation is smoother. It is therefore important to understand how entities are valued because such valuation will increase the "power" of the entity within the network (see also Kadous et al. 2005).

Controversy is related to the boundaries of calculation and commensuration, and these controversies are "good entry points" (Caliskan & Callon, 2009) to understanding the studied innovative network. Calculation is related to boundaries because "incommensurables can be vital expressions of core values, signalling to people how they should act toward those things. Identities and crucial roles are often defined with incommensurable categories" (Espeland & Stevens, 1998, p. 327). Boundaries of networks have to do with the convergence of a network. A boundary is defined in the following way: "an element may be treated as lying outside a network if it weakens the alignment and coordination – that is the convergence – of the latter when moved into the network (Callon, 1991, p. 149)".

In product development, calculation has traditionally been conceptualised as limited due to uncertainty and dominance by engineers and other groups performing the research and development of products and technologies, and greening is loaded with ideological and normative claims about the way individuals, organisations and societies should behave. Furthermore, greening may be perceived as being in opposition to capitalistic values and modes of operation, calculation and rationalisation, perhaps especially among accountants, as discussed in previous sections. In such a field, incommensurables are likely to surface and to reflect "borderlands between institutions, where what counts as an ideal or normal mode of valuing is uncertain, and where proponents of a particular mode are entrepreneurial" (Espeland & Stevens, 1998, p. 332). Greening may thus decrease the alignment and coordination of a network because it may upset the coordination (rules) of interaction and calculation. Furthermore, greening may decrease alignment; when greening crosses the boundaries of the innovation network and enters into a calculative process, if, the translation of greening into monetary scales is viewed and interpreted as imperfect or arbitrary. Hence, if greening trespasses boundaries to calculations it may weaken the alignment and coordination of the network. This is especially the case if calculations are considered mere estimates by organisational participants, i.e. if greening is considered to have low “calculability”. Investigating boundaries and conflicts about calculation is therefore an interesting focus when studying the calculation of green policies.

An innovation network seeking to incorporate and calculate environmental concerns in an innovation process may then experience decreased convergence (i.e. alignment and coordination) and it may succeed when the calculative tools create “accounting fictions” that valorise the environment, making it subject to the rationalising regime of accounting, and when they create convergence among diverse actors through calculations and through the formation of a bottom line. This process is likely to make incommensurables as well as controversies surface, as novel ways of calculating and valorising emerge. In this paper we therefore investigate “how is greening calculated in heterogeneous product development networks”. We pursue this analysis by looking into the following four factors:

Diversity and heterogeneity: the divergence in views on calculations and greening between groups and nodes in the organisation. Controversies and uncertainty are sources of social constructions (Callon, 1986, p. 199). Heterogeneity is one important aspect as instead of becoming homogeneous, networks are convergent through the alignment and coordination of heterogeneous actors (Callon, 1986). Heterogeneity is thus the starting point of an investigation of an innovation network. Specific questioning related to greening would be, for example, how much weight do groups attribute greening; is it more important than other competitive factors and should it be calculated?

Incommensurables and boundaries: the heterogeneity of views between groups is likely to mark boundaries to calculations. Disruption may appear; only where trials of strength are modified (Latour, 1987, p.93) something new can be built.

Boundaries are here important as they mark trials of strength. Only when they become surpassed can new things be created and innovation networks be built. These boundaries are related to professional identities and mark the groups' perceptions of the extent to which the item to be calculated (greening) is calculable. Is greening outside the boundary of an innovation network's calculative processes, i.e. is it considered strategic?

Calculations: following Millers call not to treat accounting "in a somewhat undifferentiated manner, and without reference to broader issues of the governing of economic life" (Miller, 2008, p. 52), a key concern is the specific calculations and processes in which calculation, innovation and greening meet. Following the perspective of Knight (1921), focusing on consolidation and grouping, increased prediction and controlling of the future, the question is, how do actors meet the uncertainty of greening moving on a scale of "calculability" from "estimates" towards empirical, statistical probability? Which modes of creating and exploring calculative spaces facilitate this move?

Convergence (Alignment and coordination): the heterogeneous networks may converge through calculations and other means that enable networks to stabilise and settle on specific priorities and arrangements. This process defines how the world is built and it is explained by actors (Callon, 1986). Diverse and heterogeneous goals become one composite goal. The result is action which "is a property of associated entities" (Latour, 1999, p. 182). This does not eliminate diversity but enables the network to function despite heterogeneity and diversity. The important questions are, will incorporation of greening into the calculative process decrease convergence (alignment and coordination) of the network? Does the network succeed in converging on greening and how does this occur?

5.2.5 Research methods

Our focus on cost, value and the environment within innovation processes guided the assembly of our empirical material and our data collection methods. In our analysis we chose not to analyse how production works to implement green policies (e.g. minimising wastewater), as we were mainly interested in how innovation and greening is connected in calculations related to products. Furthermore, Automotive Company has been an industry leader in relation to the greening of production for many years and we therefore considered production to be a less controversial and interesting research area.

Studying Automotive Company for a period of two years, we focused strongly on episodes in which product decisions were prepared and generated, and in which innovation and the environment played an important role. To discover and understand these episodes we first had to understand the development of greening in Automotive Company, the product development network and the general ways in which calculations are performed within the product development network. Following this general empirical analysis we found three interesting empirical objects or embedded cases (Yin, 1994) that were consider important in the PDN. The first case analyses how weight reduction measures are calculated in the product development network, the second case focuses on the design and calculation of aerodynamic features. The third case looks at the development and incorporation of a new lighting technology in several product lines.

All three cases cover a broad range of issues in relation to the calculation of greening. We chose cases dealing with different issues and thus providing diverse angles of how greening affects the PDN. The case on weight deals with how a general function, criterion and performance measure – which by the public is perceived to correlate with environmental friendliness – are implemented and calculated in specific projects. Aerodynamics also cuts across multiple car projects and is a function and criterion that strongly affects fuel consumption and that is heavily influenced by design. The third case of lighting technology also cuts across innovation projects and is an example of how a new, greener technology enters into calculations and car projects. Thus, we choose not to follow the development of a specific car, as the development and target costing processes in Automotive Company have a lateral focus across different models and projects (see also Hopwood, 1996). The diversity of the cases enables us to get a more complete picture of the different modes of calculation in Automotive Company. We found that all three cases were highly concerned with the issue of greening and innovation as new product specifications had to be decided and developed. The choice of the embedded cases was also, to some extent, influenced by the time available for our study. We were able to observe participants and decisions only within the two years of our study.

5.2.5.1 Data collection methods and analysis

The paper has used multiple methods for gathering data on the calculation of green issues in Automotive Company. First, we conducted 28 interviews with key respondents in the firm (see Appendix 5), ranging from the director responsible for CSR, to engineers located within product development. Secondly, we undertook participant observation, as the second author had been employed in the department of product development and innovation controlling in Automotive Company[45].

[45] The involvement of the second author in the case company presented both challenges and advantages to the research process. On the one hand, it facilitated data collection through making cases relevant to the problem at hand readily available and by being able to pinpoint key respondents in processes. Furthermore, we had complete access to a setting that is probably inaccessible to researchers, not involved in the case firm, because of confidentiality of innovation within Automotive Company. On the other hand, engagement may lead to bias and low reliability of the collected data, and problems in conducting an interview seeking to probe and develop meaning (Hermanowicz, 2002). In order to minimise the risk of biased data collection and analysis and to improve the reliability of the collected data, the first author conducted 11 interviews with 14 people (one interview was a group interview with four participants).

Thirdly, we had access to all relevant documents. Fourthly, we conducted a questionnaire with 52 respondents from R&D, finance and marketing.
The chosen approach of using multiple data collection methods (survey, documents, observation and interviews) and through letting both authors interview respondents, enabled the use of triangulation between the different data sources. This enhances reliability and validity of findings (Yin, 1994), and supported the authors in making firm inferences based on the triangulation. Our impression from interviews and observations, for instance, was that accounting was more sceptical towards the calculability of greening, which was then confirmed in our survey. Furthermore, the interviews were coded using thematic and pattern codes (Miles & Huberman, 1994), and great care was taken in the analysis in order to improve reliability and validity of the analysis.

All interviews except seven were recorded and transcribed verbatim. One interview was not transcribed as the interview mainly focused on a development project of natural gas, which was not the focus of the final analysis. The other six interviews were not recorded due to reluctance of the respondents and because it was deemed inappropriate. However, these have served as background knowledge. The unwillingness by some respondents to be recorded is an indication of the controversial nature of the calculation of green issues in Automotive Company. The few instances where quotes were used from these interviews are based on direct typing of quotes during the interview.

Company material, such as meeting minutes, presentations and documents about methods and processes could be accessed. In relation to the cases, we chose materials of key decisions to follow the actors that were involved in the decision process. Furthermore, where possible, we observed meetings in which decisions were either prepared, or taken, in order to get a deeper understanding of the specific cases, their network and the relations.

Following the analysis of our empirical material we found that the diverse views on greening, calculation and innovation played an important role in the way calculations were designed and conducted, decisions taken and processes built. If heterogeneous actors become aligned through calculation (Callon, 1991), it is important to understand their views on relevant "entities" in the study, i.e. greening, calculation and innovation. Therefore, we also conducted a survey.

We wanted to increase our understanding of the positions of how first, the groups (accounting, R&D and marketing) view greening in relation to market and customer preferences and secondly, how the different groups see calculations in relation to decisions about product features, design etcetera. We designed a questionnaire with seven statements (see Appendix 6). The focus on groups is caused by the cross functional nature of product development in Automotive Company. The different groups were represented and had specific "functions" within the process.

The interviewees should evaluate these statements with a five-point, Likert scale ranging from "totally agree" ("5") to "totally disagree"("1"). We derived the statements from the following observations. Statements 1-3 were derived from our observations in discussions about greening and customer preferences. We experienced that R&D typically view brand values and typical technological performance attributes as being highly important to customers, whereas marketing and finance had rather different views on customer preferences, greening and technical attributes. Furthermore, as Automotive Company mostly offers models in the premium, upper price level we see cost of ownership and price as an interesting factor to be compared with greening. Statement 4 is based on interesting findings in the aerodynamics case and due to the fact that design is a key competitive parameter for Automotive Company. Statements 5-7 focus on calculations and their perception within the PDN in relation to general product decisions, product innovation and product greening. These three items are not mutually exclusive. However, they reflect certain categories of different product related decisions. These questions were important in order to test and understand the different views on calculations within the PDN and the perceptions of the three items in relation to their calculability.

The questionnaire was conducted with employees from the operational level of the PDN. They were among the participants of the cross functional teams, and were highly involved in the stage-gate through which every product related decision had to pass, and gave recommendations to the technical decision circles of the projects. We chose participants that were concerned with cases of product related decisions that had to do with either CO2 measures, weight reduction measures, products labelled internally as "innovation" or environmental materials. The questionnaire was given to random respondents either by e-mail or in person and was conducted by the second author over a period of two months. The respondents were informed that their answers were randomly mixed after typing them in and that anonymity was guaranteed in order to minimise influence and bias. We aimed for 20 respondents per section, as capacity and time to pass and collect the questionnaire were scarce. We received 19 answers from finance, 17 from R&D, and 17 from marketing.

We chose to do a Pearson Chi Square test to determine if the means of the discriminant values of the groups are different from each other and thus, to test for significant differences in distributions between groups (e.g. Backhaus, Erichson, Plinke, & Weiber, 2005, p. 155-228, p. 700). Our hypothesis is that there are big differences between groups, so we have generally interpreted significant results as being indicative of differences in means between groups. However, in a few cases standard deviations were highly different, whereas means where equal. Therefore we conducted the Chi Square test pair-wise in order to indicate which groups do not differ.

5.2.6 Empirical analysis

5.2.6.1 Target costing and the product development network

In Automotive Company the product development network is concerned with the development of car projects and their integration with production. The product development network is a complex network of constituents of all areas of the organisation and it is managed through the target costing process. Among the different interests within the product development network, cost, quality, time, weight, CO2, customer value, manufacturing, social and environmental issues, capacity and law are the most important factors. With every project, R&D departments were responsible for specific parts (e.g. fuel system or seats) and were concerned with general factors, such as weight or aerodynamics. There are 5,000 to 10,000[46] employed in the R&D centre of which approximately 3% are product development controllers in the finance department. The development process – guided by the target costing system – is divided into several stages that can roughly be divided into a strategy stage, a conceptual stage and a serial development stage. The entire process takes about five years.

[46] Exact figures disguised for confidentiality, the number of employees is within the range.

In the strategy stage, the rough design concept of the car is evaluated based on market screening, and the platform and production strategy. Furthermore, based on an initial, rough estimation, a first business case of the complete project is calculated. At the end of this stage the project is confirmed based on the defined parameters.

In the concept stage, the concept is developed and verified through cost calculations and the assessment in terms of all relevant parameters. At this stage, focus is on evaluating alternatives and finding the right solutions to balance market and cost views with all relevant factors, including environmental impacts. At the end of this stage, the concept with its design and features is validated and confirmed and the target achievement of all relevant dimensions (e.g. cost, quality, weight, CO_2) is confirmed. Furthermore, most of the suppliers – who are accountable for approximately 80% of costs – are nominated at this stage, and they initiate co-development with the PDN. As this is the stage at which the calculations take place and when the main product decisions are taken, we focused on it in the analysis of our empirical material.

The development of targets is carried out in the following way. A top down target (in $/car), based on investments, market price, volume and ROI, is generated for each project for the basic model. This target is not assigned to components. It is an overall target for one project that should be reached on an overall level per car, and in which customer value is implicitly incorporated. Besides generating a top down target, another target is derived in order to reach the benchmarked level of components in the industry. This bottom up target estimates future efficiency measures in production and construction, and also anticipates the access to new and emerging markets. The bottom up target is calculated, per component, by the finance section together with cost engineers, and is derived based on the cost of the predecessor minus a percentage rate of anticipated price improvement within a range of 5%-50%[47] in three categories. This rate depends on the product and production technology of the components and sourcing opportunities, and is derived based on an extensive benchmark analysis. As these component targets are derived based on the concept of the predecessor they reflect the same functionalities as the predecessor. The gap between the top down target and the bottom up target therefore reflects the costs that could be spent based on functional differences between predecessor and successor. Additional functionalities and innovations, in the successor compared to the predecessor, have to meet the cost represented by the bottom up and the top down target.

The estimated costs of components are matched against both bottom up, and top down target, and are generated in cross functional teams consisting of cost engineering, development, purchasing, finance and production. The benefit of that system is that in the first step, component for component could be analysed and optimised to reach the industrial level. At the second step, the differences between successor concept and predecessor concept can be optimised to reach the target, and additional or removed functions can be weighed against the target and be calculated individually. As project management is held accountable for achieving both cost targets, it is in their interest to optimise concepts, screen supplier markets and find the right functionalities that differentiate the successor from the predecessor. The PDN has to find alternatives and ideas and constantly make decisions about the concepts and product substance of every single component. The ideas and alternatives are generated either in the cross functional teams or in the development and research sections. Pressure to reach cost targets and other specific targets such as weight, CO_2 or quality is mediated through decision circles in which problems are discussed and solutions demanded, and for which the concepts get calculated. The relevant factors are illustrated in financial as well

[47] The specific percentage for each category of components is highly confidential and therefore not revealed.

as non-financial measures. All financial measures are incorporated into a business case in the form of an IRR/NPV calculation with predicted cash flows. Thus, decisions to meet, for example, quality, weight, CO2 or engineered hours are always discussed under the aspect of cost and the business case. In these discussions, focus is very much on these calculations, as financial targets are tough and have to be reached.

At the last stage, the design is frozen, the first prototypes are produced and the implementation of the product into the plant is conducted. At the end of this stage, the production of the car starts and the project is handed over to serial control and steering.

The development process in Automotive Company is thus a complex calculative process that involves multiple departments that all have a say in the decision making process. The target costing management process heavily influences decisions made to the overall concept of the car. In the following we discuss greening in Automotive Company, which was increasingly the subject to the target costing process.

5.2.6.2 Greening as s strategic and an operational issue in Automotive Company

Greening has a long history in Automotive Company. The implementation of environmental management into the formal structure was conducted in the seventies; the most important changes however have taken place within the last two decades. In the new millennium, the company introduced a comprehensive sustainability strategy to address the demands of society and the demands of sustainability indexes that had gained more and more attention on stock markets and with the general population. The goal is to produce cars that can be produced, driven and recycled with minimal negative environmental effects. This goal concerns R&D, production, distribution and marketing. These areas are working on alternative engine concepts, improvement of existing engine and car concepts, recycling and material technologies, and the reduction of energy and water consumption in development and production.

The organisation was beginning to see opportunities in proactively introducing environmental technologies into their cars to gain a competitive advantage and take a leading position in the market, although in the short term they seemed to have a negative impact on the financial performance of the organisation. Greening of cars had, in most cases, been strategic top down decisions, which had often meant losses:

> *"And normally we decide no car project if we have a negative business case. But we decided a lot of projects with a huge minus because the board has the responsibility for environmental issues. And we decided all electrical and all hydrogen projects. These were decided looking just on the reputation of the company. We never earned any money on hydrogen cars. It cost us a lot of money. [...] The company always decided very responsibly in the last years*." [Manager Mobility Strategy]

In Automotive Company this had been a board issue and the board reviewed negative business cases. As the reduction of around a quarter of the emissions was decided, there was no emission tax for the customer and thus no financial benefit in having lower emissions:

"When we decided we didn't have any tax. [...]Then we reduced emissions by xx%. And there was no financial aspect at that time. There was the fear that taxes will maybe come." [Manager Mobility Strategy]

As some countries and states raised their taxes, the decisions turned out to be positive as the customer value of saved customer emission taxes had a positive financial impact on the company:

"We had a reduction of return on investment. And now, as we checked again it changed because of the European states raising the taxes. Now we have a return on investment. Now." [Manager Mobility Strategy]

Here, the anticipation of regulations and taxes was first an investment with no secure return. This was a strategic decision, without substantiating (calculative) benefits of initiatives.

Besides customer taxes, fleet taxes for the OEMs were about to be introduced in several markets and the overall emissions of the fleet would have an impact on the profit and loss statement. The taxes would be due if permitted emissions of the fleet were exceeded. With the taxes, Automotive Company generated a price tag for CO2 consumption, which was logically derived, based on CO2 fleet taxes saved when reducing one gram of CO2 / km. Developing cars with fewer CO2 emissions would thus, primarily, generate cash flow for the company if the investments for the CO2 reduction did not exceed likely tax payments.

Whenever features or technologies had to be decided, the price tag for the CO2 impact of the feature could be incorporated into the business case. Through this measure, often more expensive CO2 reduction features could be calculated alongside the price tag. The introduction of this price tag was thus important for generating ideas and incorporating them into the projects:

"[Automotive Company] has to pay a tax if it doesn't reach a certain value with his fleet, so it says, if you are, let me say five grams above this value, that means that you have to pay five times x€ per gram multiplied with one million cars, the fleet, whatever and then you can see the figure is quite big, that is when we say: "No, Automotive Company will not pay the taxes. We have a better idea; we take this money and invest it in developing new techniques," and internally we have a regulation from the controlling department, saying: "Okay, internally we give you a certain figure for one gram and then we call it a CO2 business case," it is a virtual business case, it's not real money but virtual money but we can deal this with internally…That is one way we did it, there are many other possible ways. You could argue with the marketing aspect as well but then it is hard to get the figures, right?... Who can tell us today, now we have CO2 measures in our cars, so that is the reason why we sell two hundred thousand vehicles more, nobody knows really. So our way to do it is making it with the CO2 taxes, this internal regulation.

Q: Do you think that is a good way to do it?

A: Yes, I think it helps us a lot to do this kind of ranking, that is a ranking everybody on the project understands and I think that is a good way. I say this because we didn't have this kind of business case ranking in the past and so it was far, far more difficult to reach decisions and to argue and all this again: "Are you really sure you need this much money?" [Coordinating Developer Performance and CO2]

Through the introduction of fleet taxes in the market, and their translation into a CO_2 price tag, a first step of commensuration of greening in innovation was taken. Costs that will be incurred in the future through likely tax payments are now incorporated into business cases with effects on the way decisions are negotiated and discussed. The price tag entered the regular calculation process and facilitated the decision of CO_2 reduction measures by using an understandable and commensurate price tag in the target costing process. A calculative space for greening in innovation projects was created and greening could cross the boundary between greening as a strategic element and greening as part of operational, calculative processes, without unsettling convergence.

This was, however, just one step Automotive Company took. Before investigating the other steps, we investigate the heterogeneity in the product development network by measuring different departments' positions and perceptions in relation to greening and calculation.

5.2.6.3 The nodes in the network and their views on the customer, strategising and calculation of green policies

As discussed in the method section, we conducted a questionnaire that measures the level of differences and views on calculations, greening and innovation. The analysis feeds into our qualitative interpretation of the level of heterogeneity in PDN and does not reflect a quantitative analysis of hypotheses. Specifically, we wanted to increase our understanding of the positions of how the groups (accounting, R&D and Marketing) see greening in relation to market and customer preferences and secondly, how the different groups see calculations in relation to product decisions. The results of the analysis are presented in Appendix 6.

5.2.6.3.1 View on the customer

Concerning statements 1 and 2, we have significant differences among the groups. R&D saw traditional brand values *(mean = 4.47)* and the brand typical and technical attributes, such as power (*mean = 4.71),* as more important to customers than buying a product branded and produced in an ecological manner. The means from finance (*means = 3.95 and 3.16*) and marketing (*means = 3.94 and 3.82*) also point in this direction. However, the perception of these statements is significantly stronger in R&D. So, while there is heterogeneity in relation to these issues the networks agree on greening being less important than traditional brand values[48]; the network is therefore relatively convergent on this issue.

In statement 3 the cost of ownership and the price for the customer were perceived as more important than the environmental friendliness in all three groups (*means = 3.89, 4.00 & 3.88*)[49]. Thus, developing a cost-efficient car seems to be a more important focus of the PDN than developing a "green" car. As environmental regulations started to have an effect on the cost of ownership these costs could be a lever for the greening of products. Higher cost of ownership would lead to a higher cost of retail that would be a measurable number easily incorporated into business case calculations. Here, the cost of ownership would be the cause, and greening the effect. Increasing regulations and taxes, as well as rising fuel prices, would have an impact on product decisions because they are presented as costs that could be incorporated into the PDN's decisions. The network is thus relatively homogenous and convergent on this issue.

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[48] Only one respondent scored a 3 indicating indifference, all other respondent in R&D saw technical attributes and traditional brand values as more important for the customer than "greening".

[49] The standard deviation differs between the groups and is much higher in marketing (1,32) than finance (0,32) and R&D (0,61). As the pair wise comparison indicates the results are mainly caused by the differences within the group in marketing.

Statement 4 shows no significant difference between the groups and both means and standard deviations are equivalent. Moreover, a rather strong importance *(mean=4.47 – 4.71)* for the customer that prefers well designed cars over environmentally friendly cars. This relates to the perception in Automotive Company that design is a key ingredient in Automotive Company's strong competitive position and design has a strong position within the firm. So the network is strongly convergent in relation to the importance of design as compared to greening. Design could thus be a potential barrier to greening, as will be investigated in the aerodynamics case.

5.2.6.3.2 View on calculations

Statement 5 indicates that calculating general product decisions is more important than making strategic decisions[50]. Accounting and finance's position on calculating general product decisions *(mean=4.47)* is more pronounced than in marketing *(mean=3.47)* and R&D *(mean=3.65),* which is unsurprising. The drop from statement 5 *(mean=4.47)* to statement 6 *(mean=3.42)* in accounting and finance's view indicates insecurity of the calculability of innovation, of features that haven't been in place before and whose input data cannot be derived from predecessors. Although this is not a strong indication, they differ significantly from the position of R&D *(mean=2.29)* who saw innovation rather as a strategic field. With experiencing this conflict, R&D seemed to think of innovation from a strategic point of view rather than from a calculative one. Marketing also sees calculation as more important than strategising. So innovations that were being calculated with a negative business case generated conflicts within the PDN, and the network was relatively divergent and non-aligned on this issue. Marketing and

[50] However, in marketing there is a significant within group variance, with a standard deviation of 1.18 compared to 0.51 for accounting and finance and 0.61 for R&D.

finance needs a bottom line for deciding product innovation, whereas this is less important for R&D.

Statement 7 shows a rather interesting result concerning the calculation of green product measures. Whereas statement 5 indicates that general product decisions should be calculated, statement 7 shows rather that particularly finance points to greening as being a strategic, rather than a calculative problem (*mean = 2.11*). R&D and marketing with means of 2.74 and 2.94 respectively are more in doubt on this issue. This may be explained by the general belief that the "connection" between profit and sustainability is "not clear" as one accountant stated. Because it seems that the value of greening itself can hardly be measured directly and can only be calculated indirectly in business cases (see aerodynamics and weight cases), greening was often viewed critically as a cost with no direct benefit:

> *"The connection is not really clear to me, it's a good idea, we have to do it but the connection of profit and sustainability is not really clear. There is no red line to see. [...] So is this profitable? That's the question."* [Coordinating Controller Car Projects]

Though potentially open minded for innovations and greening, accounting and finance disagree the most with statement 7 and they were sometimes sceptical towards green solutions, with a strong focus on costs dominating their outlook and evaluations. Finance's very differing view between statement 5 and 7 shows on the one hand, how strong the focus is on calculations and on the other hand, that greening to some extent is viewed as an incalculable incommensurable, especially by accounting. The missing direct and obvious link between product greening and the profit/loss statement could be the strongest reason for this, because incommensurables mark identities and differences between groups and because making "soft" calculations would undermine the value of objectivity and calculation in accounting and finance. Finance saw greening generally as an issue that had to be decided strategically top down.

In summation, R&D had more focus on technical features than other departments, while all viewed them as more important than greening and the network was converging on this issue. Design is a key value for all groups and is deemed much more important than greening. Thus, it is a potential barrier to greening. Calculation is viewed as more important than strategising in all groups, but even more so by innovation controllers. Greening is generally viewed as a factor that should be decided on strategic, rather than calculative grounds, though less so in R&D. The network was thus divergent, especially on the question of calculation of green business cases. In the following we will investigate how the network made decisions and calculated green business cases in the heterogeneous product development network, focusing on heterogeneity, calculations and convergence/calculative boundaries. The first case shows how controversial issues (here weight) can be settled by translating them into cost, and how this enables decision making and the incorporation of greening in car projects. The second case is concerned with aerodynamic features of cars to lower CO_2 emissions, and represents a case where networks were aligned before decisions were calculated and taken. The third case is an example of a new environmental feature to a car, which was highly discussed in all sectors because of design, technological, environmental and cost concerns.

5.2.6.4 Cases – Convergence and divergence of networks calculating green innovations

5.2.6.4.1 Case 1 – Price tags for weight reduction

Weight was gaining more attention in Automotive Company because of increased public discussions and test articles pointing to heavier cars as being outdated and not state-of-the-art. Car magazines wrote more and more about weight in comparisons of cars. An engineer stated:

> *"You can read it in every magazine, in every car comparison. They are writing more and more about weight and about heavier cars as not being state of the art. We have to do something."* [Coordinating Developer Weight]

Weight was increasingly seen as an indicator of the "greenness" of a car. Furthermore, weight was important for Automotive Company as weight in future electrical vehicles is extremely important for the range of the car (the distance it can drive before recharging). In the PDN the weight in kilos of the car was therefore set as a top-down, non-financial target. This was derived from the predecessor, through benchmark analyses, and technical specifications.

Heterogeneity: the relationship between weight and the bottom line

Cost targets were tough and business cases often hindered weight reduction measures. Most of the measures generated higher costs because lighter materials, such as aluminium or special plastics were more expensive than basic materials. Furthermore, the impact single reduction measures had on CO2 emissions, and thereby on the bottom line, were barely calculable. Weight reduction options, therefore, in most cases generated higher cost and the calculations argued for a dismissal of most of the proposed options. As more and more ideas of weight reduction were proposed to the projects, the projects had to have an idea, whether these ideas were cost-efficient or not. To overcome the conflict between weight and calculative processes, one project started to put a price tag on one kilogram of weight. Whenever a weight reduction measure was proposed as an alternative, the price tag acted as a monetary parameter to facilitate decisions around weight reduction measures.

With a price tag that reflected a cost-benefit-ratio, and thus a certain value for project management, business case calculations could theoretically skip decisions related to weight and argue for the decision of alternatives based on the weight price tag. This, however, generated resistance from finance because weight had no direct or measurable effect on the predicted cash flows of the company and thus on the profit and loss statement. When product related decisions were taken, finance still calculated without the price tag and argued for a negative business case. However, as project management still needed to meet the weight target, it had to discuss the negative business case of the decision under the aspect of the cost-benefit-ratio of the price tag. These discussions took place in the technical decision circle and the use of the price tag facilitated the implementation of alternatives, lowering the weight of cars. We briefly discuss this in the next section.

Calculation: valorising for decisions and the marginalisation of innovation controllers:

Projects started to rank the ideas in each project to evaluate a cost ($) – benefit (weight reduction) ratio. With this ranking they got a first idea of how efficient reduction measures would be and they got an idea of how much a weight reduction measure might be worth if it had to be decided. The project managers derived a price tag (cost [$] per weight reduction [1kg]) based on these rankings. As each project manager derived the price tags individually, they differed from project to project. Even though the price tags were obviously heavily influenced by the weight reduction target, set in the non-financial performance measure; we could not find a general systematic approach behind the derivation with respect to weight, which is probably caused by the fact that innovation controllers were not coordinating these calculations. Moreover, it seemed that the price tags were related to the size and the overall cost of the car. For example, smaller cars seemed to be more driven by cost concerns and less by weight. Bigger cars, such as SUVs, had more problems with high weight because their absolute weight is higher and their perception in the market was more and more influenced by weight. Thus, reducing weight in smaller cars would cost less than reducing weight than in bigger cars.

However, as we were not able to analyse the exact factors that drove project management to the individual amount of the price tag, we focused on how calculations within the product development network had been influenced and how decisions had been altered.

Though technical decisions concerning weight included mainly negative business cases, project management was faced with pressure to reduce weight for the overall target for the weight of the car. As they had to decide weight reduction concepts they chose the price tag as the basis for discussion and decided on concepts that had at least the same or a better cost-benefit-ratio as the price tag. In these cases finance and project management disagreed and the projects relied more on their self-made measurement. In several cases the price tag substituted the business case calculation within the decision circles and weight reduction options were able to enter the product. Besides narratives in interviews about several cases in which decisions were made “pro price tag”, we were able to follow two specific examples in which a weight reduction alternative was decided taking the price tag into consideration. We had access to the documentation of the evaluation and the decision, and were able to attend one decision circle in which one reduction alternative was decided. In both cases, the material of a body component should be switched from steel to aluminium to reduce weight. As no business case supported the aluminium scenarios (due to higher costs and low CO2 cost savings), finance strongly advised project management to stick to the steel solutions. Project management however chose the weight reduction measure pointing in both cases towards the price tag, and the decision was not only within the range of the price tag but “cheaper”.

Another interesting aspect appeared in one of the two cases where the engineers came up with a third solution to compromise on cost and weight. They evaluated all three concepts concerning technical aspects, cost and weight. The evaluation is shown in Table 3 below:

	Steel concept (status quo)	Aluminium concept	Steel light weight concept
Material	Steel	Aluminium	Steel (light weight construction)
Functional evaluation / Feasibility	ok	ok	ok
Cost	$30	$50	$45
Weight	12 kg	8 kg	10 kg
Recommendation	cost	weight	compromise of cost and weight

Table 3 – Weight reduction: evaluation of alternatives[51]

[51] Numbers are coded due to confidentiality.

As can be seen, compared to the status quo the aluminium concept had a better cost/weight reduction ratio (5 $/kg) than the lightweight concept compared to the status quo (7.5 $/kg). Although both alternatives were within the price tag range and the aluminium concept was the more expensive, project management decided towards the better ratio and chose the aluminium concept. In this case, induced by the price tag, the ratio was the key decision basis for the concept. In general, engineers came up with ideas that were rather below the derived price tag. An engineer responsible for weight stated:

> *"It is not like we are only deciding expensive measures; I mean those that are on the level of the price tag. I don't see the danger today; all of our decisions were below the price tag. Development knows exactly that they don't get credit for a measure ranging in the price tag level."* [Coordinating Developer - Weight].

Weight reduction was thus still calculated under the aspect of cost. But the original calculation, the calculation of business cases, was complemented and even replaced by the calculation of a cost-benefit-ratio in the form of a price tag.

With a price tag that reflected a cost-benefit-ratio, and thus a certain value for project management, project managers could make decisions on alternatives directly based on the calculated price tag.

Besides differing derivations of the price tags, we experienced different acceptance and different practices in product decisions. Finance accepted the CO2 price tag (as discussed in the greening section of Automotive Company). The connection between CO2 and the profit and loss statement made it possible to translate future cost into "virtual money". Automotive Company, rather than paying the taxes, invested the money in "new technologies". The situation was different with the weight price tag. The missing link between weight and organisational performance excluded the price tag from being integrated into calculations. This controversial issue could nonetheless enter the calculation stage. The calculative boundary was surpassed by valorising and creating an "accounting fiction" (Weber, 1980, §11) that translated greening/weight into monetary terms, which facilitated the coordination and thereby increased alignment and convergence in the product development process. Though disagreements on the validity of the measurement and its effect on final cash flows and returns still existed, it smoothed conflicts and enabled comparisons. This was achieved not through the price tag actually being incorporated into calculations but by having a monetary measurement that was easy to compare with the calculations. This created a "fiction of exchange" between the calculation of the reduction alternative and the price tag.

Furthermore, the price tag created not only a barrier for expensive weight reductions; it created a path for less expensive ideas. It gave researchers and developers a specific target with which they could work and it provided a horizon on which they could bring their ideas and "new technologies" into the projects. In this case, the price tag was also a measure that enabled ideas and that fostered innovation by making it possible to decide weight reduction alternatives with negative business cases.

The missing direct link between financial performance and weight reduction made weight an incommensurable factor for innovation controllers. As specific reduction alternatives in projects were not supposed to be decided on a top-down strategic basis, project leaders created a calculative space, so that weight could be translated and associated with cost and value. This process was strongly influenced by the fact that all car projects had a weight reduction measurement attached. The consequence was that project leaders should conform to the objective, and because innovation controllers chose to be spectators to the process, project leaders had to perform the calculations themselves.

5.2.6.4.2 Case 2 – Converging aerodynamics and design

As part of the CO2 emission reduction, aerodynamic features should be implemented within the projects. In the PDN, aerodynamics belong to the basic research areas in which general innovations were developed. They also have staff responsible for bringing this research into the projects and develop these ideas for them. In the studied case, aerodynamic features were to be developed and implemented into the geometry and functions for a certain car project. We focus on one particular car project in which the environmental issue could become a significant problem in the future. A product manager commented:

> *"For example, this car was in the past perceived as an environmental polluter, because it looks like it, but it isn't. We thought about it in the successor, to communicate it more in the sense of aerodynamics. This is something that changes the design. Those were our requirements. In the future the customer might have a problem with such a big car and (s)he doesn't want to be perceived as an environmental polluter, so we said to design, please shape the car so that it is not perceived as [...] an environmental dinosaur."* [Product Manager Marketing]

Aerodynamic features were thus not only concerned with the technical aspects of reducing CO2, but also with perceptions in the markets in relation to greening.

Heterogeneity: competition between design and aerodynamic features and criteria
The integration of aerodynamic features was a question of technical feasibility that was discussed with: the technical departments, to develop the concept and to check with geometrical boundaries; the plant and logistics, to check logistics and assembly; and with purchasing, to check the availability of suppliers. Besides purely technical influences, most of the features had an impact on the design and the geometry of the cars. The design department is perceived to have a very powerful position, as the company is renowned for innovatively designed cars and this value is significantly and uniformly more important than greening (see Appendix 6, question 4). In the past, changes made to their design ideas were often heavily discussed and neglected. For example, the aerodynamic department previously considered itself in a difficult position to implement geometrical changes to the shape of the cars:

> *"This is also very important because in the past often design and aerodynamics were not good friends and designers were not interested in showing aerodynamic features."* [Coordinating Developer Aerodynamics]

Although they were able to implement these features technically, they used to have problems complying with design regulations. Greening decreased the convergence in the network and in order to calculate the business case, the network had to be aligned in order to facilitate calculations and exploration of the calculative space. For aerodynamics, no primarily calculative boundary existed, but a strong actor – design –hindered its integration. How did product development face this challenge?

Convergence through attaching

The message from the market changed the PDN because it put pressure on aerodynamics and design to speak one language to address future customers. The research and design units initiated a pilot project where an aerodynamic engineer was placed in the design department two years to address aerodynamic issues . S/he should connect aerodynamics with design and improve the collaboration of both. After this collaboration s/he became head of the aerodynamic section. An engineer from aerodynamics argues that "Maybe that was one of the reasons that design said we have to be more sustainable in design". This connected the two different units and networks and fostered collaboration and support from both sides. The result was that design introduced a new stream to design the cars in a more "green" manner. The cars should look lighter and more efficient. Design was thus becoming interested in aerodynamic features. This was perceived as a new political turn:

> *"It's very important, it is a new political flow and stream here and that for example the design, they really like the feature 1 and the feature 2."* [Coordinating Developer Aerodynamics]

Through market perception, employee relocation networks were aligned and formed to promote the topic of sustainable aerodynamics. Aerodynamics had been part of automobile design for decades and had always been negotiating with design departments about taste and aesthetics. The new demand for greener products shaped the networks within the PDN and aligned them into one stream to incorporate aerodynamic measures in the cars. This can be illustrated as follows:

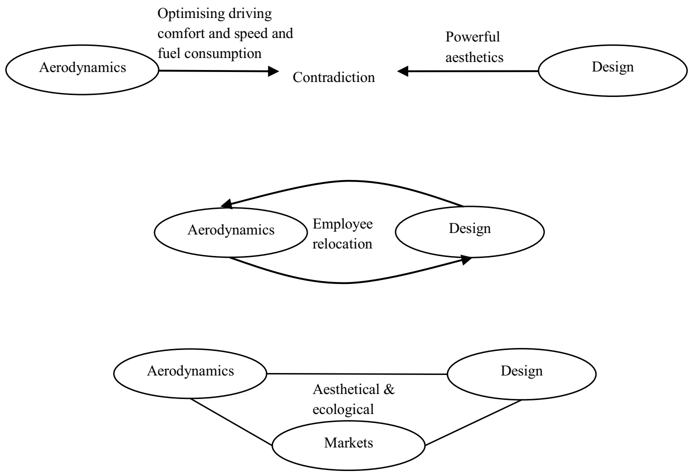

Figure 4 – Aligning networks, employee sharing and market pressure

With the alignment of the networks, new support arose for the implementation of aerodynamic features in the cars and the calculative space could be explored.

Calculations: implementing aerodynamic features through packaging

The aerodynamic section was requested by projects to evaluate all aerodynamic features concerning all relevant dimensions, including financial measures, non-financial measures and feasibility. We focus on one particular car project, which was highly discussed, in terms of aerodynamics and greening, due to the positioning in the market.

The project requested all feasible aerodynamic measures with a business case and all relevant data from the aerodynamic section. The aligned network of aerodynamics and design initiated the request by convincing project management to evaluate aerodynamic features in their project. From tests on models in wind tunnels and computer simulations the aerodynamic section could calculate the reductions in emissions that could be realised by the aerodynamic features. In a second step, the features were checked against their technical feasibility and against technical and geometrical boundaries that had been set for the model. In a third step, when feasibility had been confirmed, costs were to be calculated.

Together with finance, assembly, purchasing and the cost engineering section, costs were calculated and estimated. As the reduction of emissions pays into the avoidance of fines for emissions, the CO2 price tag (see greening in Automotive Company) could be incorporated as a credit in the business case. The reduction of single features had thus a value, which was held against the cost of the feature. This was made visible for project management, as a chart where cost and value of single features were compared to each other and ranked.

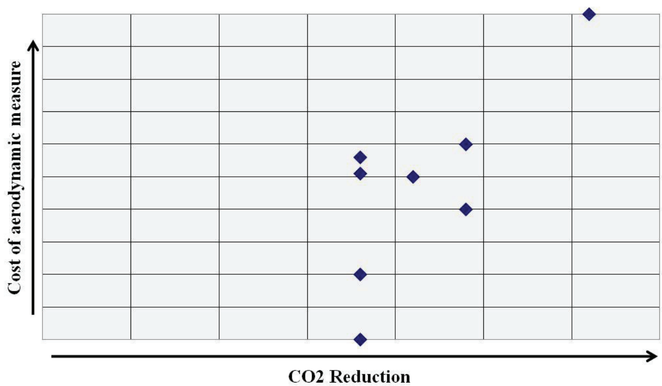

Figure 5 – Cost-benefit chart of aerodynamic measures for CO2 reduction

With this information and the investment that had to be made, a business case for *all* features was calculated. Although finance made calculations that showed that some of these features themselves had a negative business case, the sum of all features had a positive business case and was thus contributing to the attainment of the emission target. In order to avoid that single features were taken out of the project based on the individual calculations, research and development assembled all features into a package, which gave the impression that there were no alternatives:

> *"The idea was that we don't have this cherry picking. [...] In the end we wanted to have one package, it costs so much and it brings so much and in the end we need every single feature and we don't have alternatives here and we need every single feature to reach this goal."* [Coordinating Developer Aerodynamics]

This package was thus a way of avoiding single business cases, as features were decided, that individually did not have a positive business case. The focus in this discussion was set on the overall achievement of the emission target. In this process, politics and the power of the aerodynamics and design network played an important role:

> *"We discussed it with the project leader before the decision circle. So that's always what I said that I do a lot of political discussions with the project leaders and people would decide something; and then the project leader said it's a good idea to make the package[...]"* [Coordinating Developer Aerodynamics.]

Management took some convincing of the merits of the package and the resulting target achievement, and they also had to be convinced that no other alternatives were available for the reduction of emissions with aerodynamics. All the positions: marketing, design, development and quality, aerodynamics, purchasing, production, finance and cost engineering were visualised in one package. This was the outcome of an aligned network of design and aerodynamics, which were focusing on the future demand for greener products, especially when "greenness" could be visualised and given an aesthetic expression. Furthermore, this form of packaging reflected the idea of the sustainability strategy to implement new ideas:

> *"Specialists have to learn the language of the whole organisation. They have to understand how to deal with conflicts and that it is not about partial optimisation of the system but about the evaluation of all input factors and decision criteria and to find the best set at the end of the day and to implement it together in the network.."* [Manager of Sustainability Strategy Department]

The aerodynamics case highlights the work involved in integrating greening into the decision making process. The first step was to align networks, that had a history of opposing each other, through the sharing of employees. This move facilitated understanding between the nodes in the network and enabled the creation of perspectives of aesthetical aerodynamics, which was interpreted to be important in the market. It enabled the attachment of design with green product features, which enabled the projects to create a calculative space. Secondly, it illustrates how engineers pass through the decision making process by assembling single features in bigger packages that, to some extent, black box the individually unprofitable cases and enable a favourable decision on a package of aesthetical aerodynamics with both positive and negative business cases. This was possible due to a convergent network.

5.2.6.4.3 Case 3 – Calculating a new light technology

In Automotive Company, design, innovation and technology are among the most important brand values and strategic directions as detailed in the survey. To be the leader in these fields, the implementation of innovative technologies into projects is the subject of strategic discussions. In the studied case, a *new light technology*[52] that was available in the supplier market was found to meet the strategic values of the company and was considered for integration into the projects. The status quo was that Automotive Company could not differentiate itself from the market, as competitors had already introduced *new light technology* in some of their cars. The solution was to introduce the new technology and provide customers with certain effects. First, it was argued that through this technology the lighting of the road and of obstacles was improved and that safety was thus enhanced. Secondly, it was argued that through this technology, the emission of CO2 could be reduced in the future based on less electricity consumption leading to lower consumption of the light machine and thus less effort for the engine. Thirdly, it was argued that with the new technology more design features could be implemented due to reduced space requirements, which also created more options when designing the lights. It was problematic to evaluate the take-rates and market prices driven by customer demand not only because the technology was an innovation but because the value of the environmental perception and the design was hard to estimate, calculate and account for.

We focus on four different car projects in which the lighting technology was to be introduced. All projects were at the concept stage at the same time. In the four projects, the numbers and arguments have developed differently as learning effects from the first project(s) had an impact on the next project.

[52] New light technology is here used as a synonym for an innovative headlight technology.

Heterogeneity: estimating uncertain customer demand

Although there was a strategic direction of the roadmap for new lighting technology, the individual projects had to integrate the technology separately and decide upon its implementation. As the feature was an option for the customer, it could be calculated as a business case with all relevant parameters. This setting created a calculative space for every project. The projects demanded a full evaluation of the feature and requested a positive business case. However, there were problems and disagreements that needed to be resolved. First, putting customer value on the innovation and estimating take-rates and market prices was difficult, as no experience with the technology existed. Secondly, estimating cost was complex, because design and technology were not only new but also volatile. Thirdly, as both cost and profits were difficult to estimate, a calculation would include these uncertainties, which could potentially cause a lack of acceptance of a decision. Fourthly, innovations might not be cash cows as they might involve higher investments and costs without yielding an equivalent profit. A negative outcome would endanger the introduction of the innovation. We experienced all four conflicts in the analysis of the new lighting technology.

In the first car project the technology had to be evaluated for the first time and technical feasibility and quality had to be assessed and approved. As technical feasibility could be assured, the project focused on generating the numbers for the business case. Several sections in the network had to provide their information and their expertise to generate the numbers. The relevant technical specifications were negotiated between R&D, design and marketing. With this technical solution, R&D estimated costs together with cost engineers and the purchasing section. These costs were a first estimation, as they found it difficult to predict cost in an innovation project like this. Furthermore, by introducing a new technology they had to incorporate the cost-development of the new technology. They had learned from the “old” technologies that, being in the market, the cost will decrease every year by a certain amount. The learning curve from former technologies was therefore instrumental in anticipating cost-development of future technologies and cost should be incorporated as “realistic” as possible in the calculations.

Apart from the estimated costs, take-rate and market price had to be predicted from the markets. Although the specifications and customer values, such as safety, design or CO2, had been discussed with marketing they found it very difficult to get high take-rates from the markets. Furthermore, no visualisation of the new lighting system was available to the markets. The reason was that first, there was no final design decided and secondly, due to the company’s confidentiality policy, the first designs couldn’t be sent to the markets. The first estimations of the markets were perceived as very conservative and take-rates had been differing between markets that usually exhibited similar customer behaviour. Based on these estimations, a business case was calculated that was negative and which was presented to project management. As they would not decide on a negative business case, the numbers of the business case were checked again. Development costs, as well as variable costs, were revised and the numbers were given to finance to calculate the business case anew. An engineer stated:

> *“As discussed we have kneaded and moulded the numbers and revised as much as we could and as much as we could justify.”* [Coordinating Developer Light Technology]

After the revision of the cost the business case was still negative. A key problem was the heterogeneity and divergence of views on take-rates/value in the market. Numbers were insufficient due to the uncertainty surrounding the technology.

Calculations: reducing uncertainty and creating alignment through visualisation and black boxing

The project demanded further analyses of the market to get a more solid foundation of the business case. Furthermore, they showed concepts of the new lights to the central marketing manager to convince him of the technology and design. In further steps, more and more marketing managers were presented with the concept and take-rates rose:

> *"The more mature the option gets, the better we can communicate it to the markets. When we get only the information in the beginning "We are doing new light technology now" then we can only make a guess and talk to the de central markets - but nobody knows how this technology look like. But when we take the markets and give them a whole idea of the concept, there is a high possibility that this guess gets revised, because markets say "wow, that´s not how we thought about it."* [Product Manager Marketing]

The visualisation increased acceptance and the heterogeneity in take-rates among largely similar markets were converging. In order to provide management and marketing with the information of where the business case had its breakeven, a chart was calculated in which take-rate and price were related to the breakeven of the business case.

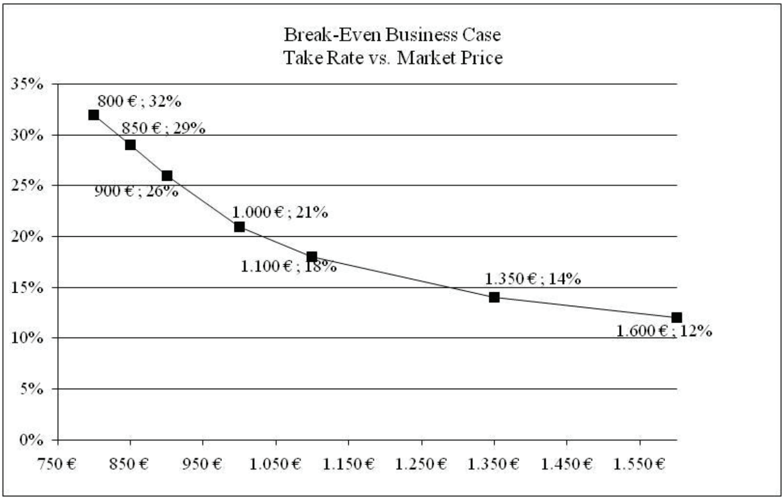

Figure 6 – Breakeven chart that displays take-rates and market prices[53]

> *"I collect all these figures[11]; I would give you a take rate for a 30%. If we sell it for €900 I could give you 40% if we could sell it for €500. It is my job then. To go to the purchasing department to calculate what the cost of manufacturing and development are and then we could decide together with controlling: do we want to sell it at a very high level to the customer or we want to generate a higher take rate and to sell it at a lower price."*
> [Coordinating Developer Light Technology]

[53] Numbers got coded due to confidentiality reasons.

Discussions with markets about take-rates and prices gained momentum and R&D tried to lower budgeted development costs as much as possible. Furthermore, purchasing started revising their numbers. The network that was brought together by this innovation got more and more aligned and it became more likely to be convincing as a breakeven of the business case:

> *"We had a discussion with the head of the product line. We want new light technology. As long as I do not have the same return on investment like I have on the old technique, then I will not buy this solution/this idea, starting with this. The Sales Department also wanted the new light technology and they raised their take rate. In this case, this means that the business case is better, that means that the controlling department has to sell business cases until we have a package that fulfils all the requirements that we and the product line have."* [Coordinating Developer Light Technology]

The new lighting technology had to meet return on investment criteria and after several rounds of revising the numbers the business case was positive and project management decided to implement the innovation into its product. With this decision, project management pointed also towards the realisation of modular technology and equal parts for future projects for generating economies of scales and reducing investments.

In this project, the network had been aligned by first, convincing partners about the advantages of the technology, secondly, through the calculation of a business case that showed a negative financial impact but visualised the potential of achieving breakeven by revising the numbers, and thirdly, by creating images of the technology, and pulling and changing all possible levers (variable cost, investment, development cost, price and take-rate) breakeven was reached.

In the other three projects, we experienced a black boxing of the estimated cost of the first project. Although all four projects were in the concept phase at the same time, the estimated costs were considered “realistic”. However, the situation with estimating the market input deviated. Take-rates and prices differed due to the different positioning of the cars and minor technological changes, obliging the markets to revise their numbers and be convinced anew. In the second project, making a package with another option could generate a positive business case. In the third project, the revision of the numbers was initiated through a meeting with marketing managers, which was arranged by project management. In this meeting a model was shown to marketing to convince them of the potential of this option, and thus, to generate higher predictions of prices and take-rates resulting in a positive business case. In the fourth project an analysis showed that take-rates and prices could never realistically allow a positive business case because of the positioning and segment of the car. As the project decided on the complete offer of the headlight options, it decided to include new lighting technology with the arguments that first, three projects had already decided on the technology, and secondly, the project had to offer this technology to meet the strategic values of the products to offer design, innovation and technology to the customer. The fact that three projects had already decided on the technology greatly influenced the decision. The technology was "institutionalised" by being decided through three positive business cases and by the fact that a converging network was behind these decisions. Even a negative business case could not question the incorporation of new lighting technology into the project.

These four projects show how numbers and calculations mediated innovation and aligned networks. The assembly of numbers in business case calculations made three things apparent, first, due to the fact that the business case was negative, numbers had to be revised to generate a positive business case, and secondly, through showing the breakeven in a chart, the possibility of generating a positive business case through revising the numbers was communicated. Investment and cost reductions and changes to the components were the outcome of this rather strict business case process as numbers, as one engineer stated, were “kneaded” as much as could be justified. Thirdly, the use of prototypes and images helped align markets, so that they revised the market numbers. This involvement formed a network that could be reassembled in the fourth project and that had enough influence to form a decision with a negative business case.

5.2.7 Discussion

5.2.7.1 Case comparison

The product development network in Automotive Company is heterogeneous. Multiple departments and sections, with differing objectives and perspectives on the development of new cars, had to develop solutions together to construct positive business cases. On some issues the network was convergent, e.g. in relation to the importance of design and the general importance of calculating business cases. In others, especially with respect to greening, the network was less convergent and the extent to which greening should be calculated was a highly discussed issue. Alignment and coordination within the network was reduced by making greening part of the product development network and the target costing process. In the embedded cases we have shown how divergent networks were then subsequently aligned and coordinated by various means. This convergence did not eradicate heterogeneity but enabled the network to communicate, coordinate and make decisions despite their heterogeneity. The cases are summarised in the following:

	Weight case	Aesthetical dynamics case	New lighting case
Problem and relation to greening.	Weight was increasingly seen as an indicator of environmental friendliness by car magazines and Automotive Company did not perform well. Furthermore, weight would be important in electrical cars.	Design is a dominating decision criterion due to the importance of design in market positioning. Design boundaries and criteria hinder the implementation of aerodynamic features that lower fuel consumption.	Automotive Company's competitors had implemented new light technology and being a technological leader is important to Automotive Company. The new technology would decrease fuel consumption, yield design opportunities and increase safety.
Heterogeneity and boundaries	Overall weight in kg for a car was set by top management and projects therefore had to decrease weight. Innovation controllers could not see any relation between weight reduction and cash flows.	Two car design criteria contradict each other: aesthetics vs. dynamics and fuel consumption. The aerodynamic department had difficulty convincing design of the value of aerodynamics.	The product development network agreed on the importance of the technology, however the cost of the new technology was high compared with estimated customer value (take-rates). Marketing was thus not convinced about the new technology and market take-rates differed widely between largely similar markets.
Convergence	The translation of weight into a price tag facilitated decision about weight reduction and meant that engineers could focus their development efforts based on the price tag. The network therefore converged through the price tag. Innovation controllers however chose not to do the calculations.	A project was set up by the aerodynamic section to improve coordination and alignment between design and aerodynamics through placing an aerodynamics engineer in design for two years. The employee later became head of the aerodynamic section. Subsequently, a focus on aesthetical dynamics in combination with calculations aligned and coordinated the processes.	Breakeven charts showed the possibility of profitable business cases. Visualisation of the new technology reduced uncertainty about the new technology, markets take-rates converged and take-rates rose.
Key calculations	A total weight target was set for the car. This target was valorised by making a price tag for one kilogram of weight and by comparing cost benefits. The price tag differed from project to project. The price tags created a calculative space.	Cost-benefit-analysis. Packaging of multiple solutions, so that all features were evaluated together. These processes explored the calculative space. Attaching aerodynamics and design created a calculative space for sustainable aerodynamics.	Breakeven charts to show and project the possibility of making positive business cases. Visualisations to reduce uncertainty. Once the first business case was calculated with positive returns, the calculations were carried over to subsequent projects. Calculations were institutionalised and solidified. These processes explored the calculative space.

Table 4 – Summary of cases

5.2.7.2 Creating and exploring calculative spaces

Accounting studies based on theoretical conceptualisations of actor networks generally view accounting as an actor or intermediary that aligns and coordinates networks. Miller and O´leary (2007) found that Moore's law, technology Roadmaps and TCO calculations aligned the semiconductor industry towards accomplishing a doubling of the capacity of chips every two years. Mouritsen et al. (2001) discuss how target costing and open books generate new strategies and core competencies. Mouritsen and Thrane (2006) discuss how accounting is an intermediary that aligns inter-firm networks. Indeed "A network starts to form as soon as there are actors joined together by intermediaries" (Callon, 1991, p. 146). In relation to the greening of cars, networks and calculative tools were related in more complex ways. Specifically, accounting was one actor and mediator alongside other actors and mediators. The cases illustrate that greening in and of itself was an actor. Likewise, design and technology were important actors in the process. Accounting was thus not an actor that "just" translated networks; it was dependent on the context of the calculations, i.e. the strategies and criteria of design, greening and technological leadership. Accounting was part of a network which it both translated and which translated accounting. Accounting was used in two distinct ways in the cases.

Firstly, in order to bring greening into calculations calculative spaces had to be *created*. A first important step in Automotive Company was making a CO2 price tag, which created a "calculative space" for assessing the economic impact of the greening of cars. A space that was not available before due to the difficulties in translating and calculating the value of "image chances". A second step, illustrated in the weight case, was to introduce another demand on innovation projects through the setting of weight targets. Through the overall weight target, projects were forced to find new solutions that reduce weight and thereby generally reduce the use of materials, meet customer requirements for lighter cars and (marginally) decrease CO2 consumption. Because the direct effect of weight reductions on CO2 consumption (and therefore cost) compared to the cost of changing materials was not sufficient to make business cases positive, project leaders created a calculative space through making cost benefit analysis on weight reduction measures. This analysis generated a price tag, which they could use to compare and rank options and make decisions that allowed them to reach their non-financial weight target. In both these cases the creation of calculative spaces was initiated to meet green concerns. Greening was the actor and the calculations mediated the networks. Thus *creating calculative spaces* refers to the step in which something is made calculable which was not beforehand.

Secondly, in other cases, calculations in Automotive Company *explored* the calculative space already installed. This was found in the new light technology case, where the new expensive technology was considered important enough to be implemented even when the business cases were negative. The negative business cases put pressure on projects to explore all options for making the business case positive. First, the groups established how far projects were from meeting the profitability criterion by comparing take-rates with cost. Groups then worked on visualising options, so that sceptical markets could see the new option and commit to higher take-rates, while groups worked on minimising costs[54]. Similarly, in the

[54] It was suggested that these processes of calculation are just a way of legitimating decisions already taken. While we would concur that it is easier to get decisions through the processes when networks are aligned – or rather make the product development network explore possible solutions, we also think that our analysis documents that more is at stake here. Firstly, in the new lighting technology case the fourth project was not able to make a positive business case, which illustrates that calculations cannot be adjusted to show whatever a convergent network wants it to show. Secondly, once calculations result in negative business cases, components, materials and functions are redesigned and budgets and targets are changed and negotiations with suppliers are initiated. So, while calculations as a legitimation of decisions already taken seems a possible interpretation, our data seems to point more towards convergence being indicative of the utilised effort in finding solutions (changing budgets, functions etc.) to the problems that calculations indicate.

aerodynamics case a non- convergent, non-aligned network hindered the use of green aerodynamic features due to design priorities and geometric boundaries. In order to explore options and the calculative space, design and sustainability were aligned and coordinated through the exchange of employees. This enabled the mixing of solutions, which could then be calculated. Thus, *exploring calculative spaces* refers to the action in which calculations, that are already in place, mobilise greening in the innovation network.

5.2.7.3 Modes of creating and exploring calculative spaces

Calculating a greener future in Automotive Company involved several ways of translating green issues into calculable entities and increasing their power within the product development network. There are six such ways of creating and exploring calculative spaces.

5.2.7.3.1 Creating calculative spaces through Valorising (price tags)

Non-financial or difficult to measure entities, such as the environment or weight, were valorised through calculations that generated a price tag. Automotive Company, for instance, had a price tag for CO2, which could then easily be entered into calculations. The CO2 price tag concerned mainly the future taxes, which car manufacturers would have to pay if limits to CO2 emissions of the fleet were exceeded. Other cases of valorisation were trickier, such as was illustrated in the weight case (Case 1). In case 1, decisions to lower weight had to be made due to the targets set on weight-reduction for each project. Here, valorisations were so disputed that innovation controllers refused to complete the calculations and project leaders made their own prices based on comparing the ratio of weight and cost between different options in the car.

5.2.7.3.2 Creating calculative spaces through Attaching

Difficult to enumerate entities could be entered into the calculation processes by being attached to entities with which the Automotive Company had more experience in monetising. Compared with packaging, attaching has to do with the functions and values that are performed by an entity, whereas packaging has to do with the final components. For example, Automotive Company had sold cars where design was an important ingredient for many years, and marketing, development, finance etcetera were comfortable with calculating the value of design by setting overall prices on cars and estimating "take-rates" on specific (design) functions given a certain price. Attaching environmental concerns to design, as illustrated in the aerodynamics case (case 2), is an example where "environmental friendliness" becomes a design expression, whose value marketing was able to enumerate by estimating prices, demand and take-rates. Combining entities and becoming attached thus increased the calculability of entities and thereby the likelihood of options being incorporated into the final product. This parallels Knight's (1921) discussion on consolidation and grouping being important ways of meeting and reducing uncertainty.

5.2.7.3.3 Exploring calculative spaces through Imagining and Prototyping

Estimating take-rates and customer value of ideas was difficult in Automotive Company. The processes often started out as general ideas with no physical expression. The calculation of ideas was thought to be highly uncertain and there were big variations on e.g. the estimated take-rates between an idea with no physical expression, and when the idea had developed into an image and/or prototype. Making images and prototypes was part of the processes of making the car and the calculations more real, and calculations based on images and prototypes were deemed much more real and realistic. This was illustrated in the lighting case where making images and prototypes was a means by which a relatively convergent network could convince markets of the value of the option with take-rates being out of sync with the general view in markets. The ability to predict (or rather converge on predictions) was thus perceived enhanced, as discussed by Knight (1921) and this finding supports Wouters and Roijmans' (2011) finding that prototypes enable knowledge integration. This finding also adds to the target costing literature through illustrating how customer value is validated in organisational processes through the use of images and prototypes.

5.2.7.3.4 Exploring calculative spaces through Packaging

The general processes of calculating business cases was focused on a case-by-case, component-by-component approach, but in some cases developers were successful in developing packages, combining several components into a function or group of components, where some components had negative returns and others positive returns. This way, complementarities between components could be maintained and project leaders and controllers would not "cherry pick", as one developer called it, the profitable components (calculated via the CO2 price tag) while leaving out unprofitable components. This was possible through project leaders being briefed by developers and convinced that only the package would be offered as a solution. Political work supported this way of packaging. Packaging thus made it possible for negative business cases of single components to receive a positive evaluation and be part of the final product by being packaged with other profitable components. This is to some extent a "perverse" effect of Knight's "grouping" mode of decreasing uncertainty because it decreases transparency; however, it facilitated the implementation of green functions and components.

5.2.7.3.5 Exploring calculative spaces through Consolidating and grouping to project the target

The literature on target costing argues that the values of functions are divided into components based on expert engineering judgment. In Automotive Company the process of setting targets was different. Targets were set based on the cost of the preceding component minus a specific percentage. This process enabled objectivity and the use of targets that were trustworthy in the process. A key way of setting targets for the projected cost of components was a process of grouping and consolidating (Knight, 1921) components in a way that projections could be made. Components were divided into low, medium and high cost reduction components. Each type of component would have a percentage cost reduction as compared to its predecessor. These general percentages were calculated and entered into calculations as facts that made the calculation of projected cost and profits possible. This adds to the target costing literature by illustrating how target cost of components may be established through historic cost and benchmarking.

5.2.7.3.6 Exploring calculative spaces through Black boxing and solidification

Calculations of specific business cases were path dependent (Dosi, 1982; Thrane, Blaabjerg and Møller, 2009) in the sense that new calculated technologies and options affected later calculations in other projects and cars. Once a new technology or option had been calculated and incorporated into a car, the cost calculations and the business case were black boxed and reused in following projects. This was seen in the case on lighting technology where, at first, calculations were carried over to the following projects and shaped subsequent decisions.

These modes of creating and exploring green calculative spaces build and extend on Knight's framework through adding and specifying new elements, such as imaging, packaging and solidifying and through illustrating how Knight's modes of working with uncertainty works in social processes within a product development network. Furthermore, our focus differs, as we are interested in illustrating first, how uncertainties related to greening are met and secondly, how the product development succeeded in generating positive business cases. Our modes furthermore extends on Jørgensen and Messner's (2010) finding that the pluralistic nature of new product development, the time-space distance between decisions and outcomes, sets limits to usefulness and applicability of accounting (as calculations as opposed to a mode of thinking). We do this by illustrating the work and modes involved in making a heterogeneous network converge on specific solutions through the creation and exploration of calculative spaces, which serve to reduce perceived uncertainties. Our findings also add meat to the structural bones of organisational practices of calculation in situations with problems with making complete performance measures (Lillis, 2002): low measurability (Rowe et al, 2008), subjective input (Kadous et al, 2005) and how these modes shape the ability to account for greening in situated practices that involve "skillful practical activity in context" (Ahrens and Chapman, 2007, p. 24).

The analysis generally illustrates how calculative process enables innovation (Ahrens and Chapman 2004: Wouters and Roijmans 2011). On the one hand, the profitability criterion applied to all decision situations at the operational level may potentially diminish the implementation of inventions that are unprofitable. On the other hand, our cases illustrate how weight targets and price tags facilitated the search for new solutions, how calculations and "attaching" facilitated the implementation of new aerodynamic features, and how calculations spurred processes of finding new solutions that would make the new light technology profitable. In this way calculations enable innovation and may be “learning machines” (Chapman, 1997).

Our study therefore illustrates that accounting is not just a (long or short) mediator aligning networks which may or may not be relevant in the calculation of uncertain entities such as greening. Rather, accounting and calculations were implicated in two steps of first, reducing perceived uncertainty through enumerating the physical entity to be calculated, and/or converging the network and thus creating the calculative space. Secondly, calculations explored the calculative space enabling optimisation through comparisons, projections and analysis which changed the physical design, composition and substance of the car. Calculations were both the output of a converging network and an input converging the network.

5.2.7.4 Incommensurables and boundaries

The extent to which the calculations performed in Automotive Company were accurate is impossible to judge. Although the quoted prices from suppliers were checked, Automotive Company did not systematically check the extent to which calculations turned out to be true. Much more important is the confidence with which calculations are performed, as there are “differences in the amount of *confidence* which individuals feel in their judgments when formed and in their powers of execution; this degree of confidence is in large measure independent of the "true value" of the judgments and powers themselves.” (Knight, 1921, p. 242)

Due to the forward-looking nature and general uncertainties related to the innovation processes (e.g. demand) this would possibly be meaningless. However, the processes and calculations in the product development network enabled the integration and convergence of the diverse knowledge sets present in the network.

Some issues, however, were simply deemed impossible to calculate but were important on strategic and other grounds. Here, the board of directors or project leaders made decisions on negative business cases that were carried through based on their strategic importance. This had the effect (or advantage) of leaving the general calculative processes unaffected, so that a focus on calculated profits could continue to be the final decision parameter. Automotive Company could continue to have rational processes for choosing and evaluating designs and other types of rationalities such as value rationality (Weber, 1980), i.e. a concern for the environment for its own sake could drive individuals' own motives when working on specific business cases, but leaving them out of the rational processes of improving the profits of Automotive Company by increasing customer value and decreasing cost.

In Automotive Company, image effects were deemed very difficult to calculate at the operational level and sometimes cases could only be justified in relation to image and reputation. They were perceived to be mere estimations. We did not investigate how decisions on the board of managers were made, so we do not know whether these latter decisions weren't calculated or just decided on, based on hunches and values, we doubt it, but have no evidence to support this supposition. However, it is certain that "just referring" to images made it much more difficult to justify investments, so that "image chances" were seen in contradiction to economic chances:

> *"I don't think there are very economical chances, there are more reputation chances, that makes things difficult, when there is only image chances and no economical chances. For the electric cars I don't think there will be the next five years or ten years. But there will come economical chances."* [Manager Mobility Strategy.]

Image chances were deemed more difficult to calculate and were deemed less important. Customers, therefore, need to be more vocal and decisive in their buying patterns, if they want more environmentally friendly products. If this is the case, Automotive Company will change the demand, take-rates and prices, and calculate the business case and supply whatever the customer prefers. A parallel point is that regulations are easy to calculate – fleet taxes on CO2 is an example – and the analysis in this paper therefore also points to the need for regulators to make regulations that enable calculation and incorporation of greening in cars and other products. Regulation and clear buying patterns move greening from being "image chances" and "estimations" that are difficult to calculate to "empirical, statistical probabilities" that can be handled more easily in R&D calculations.

The different departments in Automotive Company felt that decisions about the greening of products was more a strategic matter than a calculative one: irrespective of all the ways in which greening and accounting is actually calculated in Automotive Company. This is maybe not so surprising given the process the Automotive Company is in the midst of. It is more interesting that finance/accounting significantly more than other departments feel that strategies are more important than calculations in relation to calculation of effects of green features, technologies etcetera. This was also confirmed in the cases where, e.g. the weight reduction measure received resistance from accounting/finance due to the difficulty in establishing direct links between weight and profits. Project managers, therefore, calculated the weight measure/price tag individually, and accounting was thus not part of this process. While accounting and finance in general was deeply involved in forming decisions about green options, there were limits to the grounds on which they would perform calculations. The limit was when calculations were perceived to be in opposition to the norm of maximising profits through calculative means, and when the basis upon which calculations could be performed were perceived to be too uncertain.

5.2.7.5 Rationalisation

> *"The Puritan wanted to have a calling – we have to. As the ascetic lifestyle was transplanted from the monasteries to the world of work and began to dominate this worldly behaviour, it aided in bringing about the mighty cosmos of the modern economic order, related to the technical and economic conditions of mechanic and machine production, which today with overwhelming force determines the lifestyle of all who are born into this "machine" – not only those working directly in this machine, until the last kilograms of fossil energy is used[55]." (Weber, 2000, p. 153)*

Much literature and public debate about CSR focus on how firms, based on values and responsibility to the planet, should decrease their consumption of natural resources and help the world become a better place. In Automotive Company, though there were probably many people that were driven by higher aims than return on investment, greening was subjected to calculations of value and cost in the many direct and indirect ways we have illustrated in this paper. In this sense,

[55] „Der Puritaner wollte Berufsmensch sein - wir müssen es sein. Denn indem die Askese aus den Mönchszellen heraus in das Berufsleben übertragen wurde und die innerweltliche Sittlichkeit zu beherrschen begann, half sie an ihrem teile daran jenen mächtigen Kosmos der modernen, und die technischen und ökonomischen, Voraussetzungen mechanisch-maschineller Produktion gebundenen, Wirtschaftordnung erbauen, der heute den Lebensstil aller einzeln, die in dies Triebwerk hineingeboren werden – nicht nur der direkt ökonomischen Erwerbstätigen-, mit überwältigen Zwange bestimmt und vielleicht bestimmen wird, bis der letzte Zentner fossilen Brennstoffs verglüht ist."

greening was translated into numbers and could function in an organisation focused on reviewing all measures and options in terms of positive and negative business cases. In this sense, greening and environmental issues in Automotive Company were in the process of being made an ordinary thing; it was just one of a number of issues that are difficult to calculate and for which the company had to devise ways of translating into numbers. Therefore, CSR and greening does not provide a way to escape the “iron cage” of rational behaviour in Automotive Company. However, all the small steps taken to minimise Automotive Company´s environmental impact, facilitated by their innovative ways of calculating a greener future, may mean that Weber’s prediction, on modernity’s overwhelming drive towards efficiency and until the consumption of the “last kilogram of fossil energy” may be, if not cancelled, then delayed. Seen from a normative perspective of a wish for a greener future, this may not be that bad. Because once the greening of the industry becomes a part of firms’ normal operational processes, then we may be surer that things will change.

5.2.8 Conclusion

Calculating a greener future is a complex process involving the translations of non-economic and uncertain entities into economic entities. Calculations in this process are both an input and output of the networks within which calculations are performed, i.e. they don’t just create and converge networks but are also part of an output of the network and its processes. Translations may take place through socio-economic processes of: attaching, valorising, packaging, imaging, blackboxing and solidifying, and grouping/projecting and in Automotive Company they were always performed in order to seek to ensure that decisions were taken on a rational basis, and with a positive return.

While Automotive Company interpreted and experienced boundaries to calculations, especially in relation to monetary effects of improved image, many calculative boundaries were permeable and surpassed through the many calculative methods discussed in this paper. The limits to calculations within innovation networks discussed in the literature may, therefore, just as easily be caused by a lack of imagination on behalf of actors within the network who cannot figure out modes of translating uncertainties into numbers in a process that converges a heterogeneous network.

Greening was an actor in Automotive Company, however, it was not an actor that changed fundamental beliefs about "the business of business…", and only in some episodes did it alter the alignment and coordination between nodes and departments in the product development network. Greening, however, opened up new spaces for innovation and increased pressure on Automotive Company to find new solutions. Greening was also not an issue external to product development and target costing, but was deeply integrated in the product development processes. This transforms greening from a charitable and altruistic demand on firms that may decrease reputational risk, to a strategic and innovative lever, subject to the normal demands for profitability.

Some hoping for a more fundamental, value based impact of greening on the functioning of firms may lament this type of development, however, making greening an integrated part of product development and subject to calculations and decisions within product development may also ensure a smoother transition to a greener future. At least we may hope so.

5.3 Paper 3 -The translation of strategic objectives in the process of aesthetical design

Industrial organisations are facing strategic challenges that concern higher customer demands, cost reductions, flexibility, and social and environmental performance. An important aspect of product development is the process of creating aesthetical design and sociocultural innovation. Taking place in the fuzzy front-end and being a creative endeavour, aesthetical design is a rather unexplored area in relation to the mobilisation of strategic objectives. This study focuses on the mobilisation of strategic objectives in aesthetical design through an ANT perspective on strategising. The empirical domain is a car manufacturer and qualitative methods were applied for the analysis- using interviews, internal company material and participant observation. The paper adds to the literature on strategising and control and innovation in that it finds that strategic objectives that were initially defined may shape aesthetical design and vice versa. Here, design is loosely coupled with strategic prerequisites instead of being straightjacketed by them. Aesthetical design may either succeed in enrolling decision makers in "non-aligned-to-prerequisite" design, or succeed in enrolling in their "aligned-to-prerequisite" design. Objectives are, thus, not stable goals, but emerge through competition and the generation of design alternatives. Therefore, the mobilisation of strategic objectives may not only be a "downstream activity" in which objectives are fixed as prerequisites but it may also be an "upstream activity" in which objectives are pursued.

5.3.1 Introduction

Design and form language with regards to consumer goods, has become more and more important as customer demands, on e.g. quality, individualism, but also with respect to social and environmental performance of products, have increased (e.g. Tushman and O'Reilly, 1997; Verganti, 1999, 2006, 2008; Wheelright and Clark, 1992). Furthermore, studies are calling for more innovation and individualism in product development, through more emphasis on design and creativity, to generate price premiums (e.g. Adler and Chen, 2011; Dell'Era and Verganti, 2009; Verganti, 1999, 2006, 2008). Organisational strategies that focus on these demands are also coined by foci on e.g. cost, technological requirements or modularity.

The implementation of strategies is a key issue for organisations through which its actions should be guided and competitive advantage gained. In recent years, literature on the implementation and control of strategy has analysed this issue through various perspectives in product development settings (e.g. Chapman, 2005; Davila, 2005; Langfield-Smith, 2005; Miller and O'Leary, 2007); however, few studies have focused on the control and mobilisation of strategy in creative endeavours. Strategic control mechanisms are not only existent in mundane product development processes; in highly creative spaces, such as aesthetical design, control may be needed to guide creation processes towards organisational strategy.

Through which mechanisms strategic objectives are mobilised, in creative endeavours, have so far not been studied in detail. Verganti (1999) discussed this difficulty in the early phases stating that concept generation is, on the one hand, a "creative endeavour", but that it also concerns the downstream implementation phases in which manufacturability and technical requirements are detailed and by which strategic objectives may become more apparent (Verganti, 1999, p. 364). In relation, the literature on the fuzzy front-end describes early stages as being more formed by fuzziness and creativity, while later development stages are more coordinated and controlled by criteria such as time or cost (e.g. Ayag, 2005; Cooper and Kleinschmidt, 1996; Tatikonda and Montoya-Weiss, 2001; Reinertsen, 1999). Besides time or cost, the value of aesthetical and technological innovation is often not graspable. It is thus interesting, how strategic objectives are interacting with creative undertakings (such as aesthetical design). Especially aesthetical design is here interesting due to its creative and individualistic character. I seek to discuss how strategic objectives are translated in the conceptual stages and focus on how aesthetical design is interacting with strategic objectives within product development. The research question is:

How are strategic objectives translated in the process of aesthetical design?

I analyse where and when strategic objectives are mobilised in the process of aesthetical design. Rather than taking a sequential perspective of a stage-gate process (Cooper and Kleinschmidt, 1996; Kuczmarski, 2000; Murphy and Kumar, 1995; Song & Montoya-Weiss, 1998) I seek to take a different perspective focusing on product development as an actor-network. ANT suggests moving from sequences to networks, and investigating the boundaries and controversies between the actors (e.g. Christiansen and Varnes, 2007) and how they are settled. The settlement is here explained by Callon (1986) by the four moments of translation in which problematisation leads to interessement and enrolment of actors which are then mobilised. Through this perspective, strategy becomes something that is pursued rather than just being a thing in itself. Strategic objectives and sub-objectives become one achievement in the process of translation; they are being defined (Callon, 1991, p. 143). Literature on strategising or strategy-as-practice defines strategy as something that is done, rather than just a property of organisations (Whittington, 2003). ANT may add to this view in describing that strategising is not a social process done by people but rather a process of translation of and through different actors (e.g. Callon, 1986, 1991; Latour, 1987).

Studying the development of a car manufacturer over a period of two years I investigated design decisions in early stages, and the means by which these decisions were shaped. I focused on a number of different car development projects and traced the mobilisation of strategic objectives in three cases. The paper finds that, in the process of design, initial strategic objectives (as prerequisites) may translate design and vice versa. In the design process designers may either, succeed in enrolling the decision makers in their "*non-aligned-to-prerequisite* design", or succeed in enrolling in their "*aligned-to-prerequisite"* design. Here, initial strategic objective did not straightjacket designers; instead designers were loosely coupled to strategic prerequisites. The mobilisation of strategic objectives may not only be a "downstream activity" in which objectives are fixed as prerequisites but it may also be an "upstream activity" through which objectives are pursued by the problematisation of discussions, physical visualisations, or analyses (of e.g. cost, customers, or technological requirements).

The paper is structured as follows. First, I discuss the theoretical framework on which the paper is structured. Secondly, the empirical study is described and thirdly, I discuss the outcome of the study. Fourthly, I conclude the paper.

5.3.2 Theoretical Discussion

5.3.2.1 Coordination and creativity in product development

It is a challenge for organisations to synchronise their development activities and flexibly address the particularities of every development stage, especially in environments with "pluralistic demands and high uncertainty" (e.g. Jørgensen and Messner, 2010). This challenge grows with the complexity of the product (Nooteboom, 2000). The need to, on the one hand, anticipate product development criteria and, on the other, to react in product development processes to enhance flexibility creates a dilemma for organisations (Verganti, 1999). Although discussed by Verganti (1999) and argued that both are not mutually exclusive, a problem for managers is still to identify early "constraints and opportunities" (ibid., p. 364), to decide on product design early and to set the direction of following stages, while keeping an eye on other strategic objectives, such as cost. This is, however, difficult, at early stages. The early stage(s) (often called fuzzy front-end) are argued to be difficult to manage due to uncertainty and distance to product launch, and due to the interactions between creativity and control; this is a very interesting field and one that is yet to be studied in detail with a focus on product design and control.

Abernathy and Utterback (1978), for example, discussed innovation in early stages of organisations (being more entrepreneurial) and ambiguous performance criteria; there is uncertainty about targets and technology. In the early stages, for example, it is difficult for the decision maker to decide on major investments or costs (ibid.). Although in the literature different methodologies and measurements for decisions on concept design alternatives have been argued and developed (e.g. Smith et al., 1999; Reinertsen, 1999, Ayag, 2005), there is still the open conflict between systematic approaches that focus on coordination and control, and approaches arguing for a focus on creativity and less on control. Although control has also been discussed positively in terms of innovation management (e.g. Davila and Wouters, 2004; Simons, 1995), while building a stable basis in uncertain conditions (e.g. Chapman, 1998), there is a lack of insight of the interaction between control mechanisms and creative processes in early stages of product development.

Several studies have been discussing limits of control during product development processes. Either, management control may be perceived to hinder innovation and creativity, or values might not be calculated at all, since they are incommensurable (Espeland and Stevens, 1998). Literature argues that, for organisations, a separation of innovation activities might have a positive impact on the effectiveness of the innovation (for a comprehensive literature review please see Krieger, 2005, p. 81-85). Autonomy of different functions, depending on stages, is argued to be more successful than a complete integration and coordination of all functions. This is argued to be particularly valid for early stages (Krieger, 2005).

However, this leaves open how strategic objectives are mobilised in creative accounts in which rigid control systems seems to be absent. First, there is a lack of research on the interrelation between strategic objectives and aesthetical product design in early development stages. Secondly, organisations may have difficulties defining and anticipating strategic objectives. Thirdly, if control mechanisms are present in design processes, then the analysis of the mobilisation of strategic objectives becomes an interesting issue. Fourthly, strategies objectives may be defined upfront and act on design. However, design may also act on these strategic objectives and shape them.

I will discuss these problems from a theoretical perspective on the different characteristics of the early stage. Focusing on the role of strategic objectives, I seek to develop a perspective through which this problem can be analysed.

5.3.2.2 Strategic objectives and mobilisation

Product development is argued to be a strategic process that is crucial for the success of both the product and the organisation (e.g. Brown and Eisenhardt, 1995). In this process, strategic objectives may be defined upfront and steer the development process (*defined* s*trategic objectives mobilise aesthetical design*), or they may emerge in this process (*aesthetical design mobilises strategic objectives*). I will briefly elaborate on both views in the next two sections.

In the early stage of product development, strategic objectives define the directions of the future product. Strategic objectives are mobilised within different spaces and influence the decisions along the development process. Through the mobilisation within the development process, alternative concept designs are created, calculations are generated and decisions on the alternatives are taken. Here, decision processes are argued to play a key role in innovation as, through decision making, strategic objectives are balanced in and among projects and value is maximised (Cooper and Edgett, 1997; Wheelwright and Clark, 1992). Starting off with product development, strategic objectives are defined that position products and that state their objectives. These objectives may be inscribed in documents and are guiding development processes. From this perspective, objectives are defined as stable and static in the process, and are the input for the following processes guided by control mechanisms (e.g. Anthony, 1965). Strategic objectives then act on design processes; *defined* s*trategic objectives mobilise aesthetical design.*

Rather than following a content approach and taking a look into ideal-type strategies and their implementation, another approach may be followed focusing on how actors are involved in the process of product development (e.g. Chenhall, 2005). If strategic objectives are now inscribed into accounts, such as documents or visualisations, then these are anything but static or stable. These accounts are not just neutral but are representations, which are acted upon and that are being evaluated and calculated (Miller, 1990). These inscriptions allow for "governing at a distance", meaning that these (e.g. documents, calculations) re*present* absent things and relations (actors) and make it possible for them to be mobilised. This, however, is not only true to managerial decision processes. Christiansen and Varnes (2007), for example, argue that the work of actors prior to decisions is of major importance in understanding the generation of innovation. It is thus not only relevant to focus on how decisions in the generation of innovation are made; moreover, it becomes relevant how alternatives are generated prior to decisions and what role strategic objectives and their representations play. The interplay of these elements may thus not be regarded as sequential due to their influencing nature on each other. Alternatives not only influence decisions but decisions may influence the generation of alternatives. Strategic documents are not only part of the decision process but accompany, interact with and are shaped by the generation of alternatives (Jørgensen and Messner, 2010). Process approaches shed light on how processes shape strategic objectives and vice versa (Van de Ven and Poole, 1995). Formulation and implementation are simultaneous and strategy evolves through a process (Chenhall, 2005). From this perspective, objectives emerge and are shaped in the process of design; *aesthetical design mobilises strategic objectives.*

Thus, strategic objectives are, on the one hand, set and acted upon by the process of design yet, on the other hand, aesthetical design and the generation of alternatives may shape strategic objectives. This interaction is be followed and analysed in this paper.

5.3.2.3 Theoretical approach

To analyse the previously described issue, a process perspective may be relevant (e.g. Jørgensen and Messner, 2010); however, it may not be sufficient to understand the interactions. A process perspective on strategy is recently developed as strategising or strategy-as-practice. Strategising is a process that focuses on actions and processes rather than on strategy itself. It is a social process (Whittington, 2006). As Jarzabkowski et al. (2007, p.8) defined it:

> *"'[...]activity is considered strategic to the extent that it is consequential for the strategic outcomes, directions, survival and competitive advantage of the firm (Johnson et al., 2003), even where these consequences are not part of an intended and formally articulated strategy. [...] Strategizing' refers to the 'doing of strategy'; that is, the construction of this flow of activity through the actions and interactions of multiple actors and the practices that they draw upon."*

Literature on strategising or strategy-as-practice thus defines strategy as something that is done by social actors rather than just a property of organisations (Whittington, 2003). However, this social perspective suggests that routines and intended practices are constructed by, either more, or less, skilled people within the organisation and that strategising is thus a skill that can be obtained at either the individual or the organisational level or both (Denis, Langley, and Rouleau, 2007).

The actor-network approach here provides a perspective for discussing how strategic objectives are translated in product development because strategic objectives in this perspective can only persist as long as they are carried by actors or carry actors. Callon (1986) introduced the four moments of translation, namely, problematisation, interessement, enrolment and mobilisation. Problematisation is the process in which one actor becomes indispensable by determining other actors' links and identities. In the process of interessement the actors' goals and identities are considered; it is "the group of actions by which an entity [...] attempts to impose and stabilize the identity of the other actors it defines through its problematisation." (Callon, 1986, p. 207-208). Here, links to other identities are adjusted and become displaced towards one goal. By accepting their roles the other actors are enrolled. Mobilisation is the process of rendering entities "mobile which were not so beforehand" (Callon, 1986, p. 216). The actors are now displaced and assembled in the same space and time. The translation of individual goals of two (or more) actors results in a common goal that is different from the original ones (Latour, 1999, p. 179). By acting towards the composite goal, actors act as one unit (Callon, 1986, p. 223).

From this perspective, strategising is rather a process of translation of and through different actors in which things are being problematised, actors are interested and enrolled, and in which objectives are being mobilised. Objectives are defined and these "definitions are inscribed in intermediaries" (Callon, 1991, p. 143). Following Christiansen and Varnes (2007), I argue that through an actor-network perspective, the analysis is facilitated in that that the decision process is displaced and replaced by the process of translation, and problematisation and interessement respectively prior and outside decisions.

In a product development process there may be intermediaries carrying formally articulated strategy. These are translated through different actors in different times and spaces. Thus, we have to *"follow the actors' own ways and begin our travels by the traces left behind by their activity of forming and dismantling groups."*(Latour, 2005, p. 29). Strategising in product development networks is part of a network, which constitutes heterogeneous actors that interact with each other with a goal of providing a product or goods (Callon, 1991). Strategising is thus performed by various actors and, if successful, may lead to different convergence in networks and *"the extent to which the processes of translation and its circulation of intermediaries leads to agreement"* (Callon, 1991, p. 144).

Thus, the strategising process within new product development projects faces the following problems in the early concept stage. First, the ambivalence of technological and sociocultural innovation and the issue of control are important factors in strategic mobilisation. Also, means to steer these processes "in everyday practices are not the same as those that the companies officially declare and describe" (Christiansen and Varnes, 2009, p. 516). Secondly, the question for the generation of alternatives and for the decision process is not only when and where they take place, but through which mechanisms they are triggered. Thirdly, strategising may influence different product development networks within an organisation. Jørgensen and Messner (2010), for example, focus on two different product lines. In multi-product/derivate industries, such as the automotive industry, many product lines are at different stages at the same time and are affected through different practices and forms of strategising. These networks impact each other as the practices of one network (or project) might affect the practices of the other network. The chain of these impacts may be called long-term practice. Long term practice is not only linked to specific projects but to the accumulation of things (Latour, 1987, p. 220); the unfolding of capabilities (e.g.

learning curves, knowledge generation, structural/processual flexibility) project-by-project is what results from long term practice (structural flexibility, Verganti, 1999). Fourthly, defined strategic objectives influence the process of design, whilst aesthetical design and the generation of alternatives in turn shape strategic objectives.

Thus, strategic objectives and aesthetical design are being problematised in early stages, and in the process of strategising, actors become interested and enrolled through means such as calculations, visualisations or long term practice. How design and strategic objects interact in the process of translation is therefore of interest as both are acting on each other. This begs the question:

> *How are strategic objectives translated in the process of aesthetical design?*

5.3.3 Research design

The research domain is a mid-sized European car manufacturer in the premium sector (hereafter, Automotive Company), well known for its design and innovation competencies. The study was conducted over a period of two years (Figure 7). Within those two years, I studied three car projects (Projects 1-3) that were in their conceptual stage and were thus concerned with the generation and decision on alternative concepts. In addition, I studied former car projects through documents and interviews to get a deeper understanding of the product development process. First, I gathered company material in the form of internal documents (e.g. business cases, strategy papers, and design presentations) to understand the new product development process. The material was important to gain an understanding of the processes, decisions and changes that appeared in Automotive Company.

Furthermore, as I was employed by Automotive Company at the time of the study, I attended decision meetings and strategy discussions.[56] The documents were gathered focusing on information about the stage-gate process, decisions and milestones and also on the three projects. Decision meetings and strategy discussions were attended where possible; these added perspective to the gathered documents.

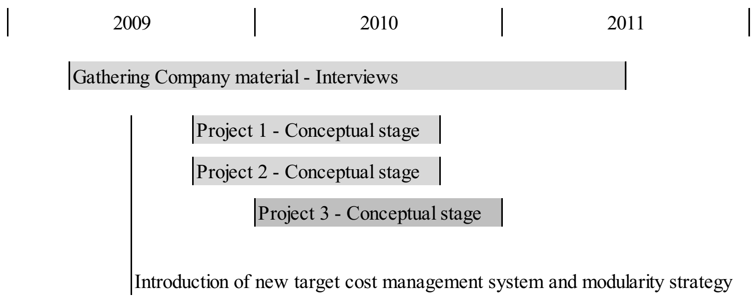

Figure 7 – Organisation of empirical material

Building on the gathered and analysed material, I conducted fifteen semi-structured interviews, within a range of 30–60 minutes, of which seven were recorded and transcribed[57] (Appendix 7). In the other eight, non-transcribed interview notes were carefully taken and as many quotes as possible were transcribed. In the interviews I focused on former and recent episodes of concept creation, selection and evaluation in concept design, and on likely frictions. The interviews were semi-structured to leave the development of episodes and problems to the interviewee.

[56] Employment may lead to bias and might negatively influence the quality of the empirics (Hermanowicz, 2002). In interviews, bias may lead to focusing too much on developing meaning that has been build up through high engagement. First, the author was not engaged directly in the calculation and concept design functions in the early stages. Second, the interviews were semi-structured, trying to focus on the theoretical developments and episodes relating to the developed focus.

[57] Design at Automotive Company is a highly confidential area. Recording interviews in that area was often impossible due to this fact.

I searched for the episodes of problems and dilemmas where strategising in form of design concepts and strategic objectives interact (Eisenhardt, 1989). The basic idea is to follow control mechanisms and the way they create, shape and mobilise objectives within organisations (e.g. Miller & O´leary, 2007). Following control mechanisms that mobilise objectives (Callon & Muniesa, 2005), or building controversies is a key point in understanding product development networks (Caliskan & Callon, 2009). Therefore, the empirical material is structured as follows; first, I focus on the defined stage-gate process in Automotive Company. Secondly, I discuss how aesthetical design concepts are generated and decided upon. Thirdly, I describe how, in three mini cases, strategic objectives were in aesthetical design. The mini cases were selected based on episodes of problems and dilemmas. In all three cases I could find emerging strategic objectives such as customer value (Case 1), costs (Case 2), or modularity (Case 3) which although being predefined became shaped by aesthetical design. The cases were selected based on gathered empirical material and based on interviews which pointed towards dilemmas of strategic mobilisation. As previously discussed, the translation processes in the cases are relevant. First, it is relevant how strategic objectives and design are problematised. Secondly, interessement and enrolment of actors are important moments towards the mobilisation of strategic objectives. The cases are structured by the moments of translation to understand the interactions of design and strategic objectives, and their mobilisation.

5.3.4 Empirical findings

5.3.4.1 Introduction of the development and design process of Automotive Company

To give a broader understanding of the design and development process in Automotive Company I will briefly describe the processes. In Automotive Company several projects are developed at the same time. There is a blueprint stage-gate process for all projects, which is only slightly adapted for individual problems and needs, such as slightly differing timelines. However, in the formal blueprint the process is roughly divided into three main-stages (see Figure 8).

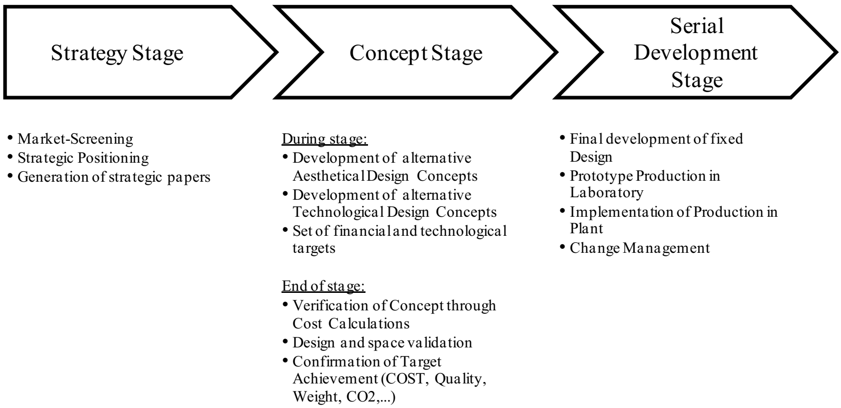

Figure 8 – The simplified stage-gate process

In the strategy stage, the positioning of the car is roughly anticipated based on market screening. Only a few people from strategic departments are active at this stage where the feasibility of a car project is evaluated. The outcomes of this stage are strategic papers/documents in which rough technical parameters of a car project and customers' preferences are described. In most cases the description of the configuration leaves room for interpretation and alternative concepts. Also, fixed prerequisites, such as norms, laws, or modularity, are set. These strategic documents are transferred to the conceptual stage, in which a technological project leader together with development teams work towards the generation of a coherent car concept.

In the concept stage, focus is set on generating alternatives, evaluating them and finding the right solutions to balance market (value) and cost views. Different departments with different foci interpret the strategic documents. There were two different spaces in which these documents are mobilised and interpreted. The first space concerned the development of technological design concepts, in which cross functional teams evaluated cost and technological criteria. The second concerned the development of aesthetical design concepts. Here, as discussed, I will focus on aesthetical concept design. Aesthetical design concerns the development of the inner and outer shape of the car, its proportions, and focuses on the sociocultural element of a car. The development takes place in a design department that is loosely coupled to the technological product development process. For every project, a "design engineer" is responsible for discussing what is technologically feasible and what is not. Thus, the design engineers bring certain design barriers into the design process. These concern, for instance manufacturability, laws or modularity. These are rather technological boundaries, which have to be considered to ensure the feasibility of a model.

Within this process, designers interpret the strategic objectives differently. In the car design process every designer has their own interpretation of the strategic objectives of a car project. Designers are confronted with the strategic documents. Every designer creates his or her own interpretation through design sketches.

From these rather rough sketches, a certain number (e.g. five[58]) of designers is chosen that may develop a clay model from their sketches. The head of the design department makes the choice. The designers start to develop their clay models together with the design engineer. After the designers create their models, the models are presented to the executive committee. These models already look like real cars. In this meeting, the five models are decided down to three[59]. The models differed in either, forms concerning the size of the components, or in additional design elements, such as chrome rings or decoys.

In these meetings, comments and discussions on the models are documented and give input to the designers. The designers rework their models based on the output of this meeting. The models become more mature and rather slight changes and adaptations are made. In the final decision round, the final design concept is chosen. This process is visualised in Figure 9.

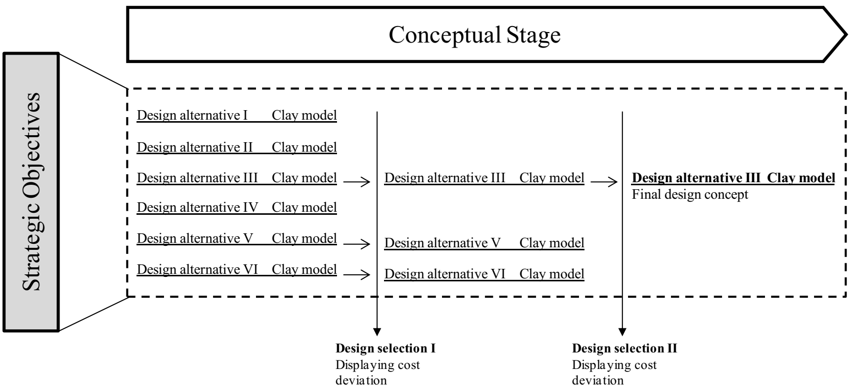

Figure 9 – The generation of aesthetical design concepts

[58] The exact number is confidential
[59] The exact number is confidential

The final design selection meeting is conducted like the first one. The generation of alternatives is thus based on the interpretation of single designers. Boundaries are of a technological nature and are discussed together with cost issues through the design engineer. In the selection process, the decisions are based on soft, rather than measurable, effects.

> *"They [the managers] chose what they liked and what was representing our brand the most in terms of form-language."* [Designer]

As discussed, the aesthetical design process is loosely coupled from the technological development process. Only design engineers are consulting the designers about technological feasibility. Of course, within the strategic documents, certain aspects, such as manufacturability, laws, or modularity are already fixed. How a strategic objective such as equal parts/modularity interacts with aesthetical design is shown in Case 3. However, in general, the interpretations of the chosen design model and the technological concept differ to some extent:

> *"The designers created the concepts very differently as that, what we were doing here on paper. And in the end we were coming together and saw some different things. Concepts were shown to the executive committee and they decided without us being part of it or being asked – of course really cool stuff as well, without that, we wouldn't build such cool cars [...] But it was separated from our process [...] because their creativity should not be influenced and that we did not rain on their parade."* [Development engineer]

The design engineers address the technological criteria, such as feasibility and strategic requirements, throughout the generation of aesthetical design concepts. However, financial information is only passively provided, in the form of cost deviation, in the two design selection meetings. How financial information in the form of cost calculations and targets interact with aesthetical design is described in case 2.

In summary, strategic objectives are not calculated and steered towards. Rather, the design process is characterised through individual interpretations, and the selection is based on forms and aesthetics rather than on calculated criteria. In the next chapter I will introduce three mini cases to give deeper insights into the generation of aesthetical design concepts.

5.3.4.2 Case 1 – Customer value as interpretative objectives

Although individual designers create aesthetical design, there are, as discussed, initial strategic objectives inscribed in e.g. text documents that act in the generation of designs. In Case 1 a new car project was developed. In the strategy stage, strategic objectives for the new project were set. The new project to be developed should have specific proportions which were inscribed in the initial strategic project description. Thus, the proportions of the car project were already directed and described by strategic objectives, which directed the generation process of aesthetical design.

5.3.4.2.1 Design test - Problematisation of proportions

In order to grasp customer demands and taste about proportions, a design test[60] was performed before designers started to build their clay models. These design tests were completed for every new model to be designed in Automotive Company. Particularly interesting, however, is this case due to the contradicting proportions. The design test was executed with target customers in two to four main target markets. In the design test, a model was shown that reflected the proportions derived from the beforehand defined strategic objectives. The model was presented, to a group of customers, together with four to eight other models from the segment, including models from Automotive Company and models of competitors.

Exterior and interior proportions were shown and a survey (quantitatively) and interviews (qualitatively) were conducted. The outcome of the interviews were gathered in documents in the form of positive and negative quotes, which provided details, such as ”the position of the license plate is too low” or “the chrome element looks nice although it is a bit too big for my taste”. In this car project, the rear of the car was rated to be the “weakest view of the car”. The proportions in the rear were perceived as too “bulky”, “looking like a big butt” or it was stated, “the rear jeopardises the storyline of the car”. It was also perceived to be too close to the existing car in the higher segment. Both, qualitative and quantitative data were gathered in one document and the outcomes were compared to the proportions which were defined in the strategic objectives, and key concerns were identified by design and management. These concerned first, the overall perceptions, which were held to be disproportionate by the customer. Secondly, the rear was found to be too bulky. Thirdly, the side, in which the side windows

[60] The design test is one of the most confidential processes and information in Automotive Company. I could not attend the design test due to confidentiality. The information in this paper is limited to text documents and interviews.

were perceived to be too small. And fourthly, the front, that was perceived to be too high.

The proportions were thus problematised by the design test which incorporated the customer's view. The proportions which were defined in strategic objectives got questioned through the design test and derived key concerns were put in an official document. With this document, the designers of the clay models that were in competition had new aspects to refer to.

5.3.4.2.2 Customer's view, initial proportions and design - Interessement and enrolment

Although there were no fixed prerequisites for the generation of alternative designs, the outcomes of the design test were taken seriously. As one designer stated (from notes taken):

> *"We have to take, of course, into consideration what the customer is saying. We do not follow all critique and still do our thing. But it is definitely influencing our work."* [Designer]

In this case, the extent to which these outcomes influenced the designs is not measurable. However, designers and decision makers used these documents for discussing clays and designs. The rear was significantly adapted. One design manager stated in a design presentation:

> *"As you can see, we tested towards the A-pillar, towards the B-Pillar and the C-Pillar and finally the rear of the car. After the Designtest the clay models differed significantly from the proportion model used in the Designtest. The rear is really light now."* [Design manager]

The outcomes of the re-modelled models were then compared to the initial proportion model and to the key findings of the design test. Through this comparison it became visible to what extent the designers adapted their models and to what extent it complies with the key critiques of the design test.

The documents from the design test represented the potential customers' view. These interested designers and management within the generation of alternative design models. Thus, customers' taste is tested on previous proportion-models that provide directions for future designs. Strategic objectives emerged from the visualisations of proportional design models as they were inscribed in the documents and the models; common goals were created within the process of design.

5.3.4.2.3 Mobilisation – Proportions, customers, and design models

Together with the comparison, the models were presented in the design selection stages in which the competing models were decided down to the final model. Thus, deviations of the models compared to the initial proportion and to the key findings were displayed in the meeting. In the last selection stage all three models were, to a certain degree, adapted based on the findings. One model, for example, was mainly adapted in the rear; another model, more in the front. Though due to confidentiality the minutes of the meeting could not be accessed, the design manager who took part in the meeting stated that the most "coherent" model was chosen and that especially the rear was important in relation to the choice process.

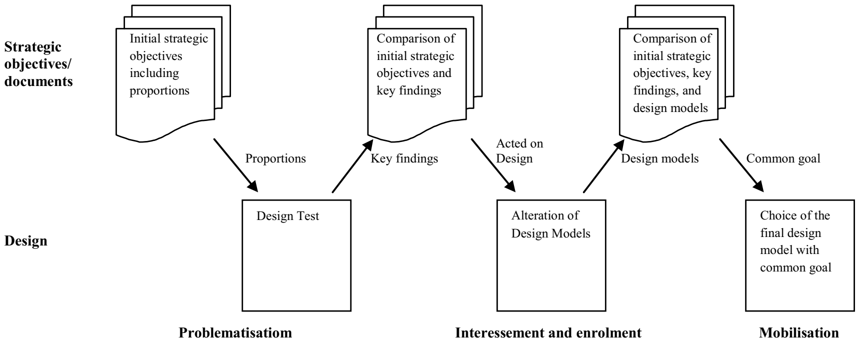

Figure 10 – The translation process towards the final model

Figure 10 summarises the translation process. In the end, the final model represented initial strategic objectives, individual interpretations and the customer's view. Through the design test and the documentation, design meetings and decisions, the customer's voice got inscribed into design models. *Design translated* and thus defined *strategic objectives,* as through the design test and the modelling of the cars the initial proportions got re-considered.

5.3.4.3 Case 2 – Resising a design element

In Case 2 a specific design element[61] was defined through the size and proportions of the predecessor model. These parameters were described in strategic documents, which were communicated to the designers who were designing the five clay models.

[61] Specific components had to be disguised in this case due to confidentiality

5.3.4.3.1 Problematisation through proportions and cost

As previously described, a design engineer evaluated the five clay models before the first selection meeting. In this case, two of the five clay models showed the design element about twice the size of the parameters set in the strategic documents. With the evaluation, design engineers provided cost estimations of the design element of the two cars, showing that the cost of the design element was twice as high as the cost of the design element of the predecessor. The cost estimations were performed by a specific department which was responsible for calculating product costs of future products. These estimations were discussed in cross functional teams and agreed upon by different departments, such as purchasing, cost engineering and accounting. The costs were provided for the size and proportions that were initially set in the strategic documents. For the two bigger design elements a surcharge was provided for the additional material, for higher logistic costs (due to size), as well as for higher tooling costs (because of the bigger size of the tools). These numbers were not generally (as well as in this case) contested in the project because they were agreed upon in cross functional teams. Based on these estimations, project management made their decisions.

5.3.4.3.2 Cost deviations and design selection - Interessement and enrolment

While the confrontation with cost usually (as in prior projects) happened in the selection stages, this time, designers were already confronted with the cost during clay design. Not only was this a new circumstance; both designers adjusted their concept towards the cost targets derived on the basis of the strategic objective. One of the designers stated:

"You see that they are killing it anyway later due to cost targets. Now I adjust it [the design element] upfront knowing that I won't be able to keep it." [Designer]

Furthermore, in one particular meeting, one of the designers was pointing towards a case in which this had happened before and that they would have problems anyhow in holding on to the concepts.

"When you design the alternatives, then you have to negotiate and argue with the managers because you may add cost and then you have to design a solution" [Designer]

During their design process, the designers were not only provided a technological evaluation but also a cost evaluation. In this case, design engineers evaluated the design concept before the design selection meetings and designers knew if they would exceed the cost of their models that they might have a problem in the selection meeting. One developer commented this new situation:

"No, because everything is focused on management, more precisely the costs; a lot of things have changed. The designers are now down to earth, way more down to earth. They know by now that they have to integrate themselves into our process." [Development engineer]

Cost estimations based on the size and definition in the strategic objectives, and deviations from this size, were thus important information for designers. This cost information problematised deviations of designs from strategic objectives and enrolled designers into the strategic objective of cost.

5.3.4.3.3 Mobilisation of cost and size as common goal

Cost as strategic objective was thus mobilised in aesthetical design. Not a decision based on a cost calculation changed the design or concept. A cost-estimation and the anticipation of the designers that higher cost could cause a change in the design decisions changed the design. Furthermore, the design engineers compared the size of the part with the size of the part of the predecessor. Thus, proportions of the predecessor were a basis for the design process as they were incorporated into the discussion about the new design and into the estimation of the cost. Hence, the concept of the predecessor was an important element in the generation of its successor's design.

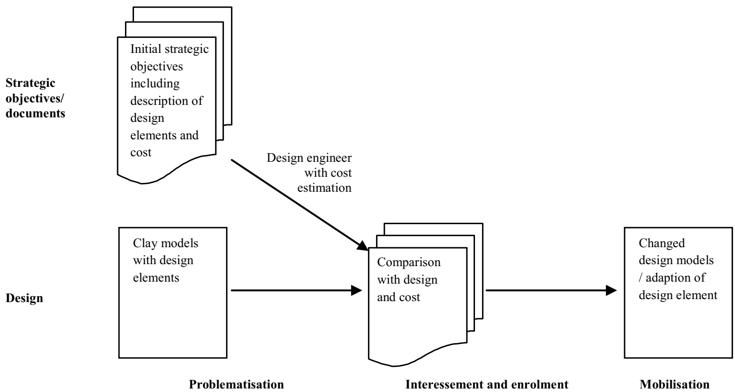

Figure 11 – Translation process of the strategic objectives size and cost

Referring to a case in which a design element was changed due to cost issues, the two designers adjusted their models in alignment with the technological concept description and parameters, which were set by the development team and incorporated thus the strategic objectives of cost. This is summarised in Figure 11. Cost as strategic objectives was defined, but also emerged through the modelling of proportions and the predecessor proportions. Although the designers still, in general terms, followed their design model and didn't steer their work towards target costs or calculations, some issues were present and influenced the design process. Thus cost, as a strategic objective, became part of the design process not directly through calculations and targets, but indirectly through anticipations of decisions. Here, the initial *strategic objectives* cost and size were inscribed in the final model, and *were* thus *translated by design*.

5.3.4.4 Case 3 – Designing towards equal parts

A new modularity strategy was being implemented. Inscribed in strategic documents, modularity became an important pillar in the development of cars with Automotive Company. Efficiency in development processes, and cost and product complexity reduction should be the long term result of using equal parts and modularity. Equal parts and modular components such as headlights were set, right after the strategic stage of a car project, by technological development teams. In strategic documents modular components and equal parts were thus described, which were provided to design. The document consisted of a list of all parts of the car project. The parts were described in this document by parameters such as size (see e.g. case 2) and whether they should be modular parts or equal/carry over parts. This was the blueprint for the development of the parts. How this strategic document is translated within design is described in the next sections.

5.3.4.4.1 Strategic and aesthetical definitions of components – Problematisation

Similarly to Case 2, equal parts and modular components as strategic objectives were communicated to design by design engineers. These objectives were discussed with the single designers and as they designed their clay models, modular components should have been taken into account and they should design the shapes and forms "around" the modular component:

> *"On the one hand we should design the cars as beautiful as possible, on the other hand we get the prerequisite to take modular components. And now, now I have to design around these components, huh?! And this has an effect of the bordering shapes. They are thus set as well. These are really constraints."* [Designer]

Like in case 2 it was, however, not always the case that the designers initially took these constraints into consideration. In this case all five clay models were initially individually designed and their headlights differed from each other. This was also the case after the first selection down to three clay models. In technological development, the modularity and equal parts strategy was, however, set, and the headlights of Project 3 should be carried over from another project to save tooling costs and proportional costs by economies of scale. The design engineers communicated this information to the designers. In the generation of alternatives thus, individual interpretations of design initially neglected set prerequisites and constraints, such as modular or equal parts.

5.3.4.4.2 Strategic objectives or individual visualisations - Interessement and enrolment

The design engineers communicated again the information to the designers and marked the headlights as not being in compliance with the strategic set of equal parts. In the design process the designers of the three chosen models adapted their headlights and put the carry over part into their clay models. Although initially the models were designed individually neglecting the prerequisite of equal parts, the designers changed their models and incorporated the technological demand for equal parts. Concerning the development of the designers within this process, the development engineer of these parts stated:

> *"The designers are no longer the freaks they have been before. They are much more structured and know technological boundaries better than I do, although I am responsible for them. They come to me and say, 'no, this is not possible, this is set as an equal part."* [Development engineer]

Bringing the process of design selection "down to earth" might be seen as a process of handling the likely risk of being thrown out when not complying with technological demands. Similarly to the cost issue in case 2, the designers were in competition to win the final selection stage and strong deviations of technological demands were risky. However, this was not always the case, as one design engineer stated:

> *"In the predecessor we had different headlights between the two models. Although there we should have already done equal parts. We had the same hood, see? The chosen model however convinced the executive*

committee to go with the same hood, but not with the same headlights."
[Design Engineer]

The chosen design model in the predecessor did not comply with the strategic prerequisites and could convince management through the visualised model. Here, it was management that got interested and enrolled in the design model through its visualisation.

5.3.4.4.3 Mobilisation of strategic objectives or individual designs

Thus, on the one hand, designers knew the prerequisite of modularity and equal parts, on the other, it was their own decision whether to cope with this prerequisite or not. They could run the risk of being thrown out of the competition due to not meeting the prerequisites. On the other hand, with their model they may convince the executive committee, the decision makers, to break with the prerequisite of modular and equal parts.

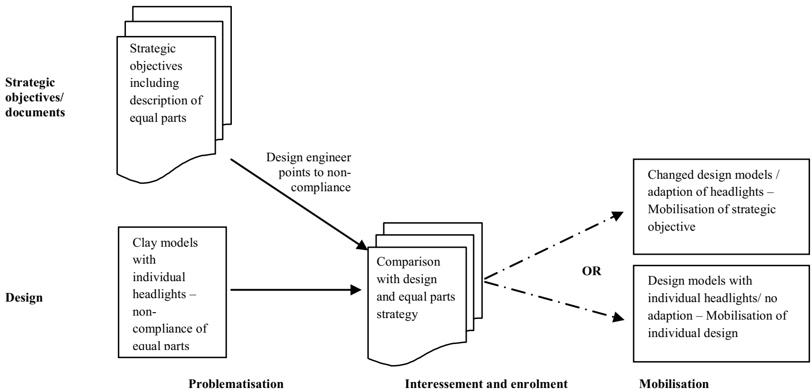

Figure 12 – Translation process of equal parts or individual interpretations

As summarised in Figure 12, strategic objectives are translated into physical visualisations and design models through inscription or non-inscription. When they are incorporated the *strategic objective* of equal parts *mobilises design*. When they are not incorporated *the individual interpretation of the designer mobilises strategic objectives*. In this case the designers adapted the headlights and the *strategic objective* of equal parts *mobilised design*. In a former project, however, the *designers' interpretation* of the headlights *mobilised the individual design as strategic objective*.

5.3.4.5 Brief summary of cases

Although both, aesthetical design and technological development were separated and although, the models designed in aesthetical design deviated from concepts developed in technological development, strategic elements were present in aesthetical design. Either *strategic objectives mobilise aesthetical design* or *aesthetical design mobilises strategic objectives*. Adaptations of designs in between the selection stages, due to the mobilisation of strategic objectives, are illustrated in Table 5.

	Case 1 - Project 1	**Case 2** - Project 2	**Case 3 -** Project 3
Stage	Concept stage – before five clay models were generated	Concept stage – five / three clay models	Concept stage – five / three clay models
Component	Whole car / exterior	Design element	Headlights
Description of case	'he car concept was contested by customers ι design test of the new model showed that the concept of the rear of the car was perceived weak 'he clay models all showed less bulky design due to outcomes of design test	ι design element was designed in all five clay models n two of the five models, the design element was "significantly bigger" than its predecessor ɛstimations during the generation of the design element and the clay models indicated higher cost, compared to its predecessor 'he design element in both models were adjusted during the design stage in clay models because of estimations indicating deviation of the predecessor	ιll five clay models were initially individually designed Ieadlights were carried over /equal part from another derivate due to cost calculations in technological development 'ollowing the selection process down to two models, the designs were changed and adjusted to the equal part
Defined strategic objectives inscribed in documents for design	'roportions of new concept ;egment	'ost of components	Iodularity/Equal part
Strategic objectives in design decisions/ selections	'orms / Aesthetics 'unctions and costs	'orms / Aesthetics 'unctions and costs	'orms / Aesthetics 'unctions and costs
Problematisation	;trategic objectives were problematised through design test	Jesign element was bigger as described in strategic documents Jesigners were confronted with cost deviation	Ieadlights were individually designed although equal parts were described in strategic documents Jesigners were confronted with deviation
Interessement and enrolment	ːey findings from design test enrolled designers	'ost information was important for designers as the cost deviation could become an issue in the design selection	'echnological information was important for designers as deviations could become an issue in the design selection n other cases management could become interested and enrolled through visualisations
Mobilisation	Jesigners adapted their models based on key findings 'he customer, and individual designs were mobilised in the final model	Jesigners adapted their models based on strategic objectives 'he strategic objective of size and of cost was mobilised	ɛither incorporation and mobilisation of strategic objective Jr ndividual interpretation of part and mobilisation of individual design
Emerging strategic objectives in design generation	**'ustomer evaluation** 'orms / Aesthetics ndividualism of designer 'easibility	**'osts** **'redecessor proportions** 'orms / Aesthetics ndividualism of designer 'easibility	**Jeviation or compliance with modularity/equal part/Individualistic designer** 'orms / Aesthetics 'easibility

Table 5 – Overview of 'mini-cases'

5.3.5 Discussion

The controlled processes of technological concept development focused on measurable issues, such as material specifications (weight, cost, manufacturability), and functions of components (cost, customer value through innovation); specific forms and shapes were developed in the aesthetical concept development. Furthermore, sociocultural innovation, such as form-language (e.g. design elements, proportions) and interfaces (e.g. dashboard), were foci of aesthetical design. In the aesthetical design process, the creation of alternative concepts was very much individualistically driven, as there were different alternatives created by single designers. Individualism may here be defined through competition between clay models and the process of interessement and enrolment of other actors into a model. The split of both processes should provide more freedom from the rather target driven technological development process. In the three cases I showed how customer value, cost, proportions, positioning and equal parts, rather than being just defined and set beforehand, were an outcome of the process of design. I discuss how design creates value, how long term practice affects the generation of design and how design is rather loosely coupled with strategic prerequisites rather than being straightjacketed.

5.3.5.1 Creation of value in design

The customer was translated into design through quantitative and qualitative statements, which were gathered in a design test with customers. The documentation of this design test represented an overall customer's point of view towards the shown proportion-model rather than an explicit route, which the designer should take account of in generating her/his proportions. Thereby, customer value was incorporated and created while generating alternative design models, and proportions became strategic interpretations alongside the design process. *Design translated strategic objectives* as through the design test and the modelling of the cars the initial proportions got re-considered. Strategic objectives, such as form language and sociocultural innovations were thus pursued in the process of design and through e.g. competition within design. Innovation thus happens through strategising in creative spaces (e.g. Davila, 2005).

5.3.5.2 Long term practice and the generation of alternatives

Through gaining importance within technological development, cost estimations had an effect on the aesthetical design process. The strategic objective cost was translated into aesthetical design by the generation and selection of design alternatives. In this case, based on prior experience and the anticipation that cost calculations may rationalise the design in decision meetings, designers changed their design element towards the size of the predecessor. Both the reference to the predecessor and the reference towards cost were mobilised within the design process.

The strategic objective of cost reduction entered aesthetical design through the "back door" by being integrated in decisions and shaping the creation process through this. Cost did not enter via the strategic documents or calculations directly in aesthetical design, but indirectly through the anticipation of likely cost issues in the decision process. This anticipation is related to long term practice in which through the accumulation of things (Latour, 1987, p. 220), capabilities unfold (e.g. learning curves, experiences, knowledge generation, structural/processual flexibility). This was shown in Case 2 where one designer pointed towards an experience in which a calculation influenced a decision on a particular component.

This feeds into the assumption that the "crafting of strategy benefits from a detailed understanding of financial implications of strategic choices" (Ahrens and Chapman, 2005).

The work prior to decisions is not only of importance in understanding innovation (see e.g. Christiansen and Varnes, 2007) but is interdependent with the decisions. Jørgensen and Messner (2010) stated for example, that *"if the output of one practice enters another practice, then practitioners of the second practice have an interest in the specification of the first one."* But interdependencies go in both directions and the first practitioners also have an interest in practices of the second. The anticipation of cost calculations, for example, mobilised the strategic objective of cost reduction and displaced it into the process of generating different aesthetical design alternatives.

5.3.5.3 Design and strategic prerequisites - loosely coupled instead of straightjacketed

Prerequisites may be transformed in the process of design. A design engineer provided technological input to ensure that the design model would be feasible for producing a car. Furthermore, the design engineer communicated cost and prerequisites such as equal parts or modularity. They created consciousness of strategic objectives in design through the communication of strategic documents. Provided by design engineers, this interactive form of control (Simons, 1995) loosely coupled aesthetical design with initially set strategic prerequisites and technological development. Although being set, modular components and equal parts, for example, may not be incorporated within aesthetical design as they represent "major constraints", as one designer stated.

Designers themselves determined whether they would accept these constraints or not. They may either be convinced that their design language overrules the technical language (e.g. form versus function/modularity), or they may be precautious and design their models in alignment with the set prerequisites. Strategic objectives in this course are encountered through the competition of individual designers, which may either succeed in enrolling the decision makers in their "*non-aligned-to-prerequisite* design", or succeed in enrolling in their "*aligned-to-prerequisite* design." Here, strategic objective did not straightjacket designers; instead designers were loosely coupled to strategic prerequisites.

In the case of the "*non-aligned-to-prerequisite* design", the visualisation of the design (design model) could enrol management and create a design language as new objective which was inscribed in the design model. In the case of the "*aligned-to-prerequisite* design", the strategic objective was inscribed in the design model and was translated through enrolling the designers. Here, designers either shaped strategic objectives or vice versa. It is thus not only decisions that determine the incorporation of strategic objectives. The generation of alternatives as a "creative endeavour" may be impacted by management practices (Verganti, 1999; Amabile, 1997), such as choosing from different alternatives. As Davila described it, "an organisation that wants to follow an aggressive innovation strategy needs to create the appropriate setting to generate variation, put in place the context to select among different alternatives" (Davila, 2005, p. 52-53).

Irrespective of the control mechanism the designers behave differently. Although the control mechanisms stayed the same, the looseness of coupling differed. Either they changed set strategic objectives ("*non-aligned-to-prerequisite* design") or they changed (their) artefacts ("*aligned-to-prerequisite* design"). The context that is created through competition and the generation of alternatives provides on the one hand, a setting for “individual action”. On the other, strategic objectives are acting in this context as they guide the action of designers. Jørgensen and Messner (2010) argued that in product development networks accounting information gives a “general understanding” that guides the development process and its actors by “reminding them of the ultimate importance of financial numbers”. Similarly, in the generation of aesthetical designs, initial strategic objectives loosely coupled the designers to the control mechanisms by reminding them of the importance of customers, technological prerequisites or cost.

5.3.6 Conclusion

Strategising in aesthetical concept design took place through competition and through the positioning of the project; strategy was not performed prior to organisational action, it was part of it. Defined strategic objectives were actors in design, which, however, had to be inscribed and carried by the process of design and in the design models. Through competition, individual characteristics became comparable and by discussing and deciding on the clay models, design strategy was created. Instead of just being an input for design, strategy was as well an outcome of that process, or more precisely, strategy was the process. Design is thus a process of strategising in which various elements, as strategic objectives, are translated, such as customers (market strategies/focus groups), modularity strategies, cost reduction strategies, or design language. These were all far from being explicit targets or measurements in the process of aesthetical design but were pursued throughout the design stages making it a strategising process. The mobilisation of strategic objectives is thus not only a downstream activity but also an upstream activity in which objectives are translated through the anticipation of customer needs, costs, or technological requirements, which are also relevant in decisions and control processes of further product development stages.

Management accountants may pursue a rational calculative approach to the management of cost and value; content strategists argue for the formulation of strategic objectives that foster competitive advantage (Chenhall, 2005, p. 13); however, in aesthetical design, competition may be the means for managing innovation and creating customer value. Actors, such as the customer were not present during the formulation of strategic objectives in control systems (e.g. Ahrens and Chapman, 2005) but through individual interpretations of designers and other actors. Cost became present through the focus on technological innovation. Value was an individual interpretation of customers, which lead to sociocultural and functional innovation.

Thus, creativity may, not only, be enhanced through stable goals that people can draw on (Amabile et al. 1996). Competition and the generation of alternatives provide a context for “individual action”. On the other hand, strategic objectives are acting in this context; they are guiding then the action of designers by reminding them of the importance of customers, technological prerequisites or cost. Routines, unintended, and intended practices are thus not only shaped by “social” actors (e.g. Whittington, 2003, 2006; Jarzabkowski et al., 2007), but by actors, such as customer surveys, functional prerequisites, or calculations. Strategic objectives can only persist as long as they are carried by actors or carry actors. Hence, strategising, rather than being a social process, is a process of mobilisation of and through different actors.

Future research and limitations

As in Case 2, future studies could focus more on the interaction of design and calculations. This *“more focused and selective anticipation may provide outstanding results.”* (Verganti, 1999). Open questions are where, when and how calculations are undertaken to enable creativity and create space for the potential of successful creativity. Furthermore, the different mechanisms in design and technological development could be further analysed; here, focus could be set on their interrelations and interactions. The mechanism of competition as a means for managing innovation and creating customer value may need further analysis. This would be especially interesting in the development stage when both become integrated and when compromises have to be reached.

This study has some limitations. First, the study is limited to one case company. Future studies could provide more insight into how strategic objectives are mobilised and how they shape and are shaped by aesthetical design. Secondly, the time available for the study was limited to two years, which limits the access to more cases. However, internal documents could extend the insights into the case company. Thirdly, the author was employed by the case company, which may have led to bias (see research methods).

5.4 Paper 4 - Controlling, separating and converging design and product development

Aesthetical design and technological innovation are highly interrelated. Designs affect the technologies, cost and functions implemented in the product and technological boundaries affect design opportunities. Therefore, it makes good sense to integrate and coordinate design and technological innovation. Design and technological innovation, however, fundamentally differ in their commensurability. Whereas design is related to "sociocultural" innovation and is largely incommensurable, technological innovation is based on technological knowledge, which is largely commensurable and deals with existing and developed knowledge. Tight integration and coordination of design and technological innovation may be problematic as the managerial tools and processes of technological innovation may destroy design's ability to generate and interpret sociocultural meaning. Controlling and managing design and technological innovation is therefore a dilemma; they should be kept apart yet they need to be integrated. In this paper we investigate how this dilemma is managed and controlled.

The paper presents an analysis of a mid-sized European car manufacturer renowned for its design and technological innovation. We analyze how design is separated from technological innovation in early design processes that focus on the generation of variability and selection through competition. Once a design has been selected, design and technological innovation converge in a phase controlled by cost calculations and compromises. In conjunction with the generally separated processes, design engineers worked as boundary breakers transmitting information *between design and technological development. These distinctions, mechanisms and processes constitute the papers' main contribution to the literature on control of innovation and design.*

5.4.1 Introduction

> *" Dear Designer, you are a small one, behind you there are 500 engineers that have to bring the car on the street, to check for homologation, for cost, that it lasts 15 years and so on...they are way more and you want to tell them to avoid the 2mm increase in the airbag rail? That does not work..."* [Design Engineer]

Controlling the dual processes of design and technological innovation is a big challenge for industrial organisations, because the uncertainty and measurability of design and technological development differ. Designers try to develop new sociocultural meaning while they, as the opening quote states, are pitted against the 500 engineers that calculate value, cost and technical specifications. This problem has multiple effects on the value and cost of products as well as on how design and technological innovation can be controlled.

The problem of the relationship between control of design, and control of technological innovation has two aspects, First, design and technological innovation may differ in their "measurability" or "commensurability" and therefore need separation. The development of design (forms) may be described as sociocultural innovation, defined by ergonomics, surfaces, and materials, whereas the development of functions may be described as technological innovation (Dell'Era and Verganti, 2009). The former is a highly uncertain, creative endeavor with a focus on the emergence of aesthetics (Verganti, 1999), whereas the latter is less uncertain and described through coordination and control mechanisms (e.g. stage-gate processes, target costing, development teams and critical success factors; e.g. Cooper, 1990; Davila and Wouters, 2004;).

Secondly, because design has a huge impact on the "manufacturability" (Bramall, McKay, Rogers, Chapman, Cheung, and Maropoulus, 2003), cost and functions of the product, design and technological innovation need to be integrated to coordinate the different elements and phases of the design and innovation process. The issue is that once designs have been developed the markets in which the company sources its components, the production technology etc. have also been determined or at least affected. This is also the key message from the target costing literature: innovation should be controlled in the early phases so that cost of up to 80% of total product cost can be controlled (Ansari, Bell and Okano, 2007; Carlsson-Wall, Kraus and Lind 2009). Thus, we would also expect that design and technological innovation is integrated in order to coordinate the different processes so that cost and value is optimised.

A core dilemma for the control of product development is therefore how design and technological innovation may be both separated (controlled) and integrated (coordinated). Given the difference in commensurability the literature would point to two solutions. The principal-agent based accounting and control literature would conceptualise the problem of control of design and innovation as a multitask problem and accordingly tasks should be separated in order to supply adequate incentives for low and high uncertainty projects respectively and minimise agency cost (Holmstrom, 1989; Holmstrom and Milgrom, 1994). This perspective, however, pays less attention to the integration and coordination problem.

The sociologically inspired accounting theory would suggest that the way in which formal control systems are used should differ. Ahrens and Chapman (2004) e.g. suggest that an enabling use of formal control mechanisms may "simultaneously support the objectives of efficiency and flexibility" (Ahrens and Chapman, 2004,

p. 298). Similarly Jørgensen and Messner (2009) argue that a strong commitment to an enabling form of control enables the firm to "balance efficiency and flexibility". While these solutions would allow the use of one formal control system to control design and innovation processes they seem to neglect the opportunity of implementing control systems which are designed, fitted and adequate to the relevant level of commensurability, i.e. one type of control for design processes and a different control system for technological innovation. It thus seems to focus on the coordination problem while paying less attention to the control problem.

In this paper we seek to investigate how both the control and coordination problem may be handled. Specifically, we want to look into the design and innovation processes through which the potentially divergent perspectives and demands of technology, aesthetics, cost and other boundaries (such as laws) are managed and calculated in complex product development networks, and how convergence is created through these processes. Our research question is therefore: *How is design and technological innovation controlled, when both separation and integration of design and product development is demanded?*

We conducted a longitudinal study over two years in which we attended meetings, gathered relevant company material and conducted interviews. Theoretically we focused on both, first, on the general mechanisms of controlling design and technological innovation processes in the conceptual stage, and second on three cases that we followed throughout the conceptual stage. The paper thus focuses both on structural detailing of the control mechanisms, and secondly, on how they are used in, affect and coordinate processes. Here, we integrate the literature of mechanism design (Hurwicz, 1973) and the approach from Callon (1991) of techno-economic networks. The perspective therefore employs both structural analysis (distal) and process focused (proximal) theorising, recognising "that the distal and proximal are both complementary yet different ways of looking at human structures" (Cooper and Law, 1995, p 238). We suggest that both distal and proximal perspectives are necessary if we are to understand the problem of control of design and technological innovation.

This paper develops the following arguments and contributions. First, we contribute to the literature of control of innovation in design and product development, as we provide a comprehensive overview of the structural mechanisms through which design and technological innovation may be controlled. Secondly, we analyse where, when and how different control mechanisms converge and coordinate the network towards one common understanding and blueprint of the product.

This is a contribution to the literature because, even though the general literature on control of innovation has achieved much depth and breadth in the understanding of when and how innovation should be controlled, design issues have largely been ignored in this literature (see e.g. Banker, Huang and Natarajan, 2011; Davila,2003; Davila and Wouters, 2004; Davila and Forster 2005; 2007; Davila, Forster and Oyon, 2009; Holmstrom, 1989; Jørgensen and Messner, 2009, 2010; Mouritsen, Hansen, and Hansen et al. 2009; Ravasi and Stigliani, 2012; Wouters and Roijmans, 2011; Zenger and . Lazzarini. 2004). Jørgensen and Messner (2010) discuss design, but do so based on a study dealing with what we could call technological innovation. This paper is thus the first within the literature on control of innovation which explicitly deals with the control of design.
Furthermore, the connection between creative design processes and product development has been studied in various works of Verganti (Dell'Era and Verganti, 2009; Verganti, 1999, 2006, 2008). Ravasi and Stigliani (2012) have

discussed here the contributions of literature on the fields of design activities, design choices, and design results; however, there are no papers analysing control of design and technological innovation together as one problem; i.e. control of the entire processes of designing and developing (consumer products)[62].

We find that design phases are separated from technological innovation phases and that they primarily are controlled through output control focused on aesthetic criteria. Technological innovation, on the other hand, is mainly controlled via targets in decentralised calculative processes. The integration between the "aesthetic" and the "calculative" process occurs through design engineers transmitting concerns between the separated phases, and through decision making in the decentralised, calculative processes.

The paper is structured as follows. First, we review the literature on control of design and product development and develop hypotheses based on the literature Secondly, we develop our research perspective. Thirdly, we provide an overview of our research methods. Fourthly, we analyse Automotor Company, focusing on the general processes and the three cases. Fifthly, we discuss and conclude our paper.

5.4.2 Theoretical Discussion - Separation, integration and control of design and technological innovation

Design and technological innovation are two fundamentally different, yet interdependent processes. Whereas design has to do with "product languages and

[62] Armstrong (2002) discusses aesthetic design in relation to management control, arguing that management accounting may be used as a modeling technique. However, the study only provides conceptual insights on the modeling function of accounting of expertise and does not give deeper insights in to the particular mechanisms of control in creative design. Furthermore, in a literature review, Ravasi and Stigliani (2012) come to the conclusion that "we still know little about the practices, structures, tools and resources that underlie innovation in product form and meanings." (p. 19).

meaning", technological innovation concerns "functionalities and technologies" (Dell'Era and Verganti, 2009, p. 1). Therefore, in order to investigate how design and technological innovation is controlled we develop the two different elements of innovation followed by a discussion of their interrelationship.

Design is related to meaning and giving form to things. Following Verganti (2008), we use Krippendorff's definition: "the etymology of design goes back to the Latin *de* + *signare* and means making something, distinguishing it by a sign, giving it significance, designating its relation to other things, owners, users or gods. Based on this original meaning, one could say: design is making sense (of things)" (Krippendorff, 1989, p 440). This definition underscores design as a process of interpreting sociocultural trends and may be approached from two distinct and basic approaches to the process of giving meaning to things (Love, 2000). First, there is the information processing approach, which focuses on how information (about e.g. users) is codified, selected and managed, and how designers can use this information to design. The approach is rationalistic and designers are seen as a "machine capable of rationally selecting and connecting elemental information to satisfy a set of constraints". The other approach views design as a creative process (Amabile, 1997). The design process is seen "as intuitive or mysterious and is the most dominant aspect of the process" (Love, 2000, p. 311). Within such a perspective, selection of design alternatives is based on feelings and it is not "possible to reduce to a set of algorithmic steps" (Love, 2000, p. 311)[63]. Similarly, Verganti argues that "the vision comes first. Figures are essential, but they come afterwards, to support its feasibility" (Verganti, 2009, p. 91). The two approaches differ in their relation to management where the information process-perspective gives primacy to management of the design

[63] To this approach a relational perspective focusing on how firms may develop their design competencies through the building of relation assets and collaboration with "key interpreters" may be added (Verganti, 2009).

processes, whereas the creativity approach rather focuses on how design is unmanageable and emotional, especially in the early stages of the innovation process. In the information processing approach, design fits neatly with technological innovation, whereas the creativity approach points to contradictions between design and technological development. Recent literature points to the latter as the more likely relationship between design and technological innovation (Hatchuel and Weil 2009; Verganti, 2009), and this is also the dominant belief in the case to be studied.

Technological innovation focuses on "technology" push and how new technologies become embedded in products. Technological innovation is generally conceptualised as related to strong notions of scientific knowledge. The focus is not just on the generation of ideas, but in managing and fostering knowledge translation in product development processes (Ayers et al., 2001). Precise directions are managed through means such as stage-gate processes and engineering knowledge (e.g. Cooper, 1991). So, where design is related to unique concepts, technological innovation is based on more explicit engineering knowledge. These differences are apparent in Hatchuel and Weil´s framework on C-K design theory (2009): where technologies belong to the "knowledge space" containing "all established (true) propositions", and design to the "concept space" and is "undecidable", i.e. it cannot be proven in the knowledge space. Therefore we would expect that:

Hypothesis 1. *Design and technological innovation differ in processes and their perceived commensurability.*

Because design and technological innovation differ in relation to their commensurability, the ways that design and technological innovation are controlled should also differ (Holmstrom, 1989; Holmstrom and Milgrom, 1991). Holmstrom argues that uncertain, innovative activities should be controlled through more "close handed" subjective monitoring (1989). Ouchi (1977) argues that, dependent on the ability to measure outputs and knowledge of transformation processes, different types of control mechanism are and should be applied. In the case of technological innovation (particularly incremental technological innovation and development, and when compared with design) we have good knowledge of transformation processes, and our ability to measure outputs is likewise relatively high. According to Ouchi this is a good situation, giving the control systems designer freedom to choose either output or behavioural controls. In relation to design, our ability to measure outputs (i.e. customer value) before the product is put on the market is limited. But, since design involves forms with aesthetical expression, outputs from design may be evaluated. Design also involves more creative processes in which the individuality and knowledge of the designer is paramount, hence our knowledge of the transformation processes is limited; according to Ouchi, this should make clan control or a non-cost based outcome measure the chosen mechanisms. These deliberations lead us to expect that:

Hypothesis 2. *Design and technological innovation are controlled via different control mechanisms.*

A key problem is how the technical/knowledge based space and the concept/design space is related, especially given a creativity perspective to design. The (perceived) differences in their nature render the integration of design and innovation problematic; if design is made with a technological focus in mind, the design solutions developed will be less innovative in relation to their sociocultural innovation element. Verganti (2009) argues, "Firms engaged in radical innovation of meanings must carefully consider another central concern: they need to avoid being diverted by constraints emerging down-stream in development that can jeopardize the identity of the vision. Once they have identified the proper new radical meaning and language, they should not compromise its integral nature and personality" (p. 186). We would therefore expect that:

Hypothesis 3. *Design is separated from technological innovation.*

Adler and Chen (2011) argue that in large-scale collaborative creativity "informal coordination must be supplemented by formal management control systems because the number of contributors is too large and their creative contributions are too differentiated and too closely interdependent". Of interest in this paper is that when design meets technology, the number of participants in the process is increased tremendously. A car that did not have to drive nor have interior, for example, could be designed by a single creative or information processing designer. A car aimed at the mass market, however, needs to incorporate multiple technologies, be able to be produced and sourced efficiently, and must have adequate quality, it must also comply with regulations and costs must be curtailed. Furthermore, since design influences all these factors, there is a need for coordinating design with technological innovation and "acknowledged best practices in product development sometimes push in" this direction (Verganti, 2009, p. 186). Such best practice is e.g. design for manufacturability. Therefore we would also expect that:

Hypothesis 4. *Design is integrated with technological innovation.*

Controlling and managing design and technological innovation is thus problematic as they differ in nature, have divergent demands and at the same time need to be integrated and separated.

5.4.3 Theoretical approach

There is no literature dealing with the element and factors, which may constitute control of design processes. We therefore need to develop our understanding of control of design from basic mechanisms. In order to do so we have chosen to focus on mechanism design. A focus on mechanism design means that rather than treating "the economic system as one of the givens. The term 'design' in the title is meant to stress that the structure of the economic system is to be regarded as unknown" (Hurwicz, 1973). This focus is helpful in our approach, given the limitations of previous research. We are not focusing on optimal mechanisms and on equilibrium criteria but on the basic concepts developed by Hurwicz (1973) as a means of comparing different mechanisms (ideal types) with each other.

The focus in the mechanism design approach is on the mechanisms that guide agents "in decisions that determine the flow of resources" (Hurwicz, 1973, p. 16). Key mechanisms here are competition and marginal cost pricing (Hurwicz, 1973, p 15). The key sub elements constituting the mechanism are optimality criterion, environment, rules for transmitting messages, language and outcome rules. An *"optimality criterion"* is the criteria that should guide agents in their actions. The optimality criterion should be defined independently of the mechanism, so that more mechanisms may be compared. Another variable is the environment of the mechanism which is "the set of circumstances that cannot be changed either by the designer of the mechanism or by the agents (participants)", examples are, technology, individual endowments and preferences. Preferences and technology in innovation processes are, however, not exogenous, as the design processes focus on bestowing meaning onto artifacts (e.g. Verganti, 2009) and technological innovation and the incorporation of (new) technologies into products, so in our study preferences and technology are endogenous to the resource allocation process.

In the processes of making decisions, participants exchange messages and are given rules as to how messages may be transmitted. The totality of messages permissible under a given mechanism constitutes its language. Messages may be "proposals of actions, bids, offers, plans of resource flow for the whole economy, or they may contain information about the environment" (Hurwicz, 1973, p. 17). Finally, an outcomes rule that "specifies what actions are taken, given the course of the dialogue" (Hurwicz, 1973, p. 17) needs to be specified. These elements will constitute the parameters within which we investigate the nature of the mechanisms controlling design and technological innovation.

However, given our purpose of studying processes in a complex, real-life setting rather than calculating the optimal control mechanism for design and technological innovation, we needed additional methodological and conceptual apparatus to inform our study. Here, Callon's techno-economic networks offers an interesting approach to conceptualising design and technological innovation. With its relational character and its focus on diversity and convergence, Callon's approach helps to understand how the mechanisms interact and how they act upon and mediate relations and decisions.

The approach consists of the following elements. A techno-economic network denotes a "coordinated set of heterogeneous actors which interact more or less successfully to develop, produce, distribute and diffuse methods for generating goods and services" (Callon, 1991, p. 133). Convergence is defined as the extent to which "the processes of translation and its circulation of intermediaries lead to agreement". A convergent network is a network where intermediaries (here control mechanisms and accounting calculations) align and coordinate the techno-economic network. Alignment means that a shared space of equivalence and commensuration (i.e. enumeration) has been created. Coordination has to do with the extent to which rules for interaction guide interaction, and about who should put intermediaries into circulation (Callon, 1991).

The approach developed in this paper to study control of design and technological innovation is therefore made up of the following components:

Concepts for describing the mechanism:
What is the optimality criterion, i.e. what is the basis upon which decisions are made?
How is the decision made, i.e. how is uncertainty reduced?
Who are the participants?
What is the language by which they interrelate and
What are the rules for transmitting messages?

Concepts and method for analysing how the mechanisms affect development in the networks:
What are the heterogeneous structures and actors?
How do mechanisms (intermediaries) align and coordinate affect decisions and processes?
How is the network converged?

We use the last three questions to guide our analysis of developments in the three embedded cases. This analysis feeds into our analysis of the mechanisms for controlling design and technological innovation. This analysis is structured around the first four questions.

5.4.4 Research Methods

Given our research question, we focused our data collection and analysis on the structure and the processes of controlling, selecting and converging design and product development; thus, employing both distal and proximal analysis (Cooper and Law, 1995). Therefore, we focused on the structure and processes of design and product development, the control mechanism and decision processes within both, and on how they converge. Furthermore, we focused on three embedded cases in which design and product development interacted and converged. This approach was chosen in order to reduce complexity and "zoom" in on the specific processes of controlling and converging design and technological development (Latour, 2005).

We have selected three embedded cases, focusing on getting variety in the types of cases, covering various parts of design and development of cars, and in relative importance of design vs. other criteria such as cost. The first case concerns the front design of a specific car, its selection process and its issues with meeting product development criteria. The second case focuses on the selection of a dashboard design and its further development in one particular car project and the third case focus on door panels and their further adjustment to product development criteria. The first case was selected because, on the one hand, the car is a design icon and, on the other hand, there is huge cost pressure on the car model. We therefore expected that both design and technological innovation would be important. The second case was selected because dashboards had become a main concern in design and within the organization. The third case was chosen because, like the dashboard, the door panels had gained importance, but had however, often been subject to cost reduction measures. This selection of cases enables us to get a more complete picture of the varying importance of design and technological innovation/cost. The cases were also chosen on the basis of availability. It was especially difficult to get access to designers as designers are separated from development in Automotor Company and information is restricted and often subject to confidentiality.

Within each case, especially in relation to the development phase, we have focused on specific episodes where controversies existed between design and technological/calculative criteria. This focus is based on the theoretical framework and is directly relevant to the core dilemma of how separation and integration is impacted by control mechanisms and organisational processes. The overall process was highly iterative (Eisenhardt, 1989) in order to converge research problems, case findings and theoretical discussions.

5.4.4.1 Data collection methods and analysis

The data collection and analysis proceeded in the following manner. First, we collected internal documents (such as strategy papers, business cases, presentations, minutes and memos) and attended meetings, and conducted participant observation (design presentations, decision circles, cross functional teams) over a period of two years. Secondly, we conducted 24[64] interviews (Appendix 8), of which 22 were recorded and transcribed. The other two

[64] Four of the 24 interviews were conducted for another study. However, as they could feed into the empirical analysis of this paper we could use them for coding.

interviews could not be transcribed, due to confidentiality constraints, but notes were carefully taken. As the first author was employed at Automotor Company[65], broad access and insights to relevant material was granted. The first author conducted eight of the 24 interviews; both authors conducted the other 16 interviews. All interviews were coded. Our coding scheme reflected the overall mechanisms of design and product development, their underlying optimality criteria, language, decision making and rules for transmitting information (Hurwicz, 1973). Furthermore, we coded the interviews for the cases, and for the general product development processes and structures in Automotor Company. In addition to the interviews specifically made for this article, we have conducted a total of 41 interviews in Automotor Company. These other interviews have served as background knowledge and to sharpen our focus for the 22 interviews and gathering of documents.

In order to increase validity and reliability of the data analysis we triangulated the interviews with company material and attended meetings. In general, statements in interviews were congruent, but in a few cases views among different actors differed. A key example is the extent to which interviewees were of the opinion that cost should be managed in design while others argued against this. This disagreement is directly related to our core dilemma and is analysed in depth throughout the empirical analysis.

[65] The employment of the first author at the case company entailed advantages and disadvantages for the research process. On the positive side is that we gained access to a setting, which is probably inaccessible to any outsider/researcher from academia. On the negative side is the potential bias and low reliability of the data collection and analysis (Hermanowicz, 2002). We have worked with this limitation in the following ways. Firstly, the second author also conducted interviews within the case firm, and secondly the second author also coded the material and reviewed all analyses.

5.4.5 Empirical Findings

5.4.5.1 The design and product development process in Automotor Company

Product development (technological innovation) and design are two separated areas in Automotor Company. In the early conceptual stage, product development is concerned with the technological development of the concept, whereas design is concerned with the aesthetical expression of the car concerning form, surfaces and ergonomic parts. Product development is heavily characterised by the mediation of performance criteria in the form of targets and estimations, guidelines and prerequisites. Teams with representatives from finance, purchasing, manufacturing, research and development and cost engineering develop concepts and alternatives based on these criteria. Teams are coordinated by a project manager who forms a decision circle in which the developed concepts are discussed and decided upon through the use of target costing (See appendix 8 for interviews and description of various actors). Parallel to that process, the interior and exterior designs of the car are selected. We specify the product development process and the design process a bit more in the coming sections and present further details in the case section.

Product development in Automotor Company is divided into two characteristic tracks and phases. A *selection and competition* phase and an *adjustment and development* phase. The selection and competition phase mainly focuses on the selection of the final design. In design, approximately 20 designers, generating sketches, initiate a project. These sketches are then selected by the head of design for the creation of a life scale, clay model, five for the exterior and four for the interior[66]. In the second selection, the five exterior clays and the four interior clays

[66] The exact number of generated clay models is confidential but is close to the ones specified in this paper.

are reduced to two through selection, and in the final selection stage, the final interior and exterior model is selected. The board of directors performs the selection of the clay models. During the selection process, the clay models become more and more developed and refined; either through individual ideas of the designers or through technological or financial criteria. These criteria include costs, weight, crash-ratings, space/storage, aerodynamics or driving characteristics. Criteria are intermediated through design engineers who connect product development and design, which will be discussed in cases and in the discussion.

The adjustment and development phase is mainly described through the adjustment of the chosen design. In this stage, smaller modifications are made to the forms and surfaces. This stage is managed through the target costing system and focuses on reaching specified criteria and targets. Thus, technological innovation and development is much more focused on goals and is as such a more managed process. Product development may influence the final design and lead to smaller adjustments in form or material. The design engineers, again, accompany these issues.

5.4.5.2 The dilemma of design and product development

Designers are given design language to frame their designs. Words such as “lightness”, “dynamic” or “aggressive” are used for design characteristics for aspects such as shapes, materials or textures. A dashboard for example should represent more “lightness” in the successor as in the predecessor, resulting in thinner dashboard layers and thinner decoy elements. “Roominess”, for example, was achieved through creating shadows and light spots in the dashboard. “Presence” was furthermore used in a discussion about the rear of specific cars leading to bigger perceived boot and tail lights. These language characteristics are translated into cars which then speak a specific design language. These give broad orientations for designers.

Despite these broad orientations, a key issue in design is to generate variety and individuality and to choose among different designs. Different models in design reflect different interpretations of the designers. The designs are completely different from each other. Furthermore, the designers have different interpretations:

> *"There were four interior designers with their ideas, one in the States, two in Asia ... And every design was nearly completely different [...] so, I think they try to give their own spirit for every bit."* [Manager Controlling]

Designers come from multiple backgrounds and even though a large number of the designers are located at the innovation center, designers come from all over the world. Furthermore, designers should be visionary and create designs that will last for decades:

> *"Design is specially trained for that, to make a forecast for the next ten years. Who can say that of themselves? [...]Therefore we have designers who do exactly this. What will the customer buy in five or ten years, not, what he wants today. Today we want white cars. We probably won't need them in ten years anymore. To predict something like this is exactly the task, and this is very exciting."* [Developer Dashboard]

Designs thus have to envisage future consumer preferences, which makes design a very uncertain process. Design is started with strategic documents of a car with a specific language. Design also wants to create customer taste, rather than merely address it. For instance, although customer reports showed that the customer did not favor certain elements or concepts, Automotor Company held on to them, arguing for not trusting the customer and for creating the customers' mind. This often results in controversial designs that split customers into two groups:

> *"Yes. Our models are separating people; on the one hand they say 'cool' on the other hand 'not cool'. For example a special model, there are only two parts of groups, one group says, 'I like this car', the other one, 'I hate this car', and if you compare, they are polarised."* [Manager Controlling]

Thus, uncertainty lies not in the ability to predict what the customer wants but in whether the market could be created with the design. Simply put, designs with their uncertainty were pushed onto the market rather than being triggered by the market. This makes it impossible to objectively evaluate the value of designs, as consumer value and preferences emerge in the future when meeting the specific design.

This approach leads Automotor Company to separate design from technological innovation. This because, firstly, product development should be more concerned with technical issues, rather than forms, and should take care that "the car has to run" and cost targets are reached. Thus, the product development process focuses on measures and calculable functions rather than on forms. Secondly and consequently, design should not be concerned with technological or financial constraints and should rather concentrate on forms and meanings, and design "into the blue sky" as one design engineer said.

The character of the designer is described as a rather individualistic type whose personal idea should be protected from being sidetracked by constraints. Furthermore, costs were seen as a specific constraint that should not sidetrack the designer from her/his "individual point of view":

> *"That's what I mean, Design shouldn't think about costs, never in the entire design floor.[...] because cost is not everything. If you save money in the wrong spot, maybe you can't sell the car anymore successfully. [...] I think he shouldn't care about costs, I think that is right, his only task should be creating design and if he took care of costs that would be uninteresting."* [Cost Engineer]

This statement came just after the cost engineer had described a perfect designer as someone who also focuses on cost issues. It seems that the cost issue is the most divergence-driving issue between design and product development. Design affected product costs, which in turn are the focus of the product development process. On the one hand, cost issues are hard to address and "establish" in design and cause problems in realising target costs, on the other hand, design is one key success factor for Automotor Company and cost may "destroy" the uniqueness of designs. This struggle was described as "fights" between the different worlds by one designer. However, this was also described as daily business. From a project perspective, two interviewees described:

> *"Designers want to do whatever they want to do, no matter the costs and we are turning every plastic part 10 times to save cents, they decide, 'We don't like this', it costs millions."* [Cost Engineer]

"Of course, money people are really focusing on money, and the design people are really focused on design. That's their personal motivation; it's natural that these different interests are focused in a different way. Like I said, finally, at the end of the day, we need to make products that sell well, so we can make a lot of money." [Designer]

Thus, designers were pitted against the "money people", i.e. engineers and controllers, whilst appreciating the interdependence between design and technological innovation.

In summary, design and product development have their specific and divergent characteristics and in Automotor it was a general view that they should be kept separated. This is briefly and conceptually displayed in Figure 13.

Design	Selection of one model for further development	Maintain design
Technological innovation	Definition of criteria in relation to cost and other	Adjust and develop functions in relation to cost and other
	Selection and competition stage	**Adjustment and development stage**

Figure 13 – Conceptual display of the concept stage

The figure illustrates the different processes in design and product development and their focus in the two stages; the selection and competition stage, and the adjustment and development stage. The different quadrants are in conflict as design and technological selection criteria differ. We expand this conceptual illustration through our cases and in our discussion.

In the selection and competition stage, heterogeneity among the different design models causes the most uncertainty about the concept. In the adjustment and development stage, different criteria and the adjustment of the selected design model need to be converged towards one final project.

Having discussed the different spaces of design and product development, and the two different stages through which the conceptual stage may be characterised, we now focus on three cases in which the mechanisms and the convergence are described in specific examples. We structure the analysis of the embedded cases through this matrix and we seek to answer the questions posed in the theoretical section: What are the heterogeneous structures and actors? How do mechanisms (intermediaries) align and coordinate decisions and processes? How is the network converged?

5.4.6 Cases

5.4.6.1 Case 1 – The front of a design model

The front of the car is one of the most contested and constrained parts of this car model, we therefore focus on this part of the design in the following. It was perceived to be "incredible to bring design into the front of a car", as one design engineer stated. This was due to crash-ratings, laws, engine space, overhang, lights and due to the front being the most exposed and sensitive exterior area.

The competition starts with 20 sketches[67]. In this process, only the form and the aesthetical understanding of the designer are paramount in the project:

> *"In principal, we are drawing without any strategy paper – very naive and blue eyed – doesn't matter what the prerequisites are, just do it. Because reducing is easier than adding."* [Designer of the chosen design]

The sketch was thus the pure interpretation and understanding of the designer of the model that had to be built. Furthermore, they knew about the constraints in general, but not in particular, because they knew they had to reduce the substance of their models and their ambitions towards the final model. Competition in the sketch stage is thus focused on pure aesthetics and design coherence.

From the twenty sketches, four models were selected to be modeled in clay. The head of the design department selected these. This form of competition was, on the one hand, a motivation for designers to win, on the other hand, that they run the risk of never being selected for modeling or clay modeling:

> *"I work on my own, I have designed the coolest concept, and then somebody comes and says, 'let's make a model out of it, I like it' and then somebody comes and says, 'let's produce the car one million times and sell it worldwide' That is totally absurd. Of course there is a lot of calculation you have to do, but in the end it is the model and the motivation to bring it on the street and to win the design competitions, that's the most awesome thing. On the other hand, if this is not working out, that is hard and then you think you are a loser and this is de-motivating."* [Designer]

[67] The specific design language for this car was confidential and inaccessible for authors.

To see the materialisation of their vision is key motivation for designers. Within the process of becoming selected from the sketches and subsequently from the clay models, criteria, such as modularity and other technical and monetary constraints became more and more apparent. They developed over time in product development, which was working on these criteria:

> *"With development, the point is that this regulation is always moving, the development department cannot say in the beginning of the project, "These are the main regulations," they are also working on it, they are getting more details, they are making tests."* [Design Engineer]

Criteria were present in the clay stages already; although somewhat fuzzily and as they became clearer they were addressed in the clay stages. The designer thus had to follow their design idea through the selection process; however, they should start to compromise on the criteria given to them:

> *"We do not include them [the criteria] in our sketches, no, never, but this is getting more and more in the virtual [and clay] stages. Every week we are looking on that. The main issues we had with our models until the end were there already in the beginning, crash ratings, and all these restrictions were there fuzzy from the beginning."* [Designer]

That these criteria were addressed did not necessarily mean that they were already incorporated into the clay models in the selection process, as after the design selection lots of criteria still had to be addressed and compromised. We touch on this process with an example in the next section.

5.4.6.1.1 Constraints and compromises in the front

In the beginning of the clay models stage, none of the four designers seemed to incorporate the criteria exactly as addressed by technological development. The design engineers were, as discussed, responsible for mediating these criteria into the clay design models. They discussed which criteria they did not meet with each designer. It was then up to the designer to decide whether his/her design should stay as it was and not meet all regulations and to see whether compromises were possible in the future, or if s/he would adapt his/her design towards the demanded criteria:

> *"And that's the point, that's the way the cookie crumbles, as they say, and the point is that every designer has to make it much interesting and much new and much emotional to design, automatically, destroying our regulations, and we have to bring them to the cars because then you don't get the laws, for example, you only have [75% crash rating], and we can do, if there's an interpretation and we have the selection, then we have to bring one page on the wall with kind of traffic lights where we say, 'Okay, this car does not meet the regulations, you have to know it [...], you have to know, we don't match it'. And that is the point [...] two of the four will be taken out, so, in future we just can say what your model can and what your model can not be, and decide, 'Well, this point is so important for my design, I want to keep it'"* [Design Engineer]

Aesthetical design and product development criteria were contradicting each other. In our case, as the four models were reduced to two through selection, the meeting of the demanded criteria was not a means for selecting these models. Traffic lights were presented to the management board in the selection process, showing which criteria the specific design models had not met. In the selection process itself these were of minor interest. The criteria were then passed to the two winning designers with the message that they should meet them in the next round. In our case, neither of the two selected models met the 100% crash rating criteria[68], which was also relevant to keep the market price of Automotor Company and thus the business case. The board wanted the emotions of these models but they had to "bring it in with 100% crash rating" as one design engineer stated:

> *"Finally the members of the board decide who to select and if they think this machine looks really super cool and they want it, then somebody says, 'Yes, but we're not too happy with the papers at the moment.' And then they say, 'Make it possible, go for it.'"* [Designer]

Decisions were thus focused on aesthetical criteria and "the papers", i.e. cost and technical specifications had to be solved afterwards. Some of the addressed criteria were implemented after the selection of the two models. However, the final, winning model still had not addressed the 100% crash rating as demanded following the first selection process, but was nonetheless selected due to aesthetics and the forms it communicated:

> *"Because here we see a new Automotor Company face, it is a very good handling of the icons of Automotor Company, it was a very good new line [...], you see the sides that the other guys don't have and one guy had, for example, yes, he made it like landscaping of the door [...] and these are the points why we choose that, for example, [...] choose one and three and four. [...] It comes more to emotions to this point, knowing what the*

[68] The exact rating is disguised due to confidentiality.

technical is. If there is, for example, we show them model A with 75%, like here, this emotion we want to have it but bring it to 100%." [Design Engineer]

Again, aesthetical criteria were key decision criterion and technical problems and other constraints were to be solved afterwards in development. The selection and competition process itself focused on selecting the "coolest" and "best" model in terms of aesthetics. Through the selection process, however, the board addressed the criteria; it was, however, still up to the designer whether s/he stayed with her/his form or if s/he incorporated all criteria into her/his form. In this case the designer stayed with his form, despite not meeting the 100% crash criteria, and got selected. Designers thus took upon themselves the risk of de-selection through not meeting requirements and the board sanctioned these choices through their selection. The important intermediary aligning and coordinating the network, thus, was not cost issues but the visualizations of aesthetic value. In the next section we discuss how the two paths of form and function converged, using the examples of the front, and the issues of crash rating and cost.

5.4.6.1.2 Adjustment and technological development phases: Convergence through compromising cost, design and regulations

The front was heavily discussed and remodeled after the final model was chosen. There were lots of constraints, such as laws, crash ratings, insurance ratings and modularity with which the front design had to deal. Cost calculations also played a major role in the process of compromising between design and technology. Furthermore, the "face", the front design should be compromised as little possible.

One designer argued, “Between the technical constraints there is only a shell of a couple of millimeters in which I can design”. Figure 14 shows the most relevant constraints in this process[69]. The outer form was subject to aerodynamic demands and crash ratings concerning pedestrian impact, or insurance ratings. Furthermore, it was important to maintain a certain height, and the wheelbase and the overhang were fixed through the engine and chassis. Modular parts, such as a bumper mounting also had an impact on the “shell” in which the designer could design his individual front. These constraints thus resulted in limited space available for the designer to shape individual forms or implement individual design elements.

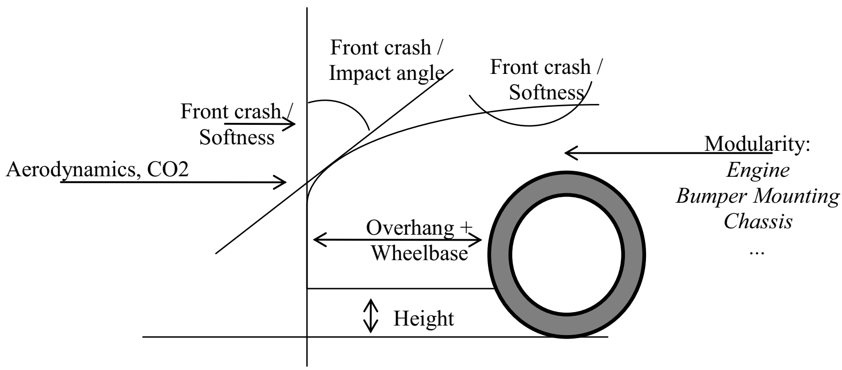

Figure 14 – Constraints in the front design

Aesthetics and crash ratings

Especially the crash rating was an issue in the process. The strategy of Automotor Company demanded 100% crash-ratings, whereas the chosen model, until that time, only fulfilled 75%. 100% could be reached with a remodeled bonnet that would compromise the initial design. The bonnet and the shape of the bonnet had to be compromised, which was a major concern in Automotor Company:

[69] This is just a simplified model of all likely constraints but visualizes the complexity of the front design

> *"Everything has to be round, everything has to be with a new radius, everything has to be kind of curved and the hood up front in the old model was also like this one, a big radius. And now, this [crash-rating] lead us to very flat here and nobody like that. [...] And now, this regulation leads us to lose the design story of the model and everybody is very sensitive and nervous about this [...] And this is the point for us, what can we do then? For example, do we leave the 100%? Okay, or we make it more round and probably only 75%. That is the discussion."* [Design Engineer]

The shape of the new car was widely debated in Automotor Company. Even the management board, which now got involved, could not make a direct decision (i.e. without further visualizations and models) regarding which bonnet to choose. A special cross-functional team was set up within design and product development. They developed two models and showed the alternatives, the model with the initial bonnet and the 75% crash rating, and the remodeled bonnet with the 100% crash rating..

> *"We got a job to make a hood with 75%, to make it more [a design icon]. And we showed it to the board, 'look, here we have it more design-ness but we ... we will not have 100%, and then you go to the ... 100%'. And we currently, we don't have the decision whether they can do it because the problem we have now is that we have already a lot of calculations, and we don't see it at the moment."* [Design Engineer]

Design criteria and crash rating criteria were in contradiction and the designer was not happy with the situation. He felt that his model was "destroyed" by the remodeled bonnet (interview with designer) and stated that the bonnet would not fit the model and would be too flat. The compromise was now between a 100%

crash rating or aesthetics, which could only be argued,not measured. In this case the management board had to take the decision. We could not take part in the final decision process due to confidentiality reasons; however, the management board based its decision on the crash rating criteria. So, in the development and adjustment process, target performance was more important than design for this model. In order to make the decision, models were created to visualise the compromises, hence both design language and criteria were important in informing the decision, i.e. the design and technological innovation was coordinated through prototypes and cost.

Cost issues and design adjustments

Another issue was the one of cost. The designer became more sensitive towards criteria such as cost after the selection process:

> *"In the beginning I wanted to make the model longer, that would have cost 10€ more. 'What, only so little?' I thought. 'That is so cool'. I fought and fought. But know I have learned,40 cent*[70] *is a lot; I won't be able to implement a feature like this. I have learned which role this plays. When I know upfront [the cost] then I won't design it. And in the beginning I thought, cool, 10€, this is not so much money."* [Designer]

The designer here explains how he realised the significance of small, euro or cent, savings on the car through the processes. The language of euros and cents per car did not make sense as he did not make the connection between the amount saved and the millions of cars sold over the lifetime of a car model, and the direct impact that this has on profits. This also illustrates how well separated the winning designer is from the language and understanding of technological innovation.

[70] Costs are disguised due to confidentiality but are close to the ones quoted.

More and more issues such as modularity, which is related to cost, became important in the design process. These were considered smaller issues, as the final design model had been selected, but they still had an impact on the overall design coherence of the car. For example, the wiper blades were set as modularity, which had an impact on the form of the upper bonnet that the designer had initially designed. He had to change this form due to space constraints coming out of the modular windshield wiper:

> *"To do modularity to save cost, for sure, but that this affects already the windshield-wiper, this change costs 40 cents and has a design impact on the hood. To win against the 40 cents with a nicer hood? I would never win."* [Designer]

Cost in the development stage is thus more important than minor aesthetical design changes.

Furthermore, cost decided over the elimination, material or size of components. The prerequisite for this model was that the concept should at least have the same concepts and components as its predecessor. However, during the process of finalising the chosen model, target cost came into play and smaller changes were made to the model, in which, for example, chrome elements were eliminated or conceptualised differently. Design was arguing that they lost design to save costs. However, throughout the process the designer of the project saw sense in dealing with the constraints, as cost issues were important for the organisation:

> *"The big challenge is to say, it is not our job to design unaffordable things, everybody can do this. No, despite all restrictions and rules and constraints, and cost pressure...That the people in the end do not see what kind of problems you had. You cannot show the model in an auto show*

and only defend yourself. And this is the cool stuff, although I am always upset when they say 'we have to save here, this is 30 cents more...', I always think, this is logic, that is the interest of the whole organization, to produce economically and that the car is overall very good." [Designer]

In the end the designer understood the constraints from technological innovation and started incorporating the view that designs also had to be produced economically.

Case 1 illustrated the following things about control of design and product development. First, the competition between clay models was more characterised by aesthetics than by cost criteria; the winning designer did not understand the language of technological development and was separated from these concerns. This means that aesthetics were the primary design criteria for the designer. Furthermore, as the models selected did not comply with the criteria set by technological innovation, design selection is primarily based on aesthetic, outcome criteria. Visualisations and clay models, therefore, had immense power in the decision making process; they were intermediaries which aligned the network, whereas estimated cost/value (the crash rating equals value) issues did not affect final decisions, as designs not complying with criteria got selected. The heterogeneity in interpretations about design was converged through the competition mechanism. Once designs were chosen, project teams worked on adjusting the design to manufacturing and other relevant criteria. Here, in general, smaller issues such as the windshield wiper or chrome elements were solved on a team and project level through cost-benefit calculations. Convergence in the adjustment phase, which seriously impacted design, however, was escalated and decided upon by top management based on new clay models, which illustrates the interconnectedness between the phases. The overall case shows two different accounts of convergence in design and technological innovation, first, through hierarchy and visualizations, design is converged and the main direction is set, and secondly, smaller adjustments are made via compromise in decentralised processes through cost benefit calculations.

5.4.6.2 Case 2 – Dashboard

5.4.6.2.1 Selection and competition phase

The design of the dashboard is a "difficult design area" as it is central to the front seat passengers' (and driver's respectively) eye line and because it is an area with high management attention. Furthermore, it was described in Automotor Company as a design icon. The meaning of the dashboard had changed for design, and increased in status in Automotor Company. Previously, the Automotor Company dashboard was considered incoherent:

> *"Six years ago a dashboard at Automotor Company was not really, or ten years ago, was not really nice. That was secondary. There we have to do something, image wise. The image is with the chassis and with the engine, but we still have to catch up with the dashboard."* [Developer Dashboard]

Furthermore, since the value of the design was not measurable in market terms, the pressure on design had risen. With the dashboard, sketches were also turned into clay models and decisions were made in steps from three to two to one. In this process, the design freedom seemed to be rather high, as the process for the dashboards always started with a blank piece of paper. Other car projects or predecessors seemed to be no points of reference. Issues such as modularity or equal parts were rather neglected in the clay processes. Using equal glove box mechanisms or the same bumpers were not issues in the design stage:

> *"We had several decisions, where we decided pro design and against cost. Modularity in the fenders for example, big cost issue. There is a tendency of more differentiation. Here one additional part more...and here and there...They never keep up with our demands, although they are necessary in our view [...] There are few topics that leaves freedom for the designer."* [Developer Dashboard]

Thus, product development was dependent on the design process itself and designers strived for more differentiation while technological innovation sought to limit their freedom. We followed one car project, through the process of design and product development, in which designs were chosen and more importantly, where controversies emerged between design and product development. As in the first cases, cost and other criteria played a rather secondary role during the generation of the clay models.

The dashboard had been specified as a one-piece dashboard, in the specific project, and with the design language of "lightness". That means that product development was focusing and estimating criteria, based on the specified concept. However, in the parallel design process two out of the three clay models showed a multi-layer dashboard. For the choice process of the clay models, information tags were provided stating that the shown multilayer concepts were more expensive. The two designers argued that only a multilayer concept would be adequate for this car project and thus argued that the more expensive solution was necessary. They pointed towards the car being in a segment where multilayer concepts are the level of that segment, whereas single layer concepts are considered to belong to lower segments.

In the decision from three to two models, the management board selected the two more expensive multilayered designs. With this decision, marketing had promised to provide an increase in the market price, arguing that the customer would pay more for the new design, pointing towards competitors and internal models and their price positioning. The price premium from the market could be used to adapt the already planned cost through a business case, which covered the higher price.

With the decision by the management board to go from two to one, product development had to incorporate criteria, such as cost, geometry, complexity or weight into their concept. There were only marginal differences between the two final concepts in relation to cost or other relevant criteria however their aesthetic form differed.

In sum, the selection stage models that did not comply with explicit criteria were selected. The designers going against criteria used a logic of positioning the car in the market. Designers were thus strategising (Jørgensen and Messner, 2010). This did not take place in product development as the formal processes prescribe, but through the interpretation of demand by designers. There was then a hierarchical decision from the top to go with the more expensive concepts, whilst attaining the market price adjustment for the positioning. In the next section we focus on the process following the selection, in which time and smaller design changes were the key issues.

5.4.6.2.2 Adjusting the final model

The time issue with smaller changes

One specific issue in the convergence of design and product development was the issue of time. After the choice process, smaller changes for product development occurred due to the advancing work in the design. These concerned only smaller changes, as the main design was chosen. Furthermore, these changes were costly due to the fact that the supplier was already nominated and changes needed to be made to their product development, and sometimes to prototype tools. The "duty" was, as one engineer stated, to "translate the design into a product". So, product development was dependent on the final elaborated design. In this process however, a fixed time schedule with milestones was set, but design did not follow this schedule and milestones weren't reached:

> *"They do not hold the schedule and we get complications, more costs [...]. This is incredible, we do not believe in our own schedule. We make schedules and do not believe in them. Not only us but as well management, not my own bosses. Everybody knows, that there is still more time and afterwards still more time."* [Developer Dashboard]

Design was allowed to surpass deadlines, which further accentuates how design processes overrule other criteria, here time. It was argued that design wanted to incorporate the latest trends in their design model, as this needed to last for the complete lifecycle of a car.

Concept development, run parallel to design and design, agreed to be ready with their complete/finished design model within five weeks. In that time, concept development elaborated on the chosen design model and discovered that specific layers could not be produced due to the forms, and because the dashboard didn't conform to crash prerequisites, which signaled that it had to go back to design through meetings and discussion with the design engineer. The dashboard got slightly higher in certain areas and lower in others. Instead of the planned and fixed five weeks, this convergence process between design and product development took about three months. A lot of compromises had to be made within these three months, including several hundred minor changes.

Two concrete and interesting issues arose after the final freeze of the design, which were minor changes on the one hand, but that, on the other hand, posed a challenge for product development, and are interesting to follow in the process of idea creation and compromise, as they illustrate how such cases, which impact the integration of phases, are handled.

Lighting-effect Case: changing designs late in the process

After the design was frozen, a recent trend in competitors' designs had to be implemented in the studied case. A lighting-feature on the dashboard should enhance the design and make it more premium-like. The head of design convinced the project leader and they decided upon the implementation of this feature, although it seemed much too late in the development process already:

> *"And then there was a meeting between the project manager and the head of design. 'This topic is to be realised, doesn't matter the cost'. Of course we estimated cost, but it had to be realized. 'We want to see scenarios how this is feasible. Can we shift development, tools, prototypes? Can we make tools out of aluminium?' Can...can"* [Developer Dashboard]

The design feature should be implemented irrespective of cost. The pressure came from the top and there was no comprehensive cost benefit calculation for this feature as in the normal discussions. Together with project management, the head of design made the decision and it was "thrown into the development process", as one Cost Engineer stated. The pressure and the risk had to be absorbed by product development.

Surface selection

In another case, the surface with which the dashboard should be decorated was highly debated. Design demanded a certain surface that had to be developed together with suppliers. Purchasing prices however, were very high for this surface and the supply was scarce because the quality was very high. Product development therefore suggested another surface, which was cheaper but didn't have the same quality standard as the surface demanded by design. Although the suggested solution was also of a very high standard, the quality was "still not enough" for design:

> *"It all makes sense, because you don't see it much, we decided to have the cheaper supplier and now that's still not enough, and now we have a meeting on Friday to decide to have the prototype a more expensive supplier for the entire lower part, and we, of course, together with the door panel because there is surface also on the door panel, and we try to fight against them, of course, because you have to look at the cost, and now we put together some figures to control design… and then it will be interesting who is the stronger."* [Purchasing]

The two different surfaces were presented to the project with two models. The decision fell towards the suggested solution of product development and thus for the cheaper surface. The visualisation showed only a very marginal quality difference and cost played the major role. Marketing also didn't see any drawback for the customer in this decision.

What was also interesting was that there was no strategy for surfaces among all car projects, thus no standardisation. This was surprising as there were strategies for other surfaces and trims to keep complexity and cost low, and to avoid further discussion like that described above. It was argued that this was because design was too strong and "too design oriented" in relation to the surface selection of the dashboard. There was thus no control over the surface design process; this is why product development set up a team through which standardisation should be set in the future. We could not follow the outcome of this team but standardisation and modularity were means to control design processes, as was seen with other projects and surfaces. This is why product development pushed the surface standardisation for the dashboard.

The surface issue showed that smaller issues could be decided within the project, based on calculations and visualizations, by weighing cost and aesthetics.

In summary, the case demonstrated four things about control and convergence of design and product development. First, designers' interpretation of market trends was more important than the explicit criterion of a single layer dashboard, and when going from three to two, the single layered design was not selected. Designers' interpretation thus overruled explicit criteria. Again, cost issues did not align and coordinate the network. Designers took chances through not adhering to criteria and were rewarded for their choice through the selection. Secondly, time was an issue, as design needed more time than was allowed for in the schedule. Development then had to cope with having less time to develop the concept. This was an example of how function follows form and design being the more important criterion. Thirdly, smaller changes were calculated and decided on an operational level rather than by hierarchy, as we also saw in Case 1. However, the lighting design had to be decided on a hierarchical basis as it had a major impact on the design, time schedule and costs. Fourthly, product development was striving for the cost control mechanism of standardisation (modularity) to meet their selected criteria and to avoid future discussions about dashboard surfaces.

5.4.6.3 Case 3 - Door Panel

5.4.6.3.1 Selection and competition phase

The selection process for the doors was the same as for the dashboard. The focus was very much set on the “meaning and feeling” of the door panel. For the competition from three down to two and to one, only the front doors were designed, as the rear doors were resulting designs with similar design patterns as the front door. The rear doors were then designed after the selection stage. In this case, we focus on the adjustment phase because the designs of the three doors did not differ significantly. Furthermore, we were not able to get access to material about the selection of the final door panels, since key persons involved in that stage either left the company or could not be interviewed due to confidentiality reasons.

However, the design of the door panels was as important as the dashboard. In the past, the coherence of the door panel design was contested and “negative press”, in former car projects, had led to a greater focus on the design of door panels. The negative press was argued to have been caused by too strong a focus on cost in the adjustment and development process. Thus, in this case we focus on the door panel of one particular project and the adjustments that had taken place after the selection. Here, two stories that had a significant impact on design and cost were of interest.

5.4.6.3.2 *Post selection - adjustments*

In the adjustment stage, the door panel that had been selected was subject to specific changes that had to deal with design elements and certain surfaces. The selected design initially showed a specific surface that was typically very expensive and hard to source. The cost engineer who calculated the cost for the door panel suggested, in a cross-functional team, to switch the surface to a cheaper one which provided the same quality standard for the customer. This seemed to be a minor issue for design as the decision went through the team and through project management rather smoothly. In the following sections we focus on two issues, which were highly debated and discussed in terms of implementation. First, we focus on the issue of equal parts between the front and the rear door, and secondly, we focus on a material change for the lower part of the door panel.

Equal parts

The design of the rear door commenced when the final model was selected. One idea was to save costs by using the same (or equal) elements from the front door, on the back door. This idea came from a design manager who had seen similar approaches in competitors' doors. In the beginning, this was just an idea that would be interesting to try out. As they modeled the clay for the rear door, they used the equal parts (such as arm rests, decoys etc.) from the front door and positioned them into the rear door, where they could be positioned ergonomically:

"Together with the designer we have positioned several components to the rear door, where they could fit ergonomically more or less. And we saw there that one component was a bit too big. And then we had to find a compromise between both doors, in length, and in positions of the components and the doors." [Design Engineer]

In order to meet ergonomic requirements and cost, the initially selected design of the front door was changed. Furthermore, the body structure of the car had to be adjusted, as the door and side architecture had to be adapted for that. This was then discussed with design and a virtual model was created together with the designer's sketches. The designer agreed to the adjusted doors after several discussions and he redrew the new models of the front and rear door using equal parts. One more feature, however, had to be compromised, as the equal parts situation had an impact on ergonomics. Compromising between design, ergonomics and cost was, however, possible:

"And it is tough to generate compromises with ergonomics and with the colleagues. They want to have the best possible ergonomics. Then you have to discuss with them about costs and so on. And with the designer it was a fight. The differences are for a normal person only marginal, but they were there. The designer did not want to see this, of course you see this a bit when you take [a look at it], there is something different. It was a hard way down to this, but we did it." [Design Engineer]

The compromise on ergonomic criteria was worked out in the decentralised process. The compromised door panels were shown to the project in clay and what was discussed and agreed at team level through designer, developers and ergonomic engineers was then presented to the project. This compromise brought significant cost savings to the project. The compromise seemed to be so tough that when the first prototype car was modeled, the doors could not close because one of the equal parts had an impact on the hinges. However, this was a minor issue that could be addressed afterwards with minor changes to the hinges. Generally, the solutions were converged through compromises between cost, design and ergonomics.

Material change to the lower part of the door panel

As cost pressure became even higher in the studied project, project management searched for cost-down measures. This process started at a very late stage of the car project. The purchasing department asked the suppliers for possible concepts with lower costs. One of these ideas was to change the material of the lower door panel to a cheaper one using different technology. The quality and the surface of the material were, however, considerably lower than what had initially been designed. The initially estimated savings sum was 20-30% of the overall cost of the door panel. For implementing this cost measure, a significant part of the production concept had to be redeveloped, causing more assembly problems and complexity, and decreasing the initially estimated savings. However, the project manager wanted this measure to be implemented to save cost and reach the cost target:

"With the material change in the door? There were the finance guys and the project manager decided "material-change, we do this now! Doesn't matter, we have a reduction measure and we do this now!" [Cost Engineer]

"We had primarily the equal parts approach in the door panel to save costs [...] that was our idea, but with the material change, that came on top." [Designer]

The design department was unable to rule against the project as development had already been in progress and the project was at a very late stage. Design was very upset about that, as they had already compromised for cost reasons.

In summary, Case 3 illustrated how compromises between design, technical issues and costs are realised at a team level, with the designer doing trial and error through visualizations. Design accepted the cost pressure, and gave in, by designing door panels that used equal parts together with product development. Cost pressure caused several design changes initiated by the financial department and decided by project management. These decisions were so late in the process that design had to accept this change. Cost, technical issues and design are compromised and converged at team level and cost control is achieved through intermediaries such as equal parts.

In the following we apply the perspective of mechanism design, to structure our analysis and, in discussion of the hypotheses. First, we discuss the findings that contribute to the control mechanisms of design and technological innovation. Secondly, we discuss the findings that contribute to the convergence processes of design and technological innovation.

5.4.7 Discussion

5.4.7.1 The nature of the control mechanisms of the cases

In the cases, it was apparent that design interacted with technical requirements in several ways. However, in general, they constitute two different processes, and the way in which decisions are made, and processes controlled, differ. As discussed in the theoretical discussion, we use the framework of mechanism design to analyse the control mechanism in Automotor Company. In Appendix 9 we have summarised excerpts from interviews. Table 6 shows the findings from our empirical analysis.

5.4.7.1.1 Mechanisms

The general mechanism for design is a process of competition. Designers compete with other designers on interpreting trends and the general strategic criteria for the car and designs are continuously deselected in the process. On the one hand, this process is characterised by the creation of variety through letting designers create their own interpretation of trends, design language and strategic criteria. The criteria acting on the process are more of a general understanding (see also Jørgensen and Messner 2010) of a certain car project than strict constraints. In Cases 1 and 2 we described how convergence and selection of one model is achieved through competition. Even though cost, value and other manufacturing criteria were conveyed to designers they did not, in the cases studied, significantly impact the choices made by the designers who won in the selection process.

In technological innovation, constraints in the form of cost, manufacturability, law, etcetera are paramount and the final design model is subject to several modifications. In this stage compromising based on calculations is the way in which convergence is achieved. This process is characterised through financial and technological calculations. These are often in conflict with design solutions and demand compromises. The overall mechanism in design is thus competition, whereas in product development it is compromise based on calculations. The overall mechanism in which design converges with development is a process of compromising in decentralised projects. We touch on that in the next section about convergence.

5.4.7.1.2 Optimality criterion

Designs, which do not meet cost and technical criteria, are selected as illustrated in the first two cases; so in Automotor Company the criteria that guide the actions in design are more related to coherence and aesthetics. Designs are not made commensurable but are selected through top managements' evaluation of aesthetics. So, the primary criteria are aesthetics and perceived value of the design. Contrary, in product development, the criteria are of a commensurable nature, in the form of either technological or financial criteria, such as cost, feasibility, weight or driving characteristics.

5.4.7.1.3 Language

In design, the language for transmitting information is visualisations in the form of sketches or clay models. This language is primary in order to establish the "value" of the concept, which is not possible through numbers. This was very important in Case 1, as two different crash ratings were presented, and in Case 3, where equal parts in the door were demonstrated. Traffic lights are used to illustrate the ability of various designs to meet technical and cost requirements; however, they play a secondary role in the design phase.

In product development the language is numbers. In this process, target costing and technological target management are the underlying managerial technologies that mediate the process. Business case calculations (e.g. modularity Case 1, multilayer concept dashboard – Case 2, and cost target in Case 3) and technological (feasibility) calculations (e.g. crash ratings – Case 1) are used to steer the process of concept development.

5.4.7.1.4 Rules for transmitting messages

In design, messages had to be transmitted through the hierarchy following a bottom up approach. These were transmitted through visualisations and presentations. For the selection meetings, traffic lights, indicating compliance or conflicts with technological or financial criteria, were used as information for the selection. This could be seen in Case 1, in which the clay models deviated from the targeted crash rating. In product development, business cases are developed in a standardised way, providing financial calculations and the affected technological criteria. These were prepared in product development teams and were presented in specific decision circles with the project manager.

5.4.7.1.5 Decisions

Decisions made on the overall design of the interior or exterior are done by the board of management together with the head of design. This is a clear top down approach, which assigns all the power to the hierarchy. Cases 1 and 2 present cases in which crash ratings and the multilayer concept were decided at top level. In product development, by being steered through criteria and targets, decisions were taken or prepared in development teams, and at component level, and decided through product development circles with the project manager in charge.

This could be seen in Case 3 where equal parts and materials were discussed and decided upon at team, and project level.

5.4.7.1.6 Uncertainty reduction

In the design phase uncertainty was reduced, through the competition of various design models, and eliminated through selection, in a hierarchical form of decision making.

A single designer eliminates uncertainty about forms. We also discussed the complexity of making a car work with all underlying functions and concepts that need to be developed by a huge amount of distributed knowledge, incorporating hundreds or thousands of engineers, which leads to uncertainty that needs to be reduced in the processes of convergence in technological development. As one developer stated:

> *"That is different in design; you have immediately a picture including every single detail. You look at a car and you see if you like the outer rear-view mirror or not. Or the trunk-lid. This is different in the development of concepts. You never know whether the glove-box works or not, whether it breaks down after two weeks, all this is uncertain. You cannot make a picture out of it. But in design, there you have immediately a picture."* [Developer]

Uncertainty in design is fundamentally different than in product development. Design uses models to visualise solutions; whereas technical requirements are analysed via cost and technological calculations in the development phase.

These circumstances furthermore suggest that while outputs and target achievement can be measured in technological innovation, design with creative processes and non-measurable output may be controlled through competition. Although goals may be perceived individually in the design process, competition and individual interpretation steer the design process towards the goal of creating aesthetical designs that the customer is expected to be willing to pay for. Furthermore, in the adjustment stage, compromising is rather an interactive control system (Simons, 1995), or an enabling of the use of the control system (Ahrens and Chapman, 2004), which is used to indicate consistency with strategies, such as modularity and profitability, on the one hand, and for guiding creative search processes, on the other. Both fields are then connected in (tactical) decisions, in which, uncertainty about design and technological and financial criteria is reduced.

	Design	Product development
General mechanism	Competition between drawings, clay models and other types of physical artifacts (e.g. Case 1+2) Output control	Target steering: Cost calculations and technological feasibility studies Fixed prerequisites such as equal parts, modularity and law (e.g. Case 1+2+3) Behavioral control of individual engineers
Primary optimality criterion	Aesthetics and coherence in and among models	Technical feasibility and estimation of value and cost
Language	Physical expressions, models, and visualisations (e.g. Case 1+2+3)	Numbers (Cost and engineering calculations) (e.g. Case 1+2+3)
Rules for transmitting information	Escalation through visualisations; Traffic lights in selection meetings transmit technical criteria (e.g. Case 1)	Standardised forms of calculations from team to project level. (e.g. Case 3)
Decision maker	Top management, CEO (e.g. Case 1+2)	Decentralised in cross-function teams based on calculations and technological criteria – Final decisions through project manager (e.g. Case 3)
Uncertainty reduction methods	Uncertainty is reduced through creating variety through the competition and eliminating/deciding on it through selection. (e.g. Case 1+2)	Reducing uncertainty through financial and technological calculations that become more solid over time (e.g. Case 1+2+3)

Table 6 – Control mechanisms of design and technological innovation

The Table illustrates the mechanisms through which design and technological innovation were controlled in Automotor Company. The two phases are illustrated as separate phases and the table thus illustrates how the two differ, and how they are managed through different control mechanisms.

This table also sums up our investigation of the first three hypotheses. Design differed from technological innovation in their perceived commensurability (1), where design is a non-commensurable but can be evaluated through aesthetic outcome criteria, and technological innovation through numbers (engineering or cost based). Design and technological innovation is also controlled via different control mechanisms (2) as illustrated in the table, where design is controlled through competition on aesthetic output criteria, and technological innovation is controlled through the achievement of targets defined in monetary or engineering terms. Finally, design was partly separated from technological innovation. Designers did not have contact with cost engineers and cost controllers in the competition and the relevant calculations of their designs were illustrated as traffic lights. The criteria calculation from technological innovation, however, did not affect final decision on models, as designers not meeting criteria often won competitions.

These findings add to the literature in several respects. Unlike literature which argues for the balancing of creativity and control in one process of product development and innovation (e.g. Jørgensen and Messner, 2009), we find that different mechanisms may be used at the same time, separating endeavours such as design, based on sociocultural innovation, and technological innovation, based on calculations'. This dual form of control mechanism may enable both accounts to strive for flexibility and guidance at the same time (e.g. Davila et al, 2009), albeit through different means and in different places (design vs. technological innovation). These findings also illustrate how big firms may overcome multitasking problems where difficult to measure activities, such as innovation activities, do not get sufficient attention (Holmstrom, 1989; Holmstrom and Milgrom, 1994). It illustrates that "the best allocation of projects is such that the projects assigned to one agent are uniformly more risky than the projects assigned to the other" (Holmstrom, 1989 p 313); this is relevant and possible in complex techno-economic networks such as Automotor Company. We extend this literature by illustrating the specific control mechanism which may accomplish this. The competitive selection process seems well suited to incentivise actors to take on high risk, e.g. through not adhering to calculated criteria. Our findings furthermore indicate that the network and organisational actors around the specific control mechanism influence the importance and weight of the control mechanism. In Automotor Company the weight and power of technological criteria was low in the selection and competition stage, as decision makers in this phase decided against criteria and rewarded designers, taking the risk of deselection, not adhering to technological criteria but seeking to maximise on subjective aesthetic criteria.

Having discussed the first three hypotheses we have just one question to answer: how did design and technological innovation converge with technological innovation? We briefly discuss this in the next section.

5.4.7.2 Processes of convergence of design and technological innovation: design engineers as boundary objects

The question is how compromises are achieved between design and technological innovation. Heterogeneous actors within the network need to be aligned and coordinated to converge towards a final product (Callon, 1991), which can be developed, sourced and produced at adequate cost and value. Though design and technological innovation were separated, the two phases also interacted. Technological development influenced design through the design engineers who were also the voice of design in technological development.

Design engineers accompany the product development process from the very beginning: from the generation of the first clay models until the very last design freeze. They are responsible for the intermediation of product development criteria into the design process, and for incorporating design aspects into product development. They are described as the advocates of both design and product development:

> *"These [design] engineers go into the technical discussions and they fight for the designs, on the other hand, they have to be realistic and guide designers in this tension of finding technical solutions and pushing the design through."* [Design Engineer]

In the selection stage, criteria are rather fuzzy and only represented by estimations. Communication of criteria is the responsibility of design engineers, however, their "identity" is mixed. A design engineer further explains:

> *"Within design we are denounced as technicians, within technological development we are denounced as designers, there they say 'ah, there is one again!'"* [Design Engineer]

Design engineers are "aliens" both within design and development. Design engineers in these two modes may be described as boundary objects (Briers and Chua, 2001). "A boundary object ties together actors with diverse goals because it common to multiple groups but is capable of taking on different meanings within each of them" (ibid., p. 241-242). They intermediated information and enabled the merger of both accounts. Convergence could only be created through the decisions made at both ends, either at team, or top management level.

We found two ways in which intermediation takes place. First, in the design phase, design engineers worked on/with designers to accomplish criteria (though designer decisions not to incorporate criteria were often not penalised because models that did not meet criteria, or did so to a much lesser degree than other models, were selected). Secondly, in the adjustment phase when designs were adjusted and calculated, big changes in designs where decided upon using a combination of the language of design (visualizations and models) and calculations, as well as through escalation to the board of directors.

In relation to the first mode of intermediation, design engineers were paramount. They are responsible for illustrating and conveying restrictions and criteria of product development, to designers, and for showing product development the intentions and languages of design. Or, bringing the "blue sky" and the "down to earth" approach of both accounts together, as one design engineer stated. It is not about one dictating the other, but about initiating compromises through the intermediation of design language and criteria:

> *"It is not like this:'I, as a designer, determine the form and technology has to come up with a solution'. That would never work. I have to tell them this car is there primarily for driving, so I have to drive. When I drive dynamically, then I need space for my knees. A designer needs to understand this, he has to be able to make compromises."* [Design Engineer]

In this space, visualizations from design and calculations from product development intermediate the processes of compromise. They are coordinated through specific rules and guidance. In the design selection stage, design engineers provide the decision makers (management board) with information about how the design models to be selected interfere with relevant criteria, such as crash ratings, costs or weight. They show traffic lights to indicate a design model's conflict or compliance with the criteria. In product development, calculations are discussed in project coordination circles, in which project management makes decisions based on information generated in the product development teams.

In the second mode of intermediation, design engineers intermediated between both accounts and prepared and moderated the process of compromise. The compromise processes primarily weighed calculations and visualisations: commensurable items and non-commensurable items:

> *"In technological development you have numbers, you can prove them scientifically and can convince everybody. With design it is very hard, [...] to say 'the curve or form has to be like this, this has to be like this, design-wise'. It's not like you can prove it like with mm in space or costs, or whatever. This makes our work very hard in the decision meetings, to argue. You cannot argue this design is not good looking, management will not understand this. That is why we have different models. To show this more or less. We sometimes visualise technological innovations and concepts into the clay to show: This is how your idea looks like. Is this really what you want, are you serious, yes or no? Sometimes it is then like 'better not', sometimes they say 'It's not that bad as you said'."* [Design Engineer]

Thus, compromising between visualisations and calculations is another way to foster convergence. This could be at a team-based level, located in technological innovation or at top management level, located in design. This seemed to depend on the complexity and on the affected environment. After the selection of a model, criteria typically became more important and solutions were mainly discussed and handled at team and project level. This was exemplified in Case 1 with the windscreen wiper, in Case 2 with the surface selection and in Case 3 with the material change or equal parts. Furthermore, fixed prerequisites, such as modularity (e.g. windshield wiper in Case 1) and standardisation (e.g. surface in Case 2) helped in converging both accounts as they left no space for bargaining about certain forms or functions. However, in Case 1 and Case 2 we saw how some decisions concerning "bigger issues" were taken and elaborated at a higher level. After the selection in Case 1, the criteria of crash rating became important and a key decision factor. Furthermore, in Case 2, a new design feature had to be implemented *ad hoc*. Thus, convergence with bigger issues, that were highly affecting development time or costs, was created through providing two alternatives where one met the criteria, and one did not. The decision was made in both cases by top management, as strategic decisions and not through calculative processes:

> *"Because design is also in a big focus of money and [the head of design] indeed himself, it's very important for him, because he is always asked in the board presentation [by the CEO], 'Are you taking care about the money?' And in one example he told [the CEO], [...]'another model is nicer but it cost about 50 million more', and [the CEO] said, 'You can leave the car, I'm not interested in [...] I don't want to see it. Those are the numbers and that's enough for me, I'm not interested in that' and that shows [the head of design], also, I can come with something very nice and*

> *if I don't match the business case then there will not be interest ...* "[Design Engineer]

Convergence was partly achieved through board of director decisions. Another means to achieve convergence was the concept of being, on the one hand, clever about cost, complexity and other technical criteria, and on the other, able to keep up with a coherent and premium design. Solutions that fit both requirements are then searched for in teams that are coordinated by the design engineer and through cross-functional development teams:

> *"Design is the key selling factor for Automotor Company, so, we have a tension between the financial and the business sector, design freedom and here we want to find the golden rule, the golden track where we have a good design and good cars at the same time. That's the key point."* [Design Engineer]

Design engineers were mediators between the two concerns and were continually crossing the boundary between design and technological innovation. In Figure 15 we summarise our findings.

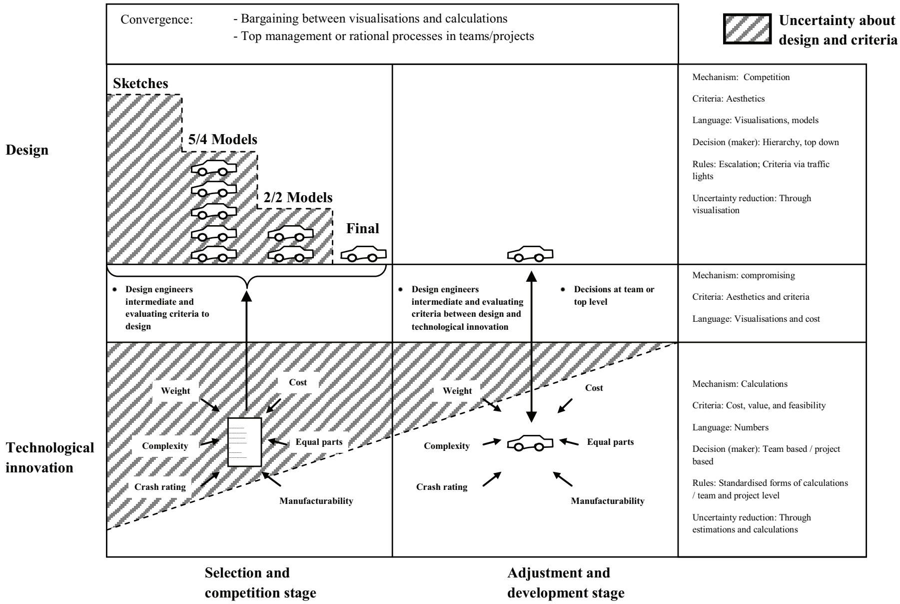

Figure 15 – Summary of findings

Figure 15 illustrates the design process, at the top, and how it is controlled. At the bottom, control of technological innovation is depicted, and in the middle we have the design engineers trying to mediate between the two processes.

We found that first, design and technological innovation may be separated and are controlled through different mechanisms as discussed in the previous section. Secondly, we found that uncertainty may be reduced and eliminated in design, through visualisations and choice, and in technological innovation, reduced through calculations. We illustrate this in Figure 15 with the shaded area. Thirdly, as the project proceeds, criteria become more apparent in both accounts: in design and technological innovation, and the two processes merge as design and technological, cost and other criteria are weighed against each other. In the adjustment and compromise stage, design engineers intermediate technological and financial criteria. We found that boundary objects (here design engineers) affect the creation of convergence through the intermediation of criteria and visualisations. Fourthly, the winning designers fight for their designs, while trade-offs are made on all criteria (aesthetic, cost and engineering). When tradeoffs have (too) big an impact on design, decisions are escalated to higher levels while in other cases compromise are made directly at the operational level, involving product development teams, single designers and the project manager.

This conceptualisation adds complexity to ways in which multitask problems (Holstrom and Milgrom, 1989), demands for flexibility and control (Davila, 2005), and the need for using formal controls in an enabling manner (Ahrens and Chapman, 2004; Jørgensen and Messner, 2009) may be handled via concrete mechanisms and processes. Our analysis illustrates how partial separation, which enables the use of different control mechanisms for different tasks, may be combined with subsequent processes that coordinate and integrate without seriously disrupting each process. In this way each process can be incentivised appropriately, while still ensuring coordination and convergence.

5.4.7.3 Limitations

This study is subject to many limitations. We have made use of qualitative data and observations within a single, complex, production network focused on design and within three specific cases. This restricts the generalisability of our findings, which would not generally be relevant for non-design orientated firms nor firms with low complexity in their operations. The selection of our empirical material was influenced by the time available for the study and we were only able to study this field in Automotor Company for a period of two years. We therefore suggest that this stream of research needs further, qualitative and quantitative development, which could further substantiate and generalise the claims in this paper. While Automotor Company´s success indicates that processes are efficient, there may be many other factors explaining their success. Hence, it would, for example, be interesting to investigate the extent to which the separation of control of design and technological development is also an effective solution across multiple cases and firms. The relative weight put on control versus coordination, and design versus technological innovation could be the object of subsequent research. We further think it is important to generate knowledge about the viability and effectiveness of the intermediating hybrid – with design engineers to mediate the two processes – in longitudinal and cross-sectional studies.

5.4.8 Conclusion

Design and technological innovation are of a different nature within consumer goods industries. In the studied case, design was separated from product development and controlled through different means; design is controlled through a competition mechanism and technological innovation through calculations in decentralised processes. The need to integrate design with technological innovation was taken care of by design engineers who move technical requirements and cost issues into the final stages of design selection. However, in the studied case, these criteria only had the effect of deselecting very unrealistic projects. In general, the message was to fix technological or financial issues at the adjustment stage; thus, even designs with severe problems in relation to technical requirements and cost were selected. This integration and convergence process reflects a process of experimentation, as going back and forth between criteria and design models, relating to trial and error practices through which the best and most innovative concept (in sociocultural and technological terms) are selected

(Thomke, von Hippel, and Franke 1998; West and Iansiti, 2003). Models or prototypes, in conjunction with calculations and boundary objects, may enable knowledge integration (Wouters and Roijmans, 2011).

Different control mechanism in the separated accounts of design and technological innovation may reflect differently perceived commensurability. In design which was characterised as incommensurable and as “undecidable”, competition as mechanism should provide maximization of aesthetic value. Not competitive pricing, but competitive aesthetics are responsible for the output. In technological innovation, as discussed, calculations were paramount and aimed at arriving at the best, commensurate solution. The control system was thus subdivided rather than merely used in an enabling manner.

Controlling design and technological innovation is thus a complex process of separation, integration and convergence. Hence, while the saying that either function follows form or form follows function indicate that either of the two dominates the other, the approach chosen by Automotor Company focused on finding the right paths on this scale, through a process of maximising both ends through separated mechanisms, and converging them through design engineers mediating between the two phases. This balance and compromise occur between the languages of physical visualisations and numbers. The transmitters of both languages are boundary objects (design engineers).
Designing and developing cars is thus subject to an intriguing control process that separates to allow for creative variability and selection, integrates through specially assigned boundary breakers in order to make convergence possible, and finally, brings all the criteria together in decentralised processes. So, while the designer confronted with 500 engineers, who calculate designs, parts and functions, may face challenges in getting their designs through, design freedom

and creativity may be achieved through the partial separation, integration and final convergence of design and technological innovation.

6 Discussion of findings

The four research papers present findings of how conflicting strategic objectives, control mechanisms and heterogeneous actors interact in innovative product development networks. Focusing on the role of control mechanisms and the way they relate to these conflicts and create convergent networks, the four papers contribute to the particular gaps recognised in Chapter 2. A brief overview of the papers' foci and findings is presented in Table 7. First, the papers seek to understand the interdependencies, in product development and innovation, between control and strategic objectives, through a perspective in which control and calculations are actors that create contexts for creating strategy and innovation. Secondly, the papers recognise boundaries and barriers of control, and calculation processes and the ways in which these are created, explored and overcome. Thirdly, the papers analyse how heterogeneity in product development networks causes conflicts, and with what means and actors these conflicts are settled. Fourthly, the papers explore the two issues of product greening and aesthetical design, and provide deeper insights that contribute to both fields.

They contribute by following an ANT approach, which sheds light on the interactions and relationships between control of strategy and innovation. Paper 1, for example, shows that although a static perspective may describe certain processes and their relationships, such as strategy, organisational structure, systems, or information flows, it does not provide sufficient insights into how things are in the making and how actors mobilise and are mobilised. Disruptions, controversies, changes, translations and convergence are thus to be traced and investigated through the ANT perspective.

I discuss the findings in the following sections, focusing on the overall contributions the papers make to the field of control of strategy and innovation. In chapter 6.1 the findings of the four papers are generalised into one model; in chapter 6.2 a brief overview of the general contributions of this thesis is presented.

Paper 1	**Focus**: Mobilisation of strategic objectives and implementation of performance measurements Barriers and conflicts in the process of mobilisation of strategic objectives	**Findings:** Attributes or accuracy are not defined through the most appropriate connection between strategy and control but through the contexts calculations provide for new strategic objectives Links of existing calculations provide contexts for the mobilisation of new strategic objectives
Paper 2	**Focus**: Conflicts and controversies between strategic objectives and calculations Means and modes of mobilisation Means and modes of creating alignment of heterogeneous views	**Findings:** Strategic objectives may be mobilised and heterogeneous networks converged through the creation and exploration of calculative spaces Product greening may be rationalised through commensuration
Paper 3	**Focus**: Generation of aesthetical concept design Mobilisation of strategic objectives Control mechanisms within this process	**Findings:** Strategy is not input for aesthetical design but is part of it Control mechanisms such as visualisations and competition build product design networks and create and shape strategic objectives
Paper 4	**Focus**: Generation of aesthetical design and technological innovation Mechanisms of control in both events Convergence of technological innovation and aesthetical design	**Findings:** Calculative and non-calculative control mechanisms may be in place at the same time focusing on technological and aesthetical design Both interact through boundary objects and converge through bargaining and compromising

Table 7 – Brief summary of foci and findings

6.1 General discussion of findings

Product development is an ambiguous task for organisations. Various actors have a stake in the process of product development, of which, some become more and more important. Customer value and cost reduction are, for example, two pillars for sustaining and gaining competitive advantage. Customer demands require low time-to-market, high-quality, individual products with high functionality, form language, and social and environmental performance of the product and of production processes. Thus, the field of product development and innovation concerns coping with these demands, and the addressing and creation of customer value. This results in the need for a creative environment in which ideas are generated and developed towards innovation, on the one hand, and in the need to direct development processes towards objectives such as cost reduction, on the other hand.

Creative processes that form innovation are here concerned with idea generation and its implementation. In this process, more and more actors need to be bundled. Technologies need to be brought together; for example, making a head-up display (HUD), which displays the navigation route on car windscreens, from: projection technology, navigation software, GPS and a well packaged dashboard[71]. The first step is the idea, the second, and more complex, step is the process of bringing the heterogeneity of actors together to assemble a technology which fulfils the requirements and strategic objectives of an organisation.

In the process of product development and innovation the thesis points to three important issues. The first one is the mobilisation of strategic objectives within product development networks. The papers disclose different means and modes

[71] This is not a case that was studied in this thesis. The cases in the papers though concern the same problem.

through which strategic objectives are mobilised and shaped, and point towards calculative and non-calculative devices which render strategic objectives mobile. The second concern is about the control mechanisms in product development networks. The papers focus on, the mechanisms through which alignment is created and found, calculative and non-calculative mechanisms, and the separation of both in a calculative and non-calculative space. The third issue concerns the integration of both spaces and how alignment and coordination is formed to create a convergent network which results in a final product.

6.1.1 Representations – Mobile strategic devices

In product development networks there are calculative and non-calculative devices that represent entities such as customers, shareholders, or general ideas (see chapter 3.2.2.1). In product development there can be an unlimited number of entities which are represented by these devices. There may be non-calculative devices such as prototypes or design models, or there may be calculative devices such as an IRR or price tags. Do these devices represent strategic objectives? Even more than that, they bring strategic objectives into being. When entities become inscribed into these devices, they become mobile in product development processes and while representing these entities, they become strategic objectives that act and are acted upon. For example, shareholders are such entities, and are transformed into a calculative device. They are, for example, transformed by taking their expectations of the financial performance of the company into account (e.g. the expectation on dividends, ROCE, and so on) and by breaking them down to a target IRR of products. The shareholders become thus inscribed into the calculative device of a target IRR. Through this calculative device they become mobile and influence decisions in product development; shareholders become mobile strategic objectives. Another example would be the idea of a sports car.

The single idea (which is also an entity) of developing a sports car may be represented in text documents describing features of the car. Should it have two or four doors? Is the motor located in the front or the middle? Is it a hybrid sports car? Should it have front- or rear- wheel-drive? The text document which contains the information represents the idea of a sports car and, here again, the idea becomes mobile as a strategic objective in product development. Calculative and non-calculative devices are thus representing entities. Through this, strategic objectives become mobile in product development processes.

For entities to be represented by devices they need to be transformed. There are different ways in which these devices are transformed. Non-calculative devices are transformed, through inscriptions, into visualisations of physical material (prototypes) or texts. These inscriptions are more interpretations than calculations; "mere mental interpretations" (see e.g. Mouritsen et al., 2009, p. 751) may transform entities into strategic objectives in product development networks. For example, teams may interpret ideas (such as a sports car) and inscribe their interpretation into documents; customers may state their individual interpretations of models (e.g. Paper 3) which are then inscribed into documents; designers may model their individual ideas into clay. The transformation of calculative devices is somewhat different. For calculative devices, entities are made calculable and a calculative space is created; then entities become transformed into numbers and summed up in the calculation (Callon and Muniesa, 2005; Paper 2). For example, entities are monetised (Paper 1; concept of "valorising" in Paper 2) to be included in business case calculations. Other examples are estimations of the value of functions or setting cost targets for single components (as discussed in Paper 2).

When do the transformations take place in product development and when are the devices mobilised? The devices are not only becoming mobile in early, strategic stages; they become mobile whenever a new entity enters the stage and is transformed into a device. Thus, the devices are mobilised throughout the whole product development process. From this perspective, strategic objectives are neither stable nor static. They are in the devices which are mobilised throughout the whole development process. This is the process of strategising; strategy is thus an outcome which is pursued rather than just being an input.

6.1.2 Alignment and separation – Control mechanisms

A control mechanism is the translation of calculative and non-calculative devices (such as text documents, calculations, prototypes), within a product development network, that leads to alignment of respective actors (see chapter 3.2.2.3, p. 44). The mechanisms create formal coordination; they form convergent networks (Callon, 1991, 1992). These control mechanisms include decisions, incentives, rewards or punishments. Every action that aligns and coordinates actors (and thus creates a convergent network) is a control action. Whether this is a decision in a design selection meeting, or an incentive of achieving a specific target, both are actions which are part of aligning and coordinating a network of actors.

In product development networks there are different control mechanisms. There are control mechanisms which are of a calculative nature, such as business case calculations or break-even sensitivity analysis (e.g. Paper 2) or there are non-calculative control mechanisms, such as competition between physical prototypes. Therefore, different control mechanisms and thus calculative and non-calculative mechanisms may take place in different spaces. In the following I will briefly discuss the calculative and non-calculative mechanisms.

6.1.2.1 Calculative control mechanisms

Calculations may not represent all actors, but they may provide a common language that links interactions of actors towards a common objective; through the calculation as reference, heterogeneous goals are displaced into a common one, and actors become aligned. Innovation in this perspective becomes a process that is coordinated by calculations. Although calculative boundaries and barriers still exist, calculations may form collectives which agree on one direction. Diverse knowledge, uncertainty, heterogeneous actors, and views and resulting conflicts are orchestrated by calculations that, instead of representing all actors, rather have the role of aligning them towards a durable whole (Latour, 1987, p. 122).

I found that calculative boundaries are surpassed by the creation and exploration of calculative spaces (e.g. Paper 2), and that calculations form collectives in innovation networks, rather than ambiguity. Calculations may provide a common language and align networks without even representing all actors or objectives (e.g. Paper 1); they form innovations (a durable whole) out of ideas and inventions.

6.1.2.2 Non-calculative control mechanisms

Some issues, such as aesthetics, image or reputation, are deemed impossible to calculate. Although alternatives may be selected and shaped by calculations (Paper 1, Paper 2), some may impose limits on calculability (Paper 3, Paper 4). Focusing on product development networks and the generation of innovations, other means as calculations may be in place. Creative endeavours (Verganti, 1999; Amabile, 1997), for example, are shaped by physical visualisations (or prototypes) of sociocultural innovations. As discussed earlier, the generation of physical models is part of the strategising process and of the process through which innovations are generated.

Physical representations and “mere mental interpretations” (Mouritsen et al., 2009, p. 751) of forms and functions are means that align and coordinate actors; they create a convergent network with a common goal (Paper 3, Paper 4). I found that competition and mental interpretation (generation of alternatives) are inherent concepts that steer the development process towards the goal of creating innovations. Here, visualisations, in the form of physical material (prototypes), reduce uncertainty about values (e.g. customer value) and may lead to agreement of participating actors. This process helps to enrol and interest actors (Paper 3) in the innovation process and leads towards alignment. Here, non-measurable output, such as aesthetics, proportions and sociocultural innovations, may be coordinated through clan-like mechanisms (Ouchi, 1979). Innovation is here not only driven by stable objectives (e.g. Amabile et al. 1996), but by actors, such as customers or technological prerequisites (Paper 3), that guide processes in which alternatives are generated and decisions towards a final product are made. The process of the promotion and selection of alternatives is a process of construction, which can be described as a “reduction to only one type of material” through heterogeneous actors “entering into fabrication of some state of affairs” (Latour, 2005, p.92). Competition is here conceptualised as a process through which one actor is successful in the process of translation, in which other actors are successfully interested and enrolled. The process leads then to a convergent network in which all actors are being aligned and coordinated without necessarily agreeing. Opinions may still be heterogeneous and instead of becoming homogeneous, networks are convergent through the alignment and coordination of heterogeneous actors (Callon, 1986).

6.1.2.3 Separation of control mechanisms

As discussed in Chapter 2, in the development of innovation, more expertise in specific technological fields and more interdisciplinary work is needed to bring together different technologies and form innovations. Furthermore, customer demands, cost pressure and time to market are strategic objectives that need to be followed in mature industries to stay competitive. Different functions and views, diverse technologies and defined and emergent strategic objectives are heterogeneous actors which need to be aligned and coordinated to form a durable whole. For dispersed actors to become redistributed in innovation they have to become one piece: through the process of translation in which networks are formed. Without a convergent network there is no innovation, no product and no car. Dispersed actors were, and are still, heterogeneous. Alignment and coordination does not mean that heterogeneity is eradicated; heterogeneous actors become aligned and coordinated towards one goal. This process, however, is not just a calculative process in which one calculation or one management control system is an actor that forms and brings together all actors. Although calculative devices may be described as "strong" actors that provide a language for everybody, it is not the single "strong" actor that develops contexts in which other actors are enrolled. Visualisations of physical material, and prototypes as form languages, may represent and shape objectives and enrol others through visual communication. In a process of competition "individual" alternatives represent different objectives, and thus shape and generate objectives in a process of selection.

However, one interesting finding of this research is the separation of calculative and non-calculative mechanisms. Incommensurable spaces, such as aesthetical design, and commensurable spaces, such as technological development, are of a different nature. Aesthetical design may be separated from technological development and controlled through different mechanisms; as discussed, design may be controlled through non-calculative mechanisms (such as competition of prototypes) and technological development through calculative mechanisms. Instead of having one general space, a calculative and a non-calculative space may exist; however, both spaces have the need to be integrated to form the final product. How this takes place is discussed in the next chapter.

6.1.3 Interaction and integration of control mechanisms

I discussed the separation of calculative and non-calculative mechanisms in the process of innovation and product development. Both mechanisms lead to alignment of heterogeneous actors and are means of creating innovation. However, although being separated, they have to be integrated to form innovation.

Both calculative and non-calculative mechanisms, which although seemingly separated to disconnect, (for example, technological and aesthetical design) are not mutually exclusive. Both run in interaction with each other and form something out of their interaction. Their interaction is shaped by intermediaries that connect both, and that are defined as boundary objects that tie together both mechanisms through exchanging calculative and non-calculative devices. In calculative spaces, texts or prototypes are brought in as actors, and in non-calculative spaces calculative devices are mobilised. Within this process of interaction both mechanisms become balanced and calculative and non-calculative devices are compromised upon. Calculations like IRR-calculations and incommensurables, such as prototypes, are then mobilised together and compromised through decisions. The interaction forms obligatory passage points which then concentrate the largest number of actors. Objectives become displaced and a common goal is created through compromise.

Thus, balancing and compromising occur through the languages of physical visualisations or texts and numbers. Through the interaction of calculative control mechanisms and non-calculative control mechanisms, innovation and product development happen interactively: by creating consistency with strategy, by shaping and developing strategy through guiding creative search processes, and through converging heterogeneous actors and processes into a durable whole. Although uncertainty[72] and heterogeneity could be the outcome of diverse control mechanisms, the mechanisms reduce uncertainty and align the innovation network to a final state of technology.

[72] Here I refer to the term uncertainty as perceived uncertainty about entities such as cost, forms, materials, technologies, etc.

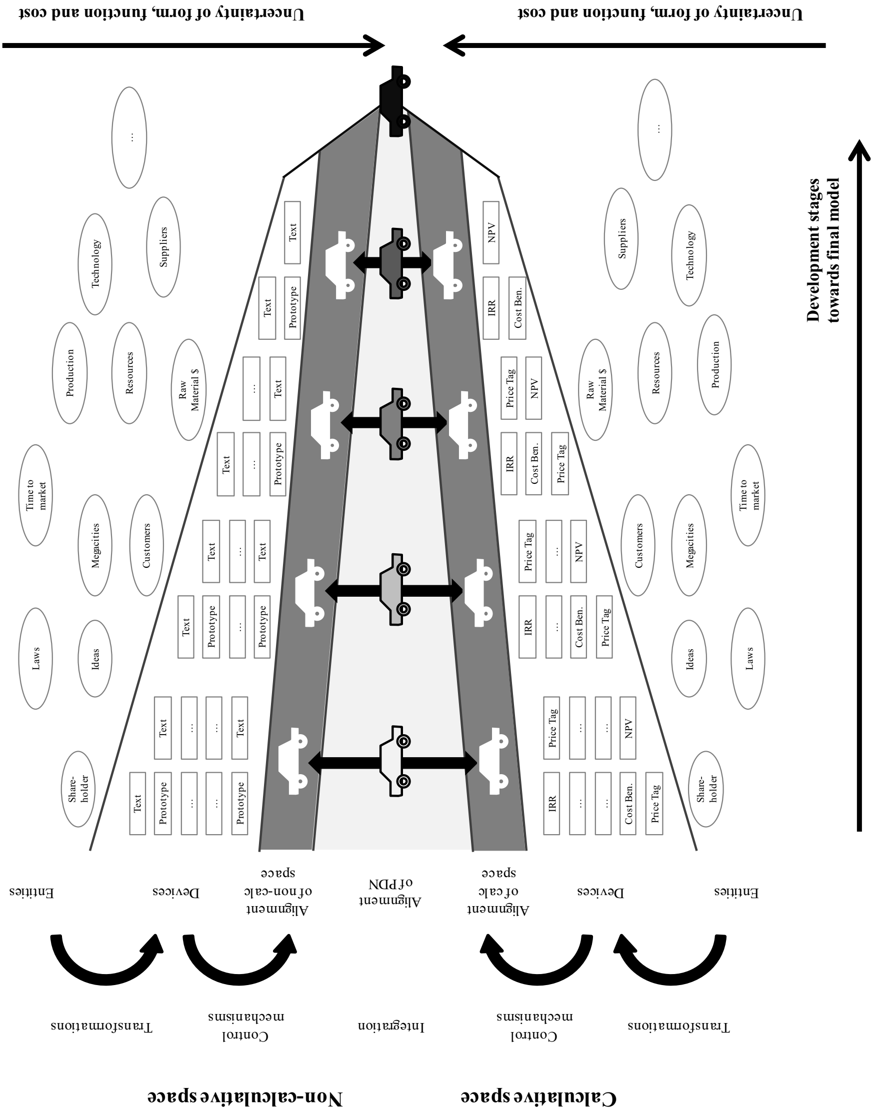

Figure 16 – The product development network

Figure 16 represents the abstracted and generalised findings from the papers. In the figure, non-calculative and calculative spaces are (as discussed in chapter 6.1.2) separated. In both spaces, entities are becoming transformed into either calculative or non-calculative devices. In the figure, the entities are displayed as shareholders, laws, ideas, and so on. They become part of the product development network by being transformed into devices. The devices are here shown as texts, prototypes, price tags or IRR. These devices are part of the product development network which consists of other heterogeneous actors, such as managers, designers, facilities, and so on. Through control mechanisms, the devices and heterogeneous actors are aligned and coordinated. I displayed here white cars as a symbol of temporary alignment in each space (calculative and non-calculative). The car represents a common goal in each space. Through balancing and compromising (as discussed previously) both, the objective of the calculative space and non-calculative space become integrated. This is shown by the car in the middle and the black arrow. To visualise the development towards the final product, I chose several stages in which the middle car develops. With each stage, more and more actors (devices) become aligned and the model becomes stronger; it accumulates more and more actors. This is shown by the car becoming darker. Fewer and fewer actors have to be aligned towards the final model and perceived uncertainty decreases in each space (which is shown by the arrows). In the end, the final product (black car) accumulates all actors within itself (Latour, 1987, p. 139); it becomes a black box.

6.2 Contributions to relevant fields of literature

As discussed in chapter 2, a deeper understanding of the interactions in product development and innovation between control mechanisms and strategic objectives is needed (p. 17). For the literature on strategy and control, and control and innovation, additional empirical evidence and detailed understanding of these interactions help to address the gaps recognised in chapter 2. The complex and conflicting field of product development needs further investigation with respect to the heterogeneity among strategic objectives, calculations, performance measurements and organisational functions. Calculative barriers and boundaries, for example, need further investigation focusing on the ways they are created, explored and overcome. Here we lack knowledge of how these limits are pursued, encountered created and explored and how they may be overcome (p. 27). Further insights into how specifically management control is productive in innovation (Davila, Foster, and Li, 2009, p. 327) are needed.

In this chapter (6.2) I will provide a rather brief overview of the general contributions of this thesis, which strive to fill the gaps identified in Chapter 2. The specific contributions are discussed in the four papers; here I provide a broader generalisation of these contributions by going back to chapter 2 and by discussing how the conclusions contribute to the management control literature presented there.

6.2.1 The strategic nature of management control

In literature it has already been discussed that, instead of taking a static view of management control and strategy, control takes a more active part in strategy making; a focus on the relationships and interactions between strategic objectives and management accounting is needed (as discussed on p. 15; see as well Chapman, 2005, Simons, 1990[73]). Practice theory has been applied in a decent number of studies in which strategy-as-practice (strategising) is a process which is performed by, e.g. managers on an individual or organisational level or both (e.g. Denis, Langley, and Rouleau, 2007; Jarzabkowski et al., 2007; Whittington, 2003, 2006). However, I found that, rather than only being practised by "social" actors (e.g. Whittington, 2003, 2006; Jarzabkowski et al., 2007), strategising is a process of mobilisation of, and through, different actors. Strategic objectives in this perspective can only persist as long as they are carried by actors or carry actors (Latour, 1987) and, thus, objectives are not stable or static, but are pursued within the process of convergence guided by intermediaries and mediators. These may be, as discussed, calculative and non-calculative mechanisms.

The contexts calculations create in decision-making play an important role in the mobilisation of strategic objectives. Calculations are argued to enable strategic change and to be important to maintain or alter patterns in organisations (Ahrens and Chapman, 2002, 2004; Chapman, 2005; Otley, 1999; Simons, 1995). Here, I found that calculations provide contexts for the mobilisation of strategic objectives through the exploration and creation of calculative spaces. Instead of just being something that people can refer to (e.g. Davila, 2005, p. 45) or being a "general understanding" (Jørgensen and Messner, 2011), calculations act as a common language into which strategic objectives may be converted through commensuration. Here, calculations that build organisational networks make strategic objectives mobile. Either, new calculations are created (e.g. Paper 1 – Product complexity price tag), or existing ones are explored (e.g. Paper 2 – Packaging of components), which mobilise strategic objectives. Through creating

[73] "The research underscores the importance of the dynamic relationship between formal process and strategy: competitive strategic positioning, management control and the process of strategy-making play one upon the other as the firm evolves and adapts over time." (Simons, 1990, p.140)

and exploring calculative spaces conflicts such as struggling with low measurability (Rowe et al, 2008), or subjective input (Kadous et al, 2005) may be smoothed.

I discussed that current studies lack a more detailed perspective of the underlying influences, through which measurements are created, and under which they find application (see p. 47-48). Addressing this gap, I found that accuracy and attributes of calculations (as, for example, discussed in Malina and Selto, 2004; Chenhall and Langfield-Smith, 1998; Lynch and Cross, 1992; Nanni et al., 1990) are defined not through the single most appropriate connection between strategy and control, but through calculative links that tie organisational networks, and through the creation of new calculations that create new links in the network (Paper 1, 2). Theorists and practitioners have to take existing actors and ties, that may create and provide the mobilisation of new strategic objectives, into consideration. Accounting calculations may not be "the single best way" (Jørgensen and Messner, 2010, p. 201) of evaluating organisational action; however, they may orchestrate different divisions and create collectives rather than determine single activities and individuals.

This thesis furthermore investigates how strategic objectives are mobilised through non-calculative mechanisms. It explores grounds of control which have not been analysed before (see p. 45); for example, aesthetical design here provided an outstanding example of how strategic objectives emerge and are mobilised by control mechanisms other than calculations. The thesis here contributed to the literature on control and strategy as mechanisms, such as competition, which may start where calculative boundaries and barriers hinder the mobilisation of strategic objectives (e.g. Espeland & Stevens, 1998).

Calculative and non-calculative (visualisations, competition) control mechanisms thus both provide space for the mobilisation of strategic objectives. Through these control mechanisms, strategic objectives can be mobilised and are shaped throughout the process of product development. Strategy-in-practice thus happens not only through decision processes (e.g. Jørgensen and Messner, 2011) but through processes such as calculating or visualisation, and alternative-generation strategic objectives become inscribed into these alternatives (Paper 3). Therefore, the work prior to decisions is important to understand innovation (Christiansen and Varnes, 2007). Strategy is thus, an input in, and output of, the process of convergence; it is part of it.

6.2.2 Management control in product development

As discussed, calculative and non-calculative devices may make strategic objectives mobile. Through control mechanisms, not only are strategic objectives mobilised, networks are also aligned. This is especially important to investigate in settings with "pluralistic demands and uncertainty" (Jørgensen and Messner, 2010) and with high product complexity, (Nooteboom, 2000) as here the orchestration of all relevant (and heterogeneous) actors leads to the materialisation of ideas and objectives (Ayers et al., 2001; Brown and Eisenhardt, 1995). Existing literature argues for the flexible use of control systems that, on the one hand, structure the processes and give directions and, on the other, are flexible enough to "take advantage of unexpected opportunities" and events (Davila, Foster, and Oyon, 2009, p. 287; furthermore Bisbe and Otley, 2004; Bisbe and Malagueno, 2009; Simons, 1995). An in depth analysis (provided here in this thesis) adds a greater insight into the interaction between controls, in interrelation to innovation (Davila, 2000, p. 405, see as well p. 24, 25). This thesis brings insights into the processes and mechanisms of product innovation and adds to the contingency literature in that, for example, it describes how calculative and non-calculative mechanisms may link and align heterogeneous actors in innovation networks. Furthermore, it sheds light on the lack of knowledge we have about how limits of the use of accounting in innovation are encountered, created and explored, how they may be overcome, and whether calculations form collectives, or more ambiguity, among actors in product development (p. 26).

Calculations are not simply mobilised as information together with strategic objectives (e.g. Jørgensen and Messner, 2010, p. 185) but as representations of objectives. Diverse knowledge, uncertainty, heterogeneous actors, and views and resulting conflicts may be orchestrated by calculations that instead of representing all actors, rather have the role of aligning them towards a durable whole (Latour, 1987, p. 122). Additionally, they, in turn, mobilise actors: engineers work towards product complexity or weight reduction, and project leaders use sensitivity analyses in business cases to form their decisions. Through calculations, "attention" is shifted towards particular strategic objectives and key success factors, such as weight reduction or complexity reduction, instead of being shifted away (Davila and Wouters, 2004). Through calculations and means such as target costing, there is no final boundary for the mobilisation of objectives and the formation of innovation. Through commensuration, objectives can be rationalised in product development processes, which are formed by calculations through exploring and creating calculative spaces in which heterogeneous or even contradicting objectives and actors can be aligned. Yet, it is impossible to judge the accuracy of calculations. What is described as "confidence" in calculations (e.g. Paper 2; Knight, 1921) or well-defined attributes and accuracy (Malina and Selto, 2004) of calculations are nothing more than the forming of collectives and alignment through calculations.

However, new insights about the mechanisms of control in innovation could be revealed in this research work. This is what is coined the "creative endeavour" (Verganti, 1999; Amabile, 1997) and feeds into Davila (2005, p. 52), in that, innovation is created in contexts that provide a "setting to generate variation, put in place the context to select among different alternatives". This feeds as well into the perspective that the work and relationships of actors prior to decisions are key elements in innovation (Christiansen and Varnes, 2007, see as well p. 25, 26). Through the selection of alternatives, all actors were aligned into one state of technology; a "reduction to only one type of material" (Latour, 2005, p.92). Creativity and innovation is thus not only enhanced through stable goals that people can draw on (Davila, 2005; Amabile et al. 1996), but through the fabrication of alternatives that inscribe objectives and actors of the product development network.

Thus, the findings of this thesis suggest that whereas in technological development, outputs and target achievement is commensurable in nature, more creative processes and non-commensurable output may be controlled through competition. Differently than discussed in literature, which argues for and analyses control and creativity in one process of product development and innovation (e.g. Jørgensen and Messner, 2009), this thesis finds that different control mechanisms may be used at the same time, separating certain processes or networks. This "dual-form" (Paper 4) of control mechanisms may enable flexibility and guidance at the same time (Davila, 2005) and will contribute to the literature of control and innovation, in that, it first, feeds into the discussion about "control" in general being of a flexible nature in innovation. Here, the focus is not only set on the conflicts of accounting calculations in innovation (e.g. Mouritsen et al., 2009) nor on the conflicts between management accounting and strategic objectives (e.g. Jørgensen and Messner, 2010); the thesis adds to the existing literature in that it displays distinct control mechanisms (calculative and non-calculative), which may provide contexts for innovation at the same time. "Informal coordination" and "formal management control" are supplemented. (Adler and Chen, 2011, see Paper 4). Secondly, it sheds light on how convergent networks are created through alignment and coordination and how interaction happens between control mechanisms. Here, boundary objects (Briers and Chua, 2001) tie together the mechanisms by intermediating objectives and goals. Rather than being "trading zones" (e.g. Dechow and Mouritsen, 2005) or mediators, they intermediated information and enabled the convergence of both mechanisms through compromising and bargaining. The intermediation of commensurables and incommensurables led to alignment through a process of going back and forth between both; through a process of experimentation (e.g. Thomke, von Hippel, and Franke 1998; West and Iansiti, 2003).

7 Conclusion and afterthoughts

With this thesis I strive to discuss different characteristics of product development and innovation focusing on the role of strategic objectives and control. I investigated how calculations and control mechanisms interact with strategic objectives in heterogeneous innovation networks. I focused on strategic and development issues, such as product greening and aesthetical design, and the process of convergence into a final product. Figure 16 displays the findings of this PhD. It abstracts the inner workings of the black box of product development and provides a deeper understanding of how control mechanisms create spaces for innovation.

First, through the creation and exploration of calculative spaces, hard to calculate strategic objectives may be mobilised. Furthermore, within these calculative spaces, collectives are formed and heterogeneity among strategic objectives, calculations, performance measurements and organisational functions are aligned. Calculations provide a common language that, although may not represent everything (e.g. complexity price tag, Paper 1), displaces divergent objectives into common ones, so if it doesn't resolve conflicts, it lessens them (Paper 2).

Secondly, some objectives are incommensurable and mobilised by different means than calculations. Here, devices such as visualisations of physical material and prototypes play important roles in product development processes; through non-calculative mechanisms these become mobilised in product development. Competition, mental interpretation and the generation of alternatives steer the development process towards the goal of creating innovations. This "creative endeavour" (Verganti, 1999; Amabile, 1997) provides the setting in which variation is created, objectives are pursued and in which common objectives are created through selection (Paper 3, Paper 4). The process of the generation and selection of alternatives leads thus to a convergent network which creates innovation; creativity and innovation is here enhanced through the fabrication of alternatives and not only through stable goals.

Thirdly, calculative and non-calculative control mechanisms interact in product development and both need to be aligned and coordinated. In this process, balancing and compromising are mechanisms (Paper 4) that form one collective, which is enrolled into the final product. This process is defined through control mechanisms, as actors become obligatory passage points when they concentrate "in itself the largest number of hardest associations" (Latour, 1987, p. 139). Whether a calculation or a prototype is able to concentrate the largest number of actors, and to translate the product development network towards an innovation is, rather than being predictable, dependant on the actors on the stage.

Fourthly, I found that strategic objectives are not static and stable. Strategy is input and output of product development networks. Control mechanisms are active parts in the making of strategy. Strategising is not a process only made by "social" actors but by actors such as prototypes or calculations.

Fifthly, this thesis contributes to the literature on product greening as it provides further and deeper insights into its implementation into product development. Product greening may become subject to calculations through the creation and exploration of calculative spaces. Thus, greening may enter calculative processes as a more strategic issue and may become an "ordinary thing" (Paper 2). Rather than being a "charitable and altruistic demand", greening may become a demand for profitability by decreasing "reputational risk to a strategic and innovative lever" (Paper 2) and, thus, become an integrated part of product development and subject to calculations and decisions. Rationalisation, and thus the calculation of product greening may be one effective solution for organisations striving towards sustainable actions.

Sixthly, this thesis contributes to the literature on aesthetical design. While both the development of forms and of functions are important processes in product development, their integration seems to be a difficult one. Shedding light on the process of the generation of aesthetical design, Paper 3 and Paper 4 discussed how competition and visualisation are control mechanisms in this process. The mechanism, of integrating the generation of forms into the generation of functions (technological development), was the way of balancing and compromising between the languages of physical visualisations and numbers. Here, intermediaries (design engineers) enabled balancing and compromise as boundary objects. "Designing and developing cars is thus an intriguing process that separate to allow for creative variability and selection, integrated through specially assigned boundary breakers, in order to make convergence possible and which finally converges all criteria in decentralised processes" (Paper 4).

As discussed in the introduction, the thesis, the cape of the four papers, reflects a meta-contribution which is of a rather broader nature. The cape itself provides a general view of the topics of control and innovation. I see this study as a starting point for developing research about control mechanisms in product development and the mobilisation of strategic objectives. Through the studies of this thesis, many questions arose which need more empirical work to develop a more comprehensive idea of how strategic objectives are mobilised through different means in product development processes. We need a deeper analysis of how strategic objectives, are affected and, affect calculations and product development, and how possible boundaries may be overcome.

However, the specific cases and episodes presented in the papers, the particular arguments and discussions of the papers and their individual contributions, provide insights into the ambiguous and complex process of product development with its infinite possibilities of bringing together heterogeneous actors and, thus, with its inexhaustible resource to produce innovations. If Schumpeter was right, endless economic growth could be provided with the resource of product development, given the fact, that in turn, collectives are formed and preserved rather than torn apart; this is especially relevant for the preservation and creation of an environment of humans and non-humans in which wealth is created, without being compromised for others. Innovation in these terms is not a form of creative destruction, but a result of heterogeneous actors that are aligned within one collective. May we find an innovation that enrols all actors and forms one durable whole: one world.

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Appendices

Appendix 1 – List of interviews

Date		Position	Duration (in h)
17.02.2009	*Transcribed*	Manager of Sustainability Strategy Department	1
25.03.2010	*Transcribed*	Manager of Sustainability Strategy Department	1
23.04.2010	*Transcribed*	Manager of Complexity Initiative	1
07.06.2010	*Transcribed*	Coordinating Developer Performance and CO2	1
08.06.2010	*Transcribed*	Coordinating Developer Light Technology	1
09.06.2010	*Transcribed*	Coordinating Developer Aerodynamics	1
09.06.2010	*Transcribed*	Developer	1
09.06.2010	*Transcribed*	Head of Sustainability Strategy Department	1
09.06.2010	*Transcribed*	Manager Accounting/Finance	1
09.06.2010	*Transcribed*	Manager Controlling of Product Development	1
10.06.2010	*Transcribed*	Coordinating Controller Car Projects	1
10.06.2010	*Transcribed*	Coordinating Developer Energy-Management	1
10.06.2010	*Notes Taken*	Coordinating Developer Mobility and Technology	1
10.06.2010	*Transcribed*	Coordinating Planner Development Resources	1
10.06.2010	*Transcribed*	Manager Development Sustainable Components	1
11.06.2010	*Transcribed*	Coordinating Developer Light Technology	1
11.06.2010	*Transcribed*	Developer	1
11.06.2010	*Notes Taken*	Manager Controlling of Product Development	0,5
11.06.2010	*Notes Taken*	Manager Materials and Sustainability	1
11.06.2010	*Transcribed*	Manager Mobility Strategy (Marketing) with three co-workers	1,5
01.07.2010	*Notes Taken*	Manager Development Exterior Components	1
06.08.2010	*Transcribed*	Coordinating Developer Car Components	0,5
09.08.2010	*Notes Taken*	Coordinating Developer Car Components	1
09.08.2010	*Transcribed*	Coordinating Developer Car Components	0,5
09.08.2010	*Notes Taken*	External Consultant KPIs	1
11.08.2010	*Transcribed*	Manager of Complexity Initiative	1
13.08.2010	*Transcribed*	Coordinating Developer Car Components	1
13.08.2010	*Notes Taken*	Project Manager	1
18.08.2010	*Transcribed*	Internal Consultant KPIs	1
29.09.2010	*Transcribed*	External Consultant KPIs	1
01.10.2010	*Transcribed*	Product Manager (Marketing)	1
14.10.2010	*Notes Taken*	Coordinating Controller Car Projects	0,5
14.10.2010	*Notes Taken*	Coordinating Developer CO2	0,5
14.10.2010	*Transcribed*	Coordinating Developer Weight	0,5
15.10.2010	*Transcribed*	Coordinating Controller CO2	0,5
18.10.2010	*Notes Taken*	Product Manager (Marketing)	0,5
10.11.2010	*Transcribed*	Coordinating Developer Weight	1
22.11.2010	*Notes Taken*	Coordinating Developer Aerodynamics	1
04.05.2011	*Transcribed*	Manager Design Strategy	1
13.05.2011	*Notes Taken*	Design Engineer	0,5
25.05.2011	*Notes Taken*	Manager Modularity	0,5
30.05.2011	*Transcribed*	Design Engineer	1
28.07.2011	*Transcribed*	Design Strategy	1
28.07.2011	*Transcribed*	Designer Exterior	1
28.07.2011	*Transcribed*	Engineer Lights	1
28.07.2011	*Transcribed*	Manager Light Strategy	1
28.07.2011	*Transcribed*	Steering Convergence of Design and Technology	0,3
05.08.2011	*Transcribed*	Cost Engineer	0,5
05.08.2011	*Notes Taken*	Manager Convergence of Design and Technology	0,5
05.08.2011	*Notes Taken*	Project Coordinator	0,5
05.08.2011	*Notes Taken*	Project Manager Exterieur	0,5
13.09.2011	*Transcribed*	Cost engineer Door Panels	1
13.09.2011	*Transcribed*	Design Engineer	1
13.09.2011	*Transcribed*	Manager Accounting/Finance	1
13.09.2011	*Transcribed*	Manager Design	1,5
14.09.2011	*Transcribed*	Design Engineer	1,5
14.09.2011	*Transcribed*	Idea Creator / Ergonomics and Comfort	1,5
14.09.2011	*Transcribed*	Manager Design	1,5
15.09.2011	*Transcribed*	Cost Engineer Dashboard	1,5
15.09.2011	*Transcribed*	Engineer Dashboard	1
15.09.2011	*Transcribed*	Manager Convergence of Design and Technology	1

Appendix 1 – List of interviews - Continued

Date		Position	Duration (in h)
16.09.2011	*Transcribed*	Cost Engineer Interior Components	1
16.09.2011	*Transcribed*	Design Coherence with Technology	1
16.09.2011	*Transcribed*	Manager Accounting/Finance	1
19.10.2011	*Notes Taken*	Coordinator Design Cost Convergence	0,5
19.10.2011	*Notes Taken*	Manager Modularity	0,5
24.10.2011	*Transcribed*	Controller Exterior	0,5
24.10.2011	*Transcribed*	Coordinator Light Strategy	1
24.10.2011	*Transcribed*	Designer Exterior (Front)	1
22.11.2011	*Notes Taken*	Product Strategy	0,5
19.01.2012	*Notes Taken*	Design Manager	0,5

Appendix 2 – Uncertainty

However, to briefly discuss the concept of uncertainty in relation to calculations, the perspective of Frank Knight might be as relevant as it is interesting. In Paper 2 Frank Knights perspective was briefly introduced as follows:

"Frank Knight (1921) analysed the problem of calculability in his work on risk, uncertainty and profit, arguing that "calculability" of (probability situations) economic situations can be divided into three groups. The first group is a priori probability which is absolute certainty about calculations based on "Absolutely homogeneous classification of instances completely identical" (III.VII.37). A priori probability is distinguished from the second category of calculability – statistical probability – through the latter's reference to empirical datum. Knight illustrates this through the following example: "an illustration of the first probability we may take throwing a perfect die. If the die is really perfect and known to be so, it would be merely ridiculous to undertake to throw it a few hundred thousand times to ascertain the probability of its resting on one face or another. And even if the experiment were performed, the result of it would not be accepted as throwing any light on the actual probability." (Knight, 1921, III.VII.25). This first form probably cannot be found in calculations of green innovations, whereas the latter is dependent on knowledge and systems in place within the firm. The third form consists of estimates, and here "there is no valid basis of any kind for classifying instances" (III.VII.37). This last form is what characterises true uncertainty and which in Knight's discussion is the basis of profits, where the two other types of probability are risks that are relatively unproblematic to deal with in business.

While Knight analyses the three forms of "calculability" and uncertainty and risk are distinct forms, he argues that uncertainty can be managed and made calculable through various means. The important question therefore is how firms move on the scale between estimates towards "statistical probability". Knight argues that there are six ways of dealing with uncertainty 1) consolidation and grouping, where the key issue is the homogeneity of classes 2) specialisation, in order to facilitate judgment 3) control of the future, e.g. through the use of marketing to manipulate the future 4) increased power of prediction acquiring better knowledge of the future through e.g. outside experts 5) diffusion of uncertainty and risk on more people/firms and 6) avoiding, staying out of uncertain business (Knight, 1921, II.VIII.10).

From an ANT perspective these six ways can be described as follows. Regarding item 1) consolidating and grouping may not be seen as making actors homogeneous but aligning heterogeneous actors. "The uncertainty tends to disappear altogether, as the group increases in inclusiveness." (Knight, 1921, II.VIII.10). The process of grouping is thus reflected through the process of translation, enrolling and mobilising heterogeneous actors through means, such as calculations. Item 2), the specialisation can then be compared to the punctualisation (Latour, 1999) of an aligned network. The "men" or the actors have to "bear" the uncertainty altogether, which is then seen as specialisation (Knight, 1921, II.VIII.10)[74]. Items 3) and 4) are resulting ways of dealing with uncertainty.

[74] "The second fact or set of facts making for a reduction of uncertainty is the differences among human individuals in regard to it. These differences are of many kinds and an enumeration of them will be undertaken presently. We may note here that there may be differences in the men themselves or differences in their position in relation to the problem. We may call the two fundamental methods of dealing with uncertainty, based respectively upon reduction by grouping and upon selection of men to "bear" it, "consolidation"*16 and "specialization," respectively." (Knight, 1921, II.VIII.10)

Control of the future and increased power of prediction relate to the statement„"the practical significance of knowledge is control, and both are closely identified with the general progress of civilization, the improvement of technology and the increase of knowledge." (Knight, 1921, II.VIII.10). Controlling and creating the future, whilst predicting it through knowledge increases certainty about the future. In terms of a network, boundaries need to be surpassed and actors that may be relevant for the future are to be integrated and enrolled in the network. Through the identification of strategic objectives and the controlling of these objectives, knowledge is acquired that is mediated within networks and may shape the future through its outcomes, its products. Predicting the future is thus only possible through anticipating it based on knowledge at hand; thus, based on enrolled actors within the network. An electric vehicle, for example, is developed based on technological knowledge of engineers on the one hand, and marketing knowledge on the other hand, both predicting technologies and market of the futures through their knowledge. Through the development through these anticipations, the future becomes durable in a final product, the electrical vehicle. Uncertainty, in these cases, is thus something that is overcome through the knowledge of anticipation and the resulting construction of the future through the products that are based on this knowledge.

What Knight calls diffusion in item 5) is the distribution of risk on the many shoulders of a collective[75]. This process is the translation of as many relevant actors into the network and thus to overcome boundaries to relevant allies. Rather than seeing item 6) as an input towards reducing uncertainty, it is rather an output of the previous five items. It is an achieved through enrolling all relevant actors,

[75] "Other things equal, it is a gain to have an event cause a loss of a thousand dollars each to a hundred persons rather than a hundred thousand to one person; it is better for two men to lose one eye than for one to lose two, and a system of production which wounds a larger number of workers and kills a smaller number is to be regarded as an improvement." (Knight, 1921, II.VIII.10)

knowledge, engineers, future markets, all held together by calculations about the future and thus about uncertainty. Reducing (or even "avoiding") uncertainty is, as discussed, only possible through getting the relevant actors on board and not only steering towards the future but to conquer it.

In summation, uncertainty and risk are potential translators that may act on more and more actors within an organisation. Thus, the role of uncertainty may be inscribed in product development through being actively part of it. Calculations are here the representation of the estimated future, which, although everyone knows that numbers are attached to uncertainty; nevertheless, may become obligatory passage points to go through.

Appendix 3 – List of interviews – Paper 1

Date		Position	Duration (in h)
23.04.2010	*Transcribed*	Manager of Complexity Initiative	1
09.06.2010	*Transcribed*	Manager Controlling of Product Development	1
10.06.2010	*Transcribed*	Coordinating Controller Car Projects	1
01.07.2010	*Notes Taken*	Manager Development Exterior Components	1
06.08.2010	*Transcribed*	Coordinating Developer Car Components	0,5
09.08.2010	*Transcribed*	Coordinating Developer Car Components	0,5
09.08.2010	*Notes Taken*	External Consultant KPIs	1
09.08.2010	*Notes Taken*	Coordinating Developer Car Components	1
11.08.2010	*Transcribed*	Manager of Complexity Initiative	1
13.08.2010	*Transcribed*	Coordinating Developer Car Components	1
13.08.2010	*Notes Taken*	Project Manager	1
18.08.2010	*Transcribed*	Internal Consultant KPIs	1

Appendix 4: Product Development Network before and after the introduction of the new strategic objective "reduction of product complexity"

Product Development Network	Before introduction of new strategic objective "reduction of complexity"	New strategic objective "reduction of complexity" translated into non-financial measure "number of parts"	New strategic objective " reduction of complexity" translated into financial measure "price tag"
Mission and vision	- Enhance profitability and create value - Being segment leader - Clear and pure products that ensure individual mobility - Communication through internal and external documents and presentations		
Key success factors in new product development	- Efficiency improvements, lower costs - Efficient design, new suppliers, enhanced processes - More customer value, innovation, quality, sustainability		
Organisation structure in new product development	- Matrix organisation, car projects and units - Decisions within car projects / high autarky, decentralisation of management - Decisions outside projects were strategic top down decisions		
Strategies and plans in new product development	- generic strategic decisions done by the executive committee - Derived plans were mediated through targets on project level - these were calculated by responsible units	- generic strategic decisions done by the executive committee - Derived plans were mediated through targets on project level - these were calculated by responsible units - new strategic objective of complexity reduction with managing initiative	
Key performance measurements, target setting, performance evaluation, reward systems in new product development	- performance measurements were derived based on strategic objectives / clear connection - agreement on performance measurements of project management - targets derived from experience of current products and strategic objectives - agreement of projects towards target achievement - evaluation and rewarding based on performance measurements	- new strategic objective 'reduction of complexity' was translated into performance measurements/target of 'number of parts' - Failed integration into decision process	- new strategic objective 'reduction of complexity' was translated into performance measurement price tag to be incorporated into business cases - Integration into decision process - no clear connection between price tag and real costs
Information flows - Systems - networks	- Were filled bottom up - restricted access based on hierarchal level - Intranet based - Were organised to provide decision meetings with performance measurements - Had a strong maturity - reassembled over and over again	- Decision meetings were provided with new information: additional part numbers and targets - System to measure and track part number status was set in place - Information was not always available in decision meetings - Decisions were still made on basis of the "old" performance measurements	- Complexity got integrated into information flow and systems through being monetised as a price tag - Not the visualisation was altered but the way the calculations were made - Calculations (IRR) included price tag - System and information flows thus were not changed
Use of measures	- performance measurements were basis for discussions in product development network in decision meetings - IRR calculations were used in every decision - performance measurement measured anticipated and estimated characteristics	- Number of parts were additionally discussed - though only in some decisions - No decisions were influenced through this performance measurement - Information about additional numbers of parts was thus not "used"	- The price tag was incorporated into IRR calculations and influenced decisions - Used as discussion basis - Price tag was already used in the construction of the product as it sensibilised engineers
Change of PMS and performance measurements	- Industry with defined and mature processes - Profitability and customer value as strategic pillar - Focus within product development network is set on IRR calculations to foster profitability of future products	- Complexity reduction as new strategic objective - Additional target and measure represented as numbers of parts in product development network - No change in networks or systems - No change in decisions or in use of measures	- Complexity represented in price tag - No change in networks or systems - Price tag used performance measurement in place (IRR) to change decision - IRR calculations had different outcomes due to incorporation of price tag
Strength and coherence	- Working product development network - IRR calculations linked management and product alternatives and generated decisions - IRR was present in every product decision and enabled decisions	- Number of parts (measurement and target) could not link management and product alternatives - No new links	- Price tag could link management and product decisions as it used the language IRR calculations - Price tag influenced decisions and could influence the way in which the engineers think as they got aware of price tag

Appendix 5 – List of interviews – Paper 2

Date		Position	Duration (in h)
17.02.2009	*Transcribed*	Manager of Sustainability Strategy Department	1
25.03.2010	*Transcribed*	Manager of Sustainability Strategy Department	1
07.06.2010	*Transcribed*	Coordinating Developer Performance and CO2	1
08.06.2010	*Transcribed*	Coordinating Developer Light Technology	1
09.06.2010	*Transcribed*	Coordinating Developer Aerodynamics	1
09.06.2010	*Transcribed*	Manager Controlling of Product Development	1
09.06.2010	*Transcribed*	Head of Sustainability Strategy Department	1
10.06.2010	*Transcribed*	Manager Development Sustainable Components	1
10.06.2010	*Transcribed*	Coordinating Controller Car Projects	1
10.06.2010	*Transcribed*	Coordinating Developer Energy-Management	1
10.06.2010	*Transcribed*	Coordinating Planner Development Resources	1
10.06.2010	*Notes Taken*	Coordinating Developer Mobility and Technology	1
11.06.2010	*Transcribed*	Manager Mobility Strategy (Marketing) with three co-workers	1,5
11.06.2010	*Notes Taken*	Manager Materials and Sustainability	1
11.06.2010	*Transcribed*	Coordinating Developer Light Technology	1
11.06.2010	*Notes Taken*	Manager Controlling of Product Development	0,5
06.08.2010	*Transcribed*	Coordinating Developer Car Components	0,5
09.08.2010	*Transcribed*	Coordinating Developer Car Components	0,5
18.08.2010	*Transcribed*	Internal Consultant KPIs	1
29.09.2010	*Transcribed*	External Consultant KPIs	1
01.10.2010	*Transcribed*	Product Manager (Marketing)	1
14.10.2010	*Notes Taken*	Coordinating Developer CO2	0,5
14.10.2010	*Transcribed*	Coordinating Developer Weight	0,5
14.10.2010	*Notes Taken*	Coordinating Controller Car Projects	0,5
15.10.2010	*Transcribed*	Coordinating Controller CO2	0,5
18.10.2010	*Notes Taken*	Product Manager (Marketing)	0,5
10.11.2010	*Transcribed*	Coordinating Developer Weight	1
22.11.2010	*Notes Taken*	Coordinating Developer Aerodynamics	1

Appendix 6 – Descriptive statistics and results of group analyses

		Descriptive Statistics						Chi-Quadrat-Test							
		Finance		R&D		Prod.		Overall		Finance vs. R&D		R&D vs. Marketing		Marketing vs.	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Pearson Chi	Sig.	Pearson Chi	Sig.	Pearson Chi	Sig.	Pearson Chi	Sig.
1	For our customer our traditional brand values are more important than the brand value sustainability and product greening.	3,95	,62	4,47	,62	3,94	,24	**17,259***	**,002***	**6,023***	**,049***	**12,522***	**,002***	5,277	,071
2	For our customer brand-typical technical specificities, such as speed, power, and acceleration are more important than green	3,16	,37	4,71	,47	3,82	,39	**55,932***	**,000***	**28,477***	**,000***	**19,263***	**,000***	**15,951***	**,000***
3	For our customer the total cost (price and cost of ownership) are more important than the environmental friendliness of a car.	3,89	,32	4,00	,61	3,88	1,32	**32,177***	**,000***	4,388	,111	**15,333***	**,002***	**27,396***	**,000***
4	For our customer the design of the car is more important than the environmental friendliness of a	4,47	,51	4,71	,47	4,71	,47	2,797	,247	1,990	,158	,000	1,000	1,990	,158
5	For Automotor Company it is more important to calculate general product decisions with business cases than deciding them on a strategic basis.	4,47	,51	3,65	,61	3,47	1,18	**25,988***	**,000***	**13,383***	**,001***	**9,543***	**,023***	**11,514***	**,009***
6	For Automotor Company it is more important to calculate and decide innovation of the product with business cases than deciding them on a	3,42	,69	2,29	,47	3,53	,62	**25,576***	**,000***	**17,419***	**,000***	**19,399***	**,000***	,300	,861
7	For Automotor Company it is more important to calculate and decide the greening of the product with business cases than deciding them on a	2,11	1,29	2,71	,59	2,94	1,48	**26,859***	**,001***	**17,472***	**,002***	**11,193***	**,024***	**12,430***	**,014***

* $p < 0.05$

Appendix 7 – List of interviews – Paper 3

Date		Position	Duration (in h)
04.05.2011	*Transcribed*	Manager Design Strategy	1
13.05.2011	*Notes Taken*	Design Engineer	0,5
25.05.2011	*Notes Taken*	Manager Modularity	0,5
30.05.2011	*Transcribed*	Design Engineer	1
28.07.2011	*Transcribed*	Design Strategy	1
28.07.2011	*Transcribed*	Engineer Lights	1
28.07.2011	*Transcribed*	Designer Exterieur	1
28.07.2011	*Transcribed*	Manager Light Strategy	1
05.08.2011	*Notes Taken*	Project Coordinator	0,5
05.08.2011	*Notes Taken*	Project Manager Exterieur	0,5
05.08.2011	*Notes Taken*	Manager Convergence of Design and Technology	0,5
05.08.2011	*Notes Taken*	Manager Convergence of Design and Technology	0,5
05.08.2011	*Notes Taken*	Project Manager Exterieur	0,5
05.08.2011	*Transcribed*	Cost Engineer	0,5
19.01.2012	*Notes Taken*	Design Manager	0,5

Appendix 8 – List of interviews – Paper 4

Date		Position	Duration (in h)
09.06.2010	*Transcribed*	Manager Accounting/Finance	1
09.06.2010	*Transcribed*	Developer	1
11.06.2010	*Transcribed*	Developer	1
28.07.2011	*Transcribed*	Steering Convergence of Design and Technology	0,3
28.07.2011	*Transcribed*	Designer Exterior	1
13.09.2011	*Transcribed*	Manager Design	1,5
13.09.2011	*Transcribed*	Manager Accounting/Finance	1
13.09.2011	*Transcribed*	Design Engineer	1
13.09.2011	*Transcribed*	Cost engineer Door Panels	1
14.09.2011	*Transcribed*	Manager Design	1,5
14.09.2011	*Transcribed*	Design Engineer	1,5
14.09.2011	*Transcribed*	Idea Creator / Ergonomics and Comfort	1,5
15.09.2011	*Transcribed*	Engineer Dashboard	1
15.09.2011	*Transcribed*	Cost Engineer Dashboard	1,5
15.09.2011	*Transcribed*	Manager Convergence of Design and Technology	1
16.09.2011	*Transcribed*	Cost Engineer Interior Components	1
16.09.2011	*Transcribed*	Manager Accounting/Finance	1
16.09.2011	*Transcribed*	Design Coherence with Technology	1
19.10.2011	*Notes Taken*	Manager Modularity	0,5
19.10.2011	*Notes Taken*	Coordinator Design Cost Convergence	0,5
24.10.2011	*Transcribed*	Designer Exterior (Front)	1
24.10.2011	*Transcribed*	Coordinator Light Strategy	1
24.10.2011	*Transcribed*	Controller Exterior	0,5
22.11.2011	*Notes Taken*	Product Strategy	0,5

There are different actors that are part of the product development process. Project leaders are responsible for a certain car project and steer the development process towards all relevant targets and towards the start of production by forming all decisions. Product development engineers are responsible for the technological development of certain parts of a car. They are held responsible for achieving their given targets and thus have to develop parts that correspond to their targets. Process engineers bring in their expertise of production and assembly processes and evaluate relevant alternatives regarding cost and feasibility. Furthermore, they have to implement the engineered concepts into in-house production. Designers draw sketches, they model clay models and provide design alternatives which may then be chosen as the final design model. In this process, design engineers communicate targets between product development and design. Marketing is responsible for bringing in customer demands on the product substance and discusses their requirements with the other actors in the product development network. Controllers calculate the business cases for decisions and steer the target cost management process. Purchasers have to find suppliers that are then nominated to deliver a part or parts. They furthermore estimate the costs of certain alternatives. All of these actors were part of the product development network and interacted within it.

Appendix 9 – Excerpts from interviews – Paper 4

	Design	Product Development
Mechanism (compt, compr,)	It is very tough with design, you may convince people with design, but it is hard [...] It is as well hard for our work in the projects, to argument, to argument that proportions are not coherent, the design is not coherent and so on, but the project manager won't understand that. That is why we have more clay models in design. [Design Engineer] You can draw ten years long the coolest sketches, if your boss does not like them, you are out [...] the head of design is the boss here and he says "no, I don't like that, I want to have that one and not this". The management board then comes into play when the clay models are there. They are then more powerful than the head of design. The final model is decided by the management board. [Designer]	The problem is in product development everything is measurable, cost, or CO2 emissions, everybody have their own currency. Aerodynamics is the best example. They have their cx-value. They say to us: "If you don't believe the numbers, we do a nightshift in the wind-tunnel." And then they have the exact values and you may have to fight against this. [Designer]
Language	That is a must because they don't know what the target picture is, so how to tell them what they should do. And that is an important issue again, we build up a car at the moment to show it to them because we always need to show it to them it in a perfect way, the way we will do it and we will have it in this package, so look, it's possible to do it in this package and the next thing it will cost a sum of money for it, so there is some chance to get a few bits in the car realised. [Design Engineer] And this demonstrating is always a difficult thing. I did some this year [...], and I said, okay we should have ten different storage areas as options to offer. And I can't imagine what this looked like. So we picked up a few cars and a few mock-ups and had it sent as a small exhibit and showed it to a few people and the people who saw it, said, „Okay, it looks nice, we can imagine that we can convince the customers with this, but on the other side, we need to have it more exclusive, more value on it, better materials on it to get a better impression on this". So, next we bring it into a real car, bring all these items and show it to the different guys and convince them. "It's a very good thing and we can sell this and we can make profit with this." [Design Engineer] That is different in design, you have immediately a picture including every single detail. You look at a car and you see if you like the outer rear-view mirror or not. Or the trunk-lid. This is different in the development of concepts. You never know whether the glove-box works or not, whether it breaks down after two weeks, all this is uncertain. You cannot make a picture out of it. But in design, there you have immediately a picture. [Developer]	In technology you have numbers, you can prove them scientifically, you can convince everybody [...] you cannot proof [design] in numbers, whether it is costs, or package-mm, you cannot proof it. [Design Engineer] Manufacturing and all the upfront cost, also investments. And I had to calculate [...] development costs for the supplier and for Automotive Company. Out of these cost, controlling calculates the business case. And then we would make an offer to our project [managers] and they decide if they want to buy or order this topic in their development department. [...] And the business case shows that we have return on investment, the same or better than the system we have in the moment. [Developer] The markets say I can sell the car for 1.000€ more, because the customers pay for it. Then we get 400€ that we can spend and they are distributed to the components. They can spend 300 and the others 100, and this is how we split it and then we can spend it. [Developer]

Optimality criterion	The premise was at least the same contents as predecessor [Designer] And we considered the positioning of the car [...] The car was on mid-segment level, and design sees it on a premium segment level. That's why the demands were so high and that's why there were such a scepsis to decide. [Developer] They have done studies and things, if you talk to experts, it's the biggest selling factor all together. It's not the six cylinder engine, it's not the 350 hp, it's people see the new car and say, „Wow, that is so cool, I want to have it." It's not the 19" wheels, of course, the wheels have an influence but the design comes first and then there are some other things that follow. That can change in the hierarchies as well, many people at [Automotive Company] agree with this. Design is the key selling factor altogether. [Designer] Why? Because design is the selling factor number one and the exterior design respectively, that's what market research says too [Manager Controlling] So; we know that we sell our cars through design. That's for sure. If it is interior design or exterior design and when we draw the line when the customer gets into the car and buys it, is hardly measurable. The image is the chassis and the engine, but design, that's where we have sometimes to get better. [Developer]	You have acceleration, you want to be top stream or have another standard. And this make the division where we want to be with. For example, one could be acceleration, best in segment. That means, okay, acceleration ... That means that the segment wants to 0 to 100 in about five seconds. So, this is one point, the one number for example, and we need loading space in the rear of about 500 litres, the next one, 500 litres. And all requirements, you have a lot, […] and then we have all the regulations and laws, because we want to sell all our cars worldwide, this means, okay, specs, yes, what is the requirement? What is the law in US? And this is always moving. Then we have the customer. The customer is expecting [crash ratings]" Hagel You normally do it with a cost benefit analysis and then you get some crazy numbers behind it. [Cost Engineer] Technology, it has a very high standing, but not at any cost. So technology is important and there were times at Automotive Company where we wanted to be leader in innovations, it is still like this today. But we categorise whether we want to be best in segment or top three or maybe some technologies are not even relevant for our cars. We call that prodcut configuration profile what we picture there [...] With the innovations it is maybe like this, we have to weigh up, to find an optmial balance between cost and value. So we do not bring a whole bunch of innovations into the car at any price. That's what I meant before. We have to think about which innovation at which point in time. Maybe somebody else brings the innovation to the market and we may be fast follower and we say "ok, I use what has already been developed, I use the ideas and make them more cost efficient. [Manager Controlling]
Decision (maker)	[The head of design] makes a recommendation and usually the board is following the recommendation and then okay, [...] I choose one and three and four. [Design Engineer] The project managers are briefed regularly from the management board and from the head of design for escalation topics and they are grilled, you can say it like this. They are urged to address these topics. [...] Sure, there are topics which can be decided by the designer, but if the design language is fading away through anything, or if the designer has been told by the head of design " I want that you do this, that you show lightness, flying forms, I want to have high perceived value." And if a single designer says now "we are going into a wrong direction" than normally things get escalated. [Developer] Yes, people don't understand, when it is getting to expensive or if stuff doesn't work. And then you change the lines and forms a bit, and they don't care. But you can not measure it and you are the weakest link [...] you always need the highest manager, he needs to be convinced and then his words gain weight and he says "do it!" and then it works. [Designer] The final autonomy is with the chief designer. He's the authority of the design and is the spokesman to board and to management and the designer doesn't have autonomy, he has very strict boarders within the company and is challenged. [...] Finally the members of the board decide who to select and if they think this machine looks really super cool and they want it, then somebody says, „Yes, but we're not too happy with the papers at the moment." And then they say, „Make it possible, go for it." [Design Engineer] Yes, we have points where we have escalation levels and we have special circles, topics become packaged and we let them decide and if a project manager has a topic which is important for us and decides against it, we use a design-talk where the head of design and the project leader have a four-eyes talk. [Design-Technology Convergence]	In development, we have a broad mass of decision power. [Developer] The final decision is with the project manager or management board. And there are topics where we try to take care that not every single project leader decides for itself whether they like chrome-exhausts or not. There are several topics which need to be not only coherent to the predecessor and to the competition but as well to our own car-hierarchy. [Design-Technology Convergence] And I think that the leaders set targets and that they really want a topic."Sit down and find a solution!" And the interesting stuff is that the organisation does that quite well; finding solutions for things, that are more or less impossible and which nearly doesn't exist. We always did it. And that is one aspect that the leadership has, I think. [Manager Controlling] And the project leader could decide qhether he increses the price. And technically it was a price adaption. [Development] The project leader decided whether we may deviate from dates or not, whether we may deviate from the target or not. Or we do not do it. These two possibilites we have. [Development]

Rules for transmitting messages	Then we have to bring one page on the wall with a kind of traffic lights where we say, "Okay, this car does not meet the regulations," you have to know it or if you think it, you have to know, we don't match it. And that is the point. [Design Engineer] Design Engineer: For example, the designers know they have to convince the management. Author: Is managament now the management of design or the management of the board? Design Engineer: It goes always up the hierarchy, the first one is head of design, his point of view to design … They come out with a recommendation and they are meeting with the management board, and the head of design always makes the recommendation, the whole deparment recommends, model one or model three but why this, this and this.	And we do a business case so we check the cost part and the income and the development costs are big in innovations, so we try to focus on these topics by rating them, how is the income and profitability of this innovation, it's the business view of the thing, and it is not easy because the part of the development wants to have this innovation and the business case is bad. [Manager Controlling] Now we have the design-technology circles, functional design and geometrical design. This is the meeting you have to go in before you go into the project manager…for example from the body in white departments they have some meetings there are the integration teams, you have them for aerodynamics, for safety for everything, and for all functional issues. [Developer] But we have to calculate a business case and but first of all we have to check geometrical possibility and then we have to check boundaries that we can build the cars and then we have to check for insurance and crash safety and insurance…and for that we have a test ... so these are all points we are trying to ask everybody in the whole process which may be the problems and how we could solve that and then we make a business case and all the details I made with financial departments and..with development because they have to build these parts and then in the end we go to the project manager and we said ok these are the features, are we willing to spend this money or not. [Developer]

Appendix 10 – Contribution statement

Copenhagen, February 2012

To whom it may concern,

The authors hereby certify that the papers *"Calculating green innovation: Creating and exploring calculative spaces for innovation and the environment in the automotive industry"* and *"Controlling and converging design and product development"* published in the PhD thesis *"Management Control, Innovation, and Strategic Objectives – Interactions and Convergence in Product Development Networks"* of Nico Peter Berhausen are based on equal contributions by the respective authors, Sof Thrane and Nico Peter Berhausen.

Sof Thrane

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